RHODE ISLAND COASTLINE
COASTAL STORM RISK MANAGEMENT
Final Feasibility Study

APPENDIX C: Economic and Social Considerations

US Army Corps of Engineers®
New England District

January 2023

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FINAL FEASIBILITY REPORT
Appendix C: Economic and Social Considerations

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1.0 INTRODUCTION

The purpose of this appendix is to evaluate the economic feasibility of providing coastal storm damage risk reduction along the Rhode Island coastline from the western limit of Point Judith to an eastern limit of the Massachusetts State line. The study is conducted in Washington, Newport, Kent, Bristol and Providence counties. This appendix will provide details for major decision points along the study timeline beginning with the original study areas, through the selection of the National Economic Development (NED) plan. The analysis includes an evaluation of existing coastal storm damages, evaluation of alternatives, and calculation of coastal storm damage reduction benefits. Structural and nonstructural plans will be screened for cost-effectiveness based on with- and without-project damages and calculation of benefit-cost ratios. The analysis also evaluates the impacts associated with Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE) such as impacts to life safety and local and regional economies.

The economic analysis is consistent with Federal water resources policies and practices, including Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G, 1983) as updated by the Principles, Requirements and Guidelines (PR&G) approved by the Water Resources Council in 2014, as well as the Corps Planning Guidance Notebook (ER-1105-2-100, 22 April 2000), and ER 1105-2-101, *Planning Guidance, Risk Analysis for Flood Damage Reduction Studies. The National Economic Development Procedures Manual for Flood Risk Management and Coastal Storm Risk Management*, prepared by the Water Resources Support Center, Institute for Water Resources, was also used as a reference, along with the Generation II Coastal Risk Model (G2CRM) User's Manual v4.556.3.

The economic analysis for plan selection is based on October 2020 (Fiscal Year 2021) price levels and the Fiscal Year 2021 Federal Discount Rate of 2.5 percent. The final analysis of the Recommended Plan is updated to the October 2021 (Fiscal Year 2022) price level and annualized using the 2022 Federal Discount Rate of 2.25 percent.

1.1. Study Authority and Purpose

The study is authorized by the following: a resolution adopted by the Senate Public Works Committee dated 12 September 1969, resolution adopted by the Senate Committee on Environment and Public Works dated August 2, 1995, and by Public Law (PL) 84-71.

The resolution by the Committee on Public Works of the United States Senate, dated September 12, 1969, also known as the Southeastern New England Resolution, states:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the feasibility of providing water

> resource improvements for flood control, navigation and related purposes in Southeastern New England for those watersheds, streams and estuaries which drain into the Atlantic Ocean and its bays and sounds in the reach of the coastline of Massachusetts, Rhode Island and Connecticut southerly of, and not including, the Merrimac River in Massachusetts, to, and including, the Pawcatuck River in Rhode Island and Connecticut, with due consideration for enhancing the economic growth and quality of the environment."

The resolution adopted by the Senate Committee on Environment and Public Works on August 2, 1995 states:

> Resolved by the Committee on Environmental and Public Works of the United States Senate, that the Secretary of the Army is hereby directed to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document number 14, Eighty-fifth Congress as modified by Senate Public Works Committee Resolution on September 12, 1969, Ninety-first Congress, with a view to determine whether modification of the recommendations contained therein are advisable in the interest of improved flood control, frontal erosion, coastal storm damage reduction, watershed, stream and ecosystem habitat viability, and other purposes, in the area from Watch Hill, Rhode Island to Narragansett, Rhode Island."

PL 84-71 was signed on June 15, 1955. It authorized an examination and survey of the coastal and tidal areas of the eastern and southern United States, with particular reference to areas where severe damages have occurred from hurricane winds and tides. PL 84-71 states:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricane of October 15,1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.

Such survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

As such, the purpose of the study is to identify which areas within the overall study area are most vulnerable to coastal storm risk and then investigate a combination of structural and nonstructural measures and alternatives that if implemented might significantly reduce storm induced damages in those areas.

1.2. Four Accounts

The P&G established four accounts to facilitate and display the effects of alternative plans in the formulation of water resource projects while recognizing the importance of maximizing potential benefits relative to project costs. These accounts include National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). The NED account documents the economic value of the national output of goods and services produced by the proposed investment. The EQ account documents ecological, cultural, and aesthetic effects on significant natural and cultural resources that cannot be measured in monetary terms. The RED account registers changes in the distribution of regional economic activity that result from each alternative plan, including the regional incidence of NED effects, income transfers, and employment effects. The OSE account includes urban and community impacts and effects on life, health and safety, and relevant effects not reflected in other accounts.

This economics appendix will address these four accounts consistent with the memorandum dated 3 April 2020, "Comprehensive Documentation of Benefits in Feasibility Studies", as well as the associated Policy Directive dated 5, January 2021, "POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document". Details and results of the economic analysis associated with each of these four accounts can be found in the subsequent sections of this appendix.

1.3. Description of Study Area

The study area is located along the coastline of southern Rhode Island extending approximately 23 miles from Point Judith in Narragansett to West Beach in Westport Point including Block Island as well as inland to Providence Harbor (as shown in **Figure 1-1**). There are currently more than 650,000 people residing in the 19 towns included in the study area. Approximately 75 percent of the state population resides in a 40-mile long urban/suburban corridor along the shores of Narragansett Bay. Structures in the area consist of a mix of single-family homes, apartment buildings, and commercial buildings. A considerable portion of these buildings have basements and are over 50 years old. Over 12,000 structures in the study area are designated as FEMA special flood hazard area zones VE, which means that they are inundated at 1% AEP with additional hazards associated with storm-induced waves, and AE (inundation at 1% AEP using methods with Base Flood Elevations). Hurricane Sandy, the last major Hurricane to impact the area, resulted in more than $39.4 million in support from four federal disaster relief programs for the state of Rhode Island. The website of the Federal Emergency Management Agency reports the National Flood Insurance Program (NFIP) paid more than $31.1 million for more than 1,000 claims as a result of the storm.

The study area located in Rhode Island Congressional Districts RI-01 and RI-02 represented by the following members of the 116th U.S. Congress: Representative David Cicilline (D) and James Landevin (D) respectively; Senators Sheldon Whitehouse (D) and Jack Reed (D).

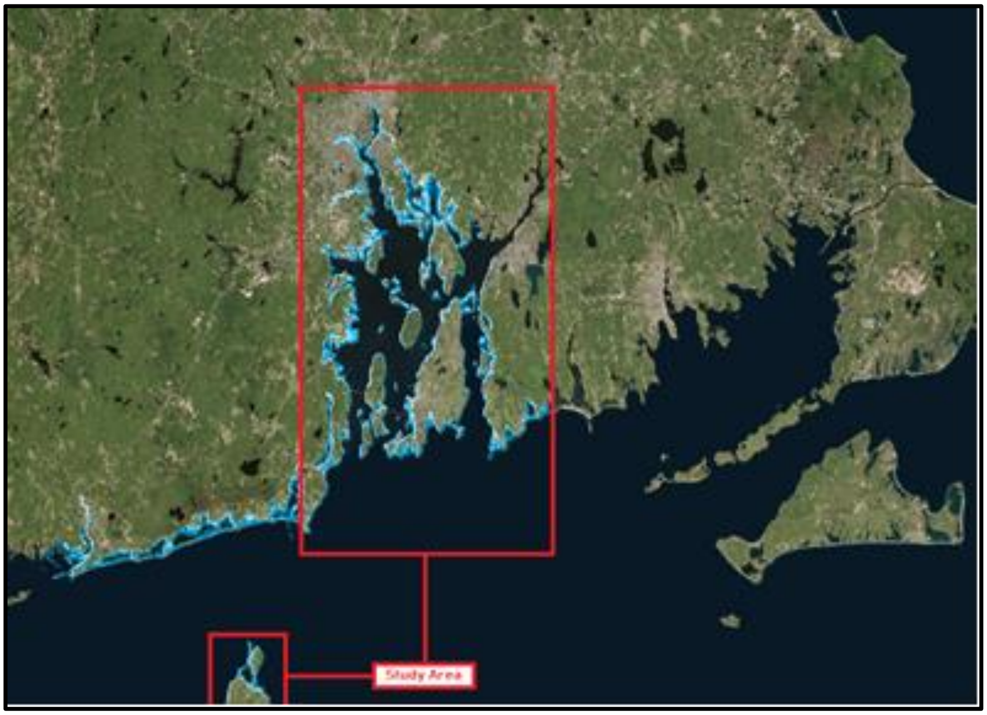

Figure 1-1: Overall Study Area

1.3.1. Geography and Land Use

Rhode Island is located in New England, south of Massachusetts and east of Connecticut. The State lies along the western shoreline of the Atlantic Ocean and is characterized by low topographic relief. The average elevation is approximately 350 feet North American Vertical Datum of 1988 (NAVD88). Soils consist primarily of unconsolidated sand and clay strata.

Providence is the largest city located at the northern point of Narragansett Bay, followed by Cranston and Warwick. Rhode Island is bordered by Massachusetts to the North, Long Island Sound to the South, and Connecticut to the West. Following the horseshoe shape of the Rhode Island coastline from a southwest point up to the northern most point, then southeast back down, includes the following main geographical features. Starting with Long Island Sound and moving up the coast, Narrow River runs just a few hundred feet inland parallel to Narragansett Bay. Along the way north up to Providence Harbor there a numerous coves and harbors such as Wickford Harbor, and Allen Harbor. The Potowomut

River meets the Narragansett Bay and runs inland towards East Greenwich. Moving slightly north again to Greenwich Bay, just south of Warwick. Narragansett Bay reaches its most northern point meeting the Providence River just south of Barrington. The Providence River then breaks off into the Pawtuxet River running west towards Cranston. The Providence River finally meets up with Provience Harbor before splitting into the Woonasquatucket River, Moshassuck River and Seekonk Rivers. Moving south down the eastern coast of the Narragansett Bay we reach the Warren River which flows north into Barrington and Warren. Moving further south we reach Bristol Harbor then Mt. Hope Bay, just north of Tiverton and Portsmouth. Then finally Easton Bay that splits out into the Long Island sound.

The U.S. Census totals the number of developed and undeveloped land within Rhode Island as 668 square miles. According to CRS activities completed by the County, approximately 12,500 acres of land is preserved in its natural state as open space. Residential buildings make up only 22%. However, within the coastal study area, they make up most of the land use. Land use for the State can generally be characterized according to the following table.

Table 1-1: Rhode Island Land Use

Class Name	Acres	Percentage of Total
Agricultural	8,400	1%
Commercial	18,200	3%
Conservation	90,000	13%
Industrial	26,400	4%
Recreational	77,000	12%
Residential	471,800	74%
Miscellaneous	8,200	1%
Total	**700,000**	**100%**

Source: http://www.planning.ri.gov/documents/guide_plan/landuse2025.pdf

1.3.2 Study Focus Areas

Focus areas for the study were identified based on elevation data, structure density, and discussions with town and state officials regarding high damage-prone areas and history of coastal storm damages. A key component of choosing the study focus areas was USACE's ability to construct projects to alleviate coastal storm damage risk. Eleven focus areas were originally identified and are shown in **Figure 1-2** below and defined as follows:

- Area 1, in the northern part of the study area there is Barrington/Warren/Bristol Rhode Island (Structures and Rte 114).
- Area 2, Newport Downtown area. This area contains a very densely populated community with a large mix of residential and commercial structures as well as being a large tourist destination.
- Area 3, furthest east along the coast is the Newport/Middleton Reservoirs, four potable water reservoirs located immediately adjacent to shoreline with low-

lying perimeter berms that are potentially subject to failure during major storm event

- Area 4, Bristol is a primary evacuation route subject to flooding with a low-lying historic district along the downtown waterfront
- Area 5, Wickford Village (North Kingstown) is a densely populated area containing shops and residential homes. This area is very close to Wickford Cove
- Area 6, Island Park/Common Fence Point (Portsmouth) is a very water forward area. There are residential structures.
- Area 7, furthest inland is the Providence Harbor Waterfront (Fields Point/Prov Port) area. This area is primarily industrial, containing important supplies for State infrastructure.
- Area 8, The Newport Bridge Approach (Jamestown). This bridge connects the island of Jamestown to both Newport and North Kingstown.
- Area 9, The Narrow River (Narragansett) runs behind a peninsula in Narragansett that contains residential structures. This river also opens into Long Island Sound.
- Area 10, Warwick Neck is a plot of land that extends into Narragansett Bay while also being surrounded by Warwick cove.
- Area 11, Corn Neck Road (Block Island) is a main road. Runs from the northern tip of the island to about the midway point along the eastern coast.

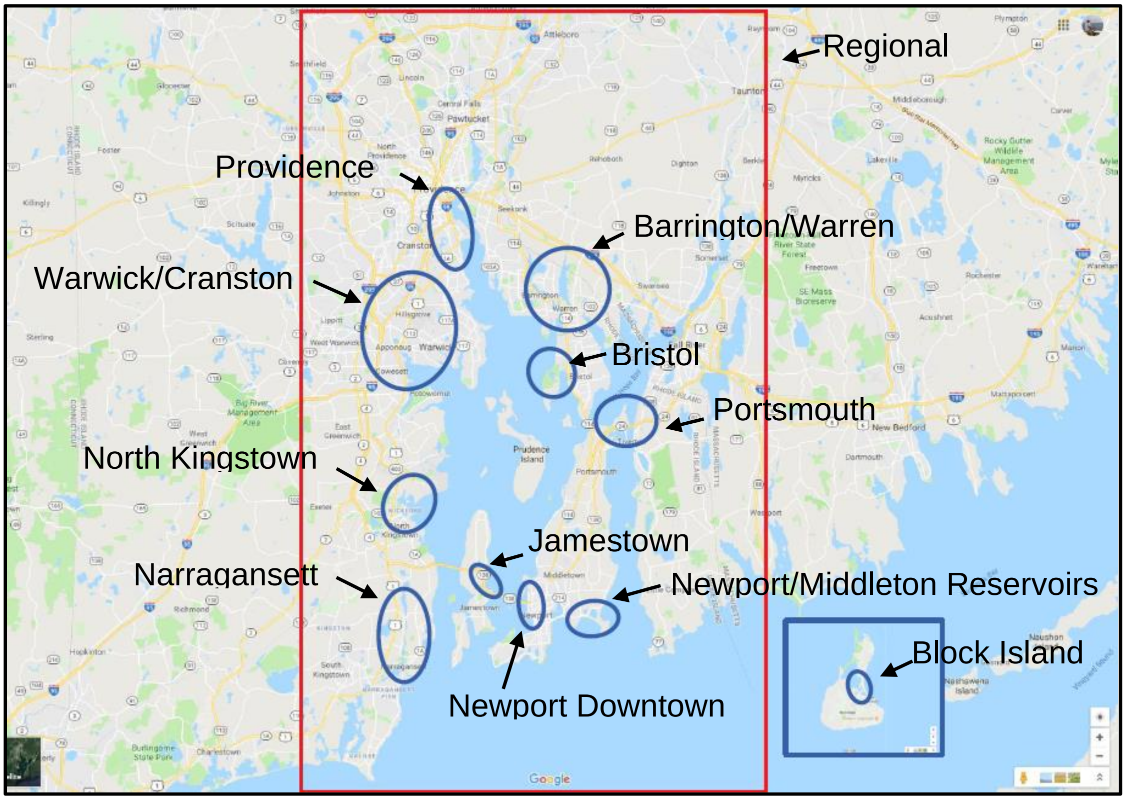

Figure 1-2: Focus Areas

1.3.3 Socioeconomics

Demographics and Housing. Based on the 2020 census, the eleven towns in the study area had a total population of 416,234 and contained 162,886 housing units. Other than Providence and Jamestown the towns in the study area showed slight population declines from 2010 to 2020, all are projected to show continued decreases in population through 2040, except, Bristol, Jamestown, Narragansett, North Kingstown and Block Island, according to state projections. Actual and projected population for the towns in the study area and the state are shown below. Providence is the largest town in the study area, followed by Warwick. The actual population of all eleven towns increases in the summer months, with the influx of tourists, boaters, and beach goers.

Table 1-2: Actual & Projected Population

	2010	2020	% Change 2010-2020	Projected 2030	Projected 2035	Projected 2040
Providence	178,042	190,934	1.2%	187,547	189,698	190,601
Newport	24,672	25,163	(2.4%)	20,736	19,796	18,758
Barrington	16,310	17,153	(1.4%)	15,914	15,791	15,569
Warren	10,611	11,147	(1.2%)	9,640	9,388	9,083
Bristol	22,954	22,493	(4.4%)	23,638	23,782	23,770
Jamestown	5,405	5,559	1.7%	5,638	5,674	5,674
Narragansett	15,868	14,532	(3.4%)	16,376	16,447	16,411
Warwick	82,672	82,823	(2%)	77,751	76,458	74,701
North Kingstown	26,486	27,732	(1.1%)	28,968	29,295	29,435
Portsmouth	17,389	17,871	(1%)	17,773	17,841	17,792
Block Island	1,051	827	(21%)	1,239	1,283	1,319

Sources: 2010 and 2020 - US Census Bureau
Projections - Rhode Island Statewide Planning Program, Technical Paper 162, Rhode Island Population Projections

Additional demographic data and housing data are shown in the table below. The population in the study area towns is primarily white, with other races generally making up less than ten percent of the population. Providence and Warwick contain the most housing units in the study area, with 62,046 and 38,625 housing units respectively, of which 4.1 percent and 20.9 percent area seasonal or recreational housing units. In contrast, the state as a whole, has a surprising 23% of housing units that are seasonal or recreational.

Table 1-3: Demographics and Housing Units

	Providence	Newport	Barrington	Warren	Bristol	Jamestown	Narragansett	Warwick	North Kingstown	Portsmouth	Block Island
AGE											
Median age (years)	31.9	35.4	44.9	48.2	40.7	52.8	46.8	44.7	45.4	47.7	52.5
18 years and over	42,769	21,556	11,809	8,779	18,872	4,430	13,625	66,525	20,910	13,897	752
21 years and over	125,722	19,518	11,495	8,569	16,000	4,281	12,683	63,975	20,146	13,249	718
62 years and over	27,937	5,369	3,354	2,590	5,509	1,729	4,765	20,271	6,238	4,660	317
65 years and over	20,620	4,550	2,664	2,211	4,580	1,403	3,761	16,880	3,349	3,889	213
RACE											
White (alone)	524%	84.1%	92.8%	96.3%	94.2%	90.4%	93%	86%	90%	89%	90%
Black or African American	21%	7.1%	0.5%	0.4%	2.4%	0.4%	0.6%	2%	1.3%	1.6%	1.2%
American Indian and Alaska Native	0.5%	1.4%	0.1%	0%	0.1%	0.2%	0.5%	0.3%	0.6%	0.2%	0.5%
Asian	5.5%	2%	3.7%	0.4%	1.6%	7.1%	1.3%	3%	1.9%	1.7%	0.4%
Native Hawaiian and Other Pacific Islander	0.0%	0.4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hispanic or Latino (of any race)	44.2%	9.8%	3.6%	2.5%	2.9%	0.4%	0.8%	3%	3.6%	3.6%	4.7%
Some Other Race/Two or more races	6.7%	3.6%	2.7%	2.3%	0.8%	1.8%	3%	2.6%	5.4%	6%	3.9%
HOUSING											
Total Housing units	62,046	10,211	6,029	4,884	5,495	3,122	9,857	38,625	12,189	8,610	1,818
Seasonal, recreational or occasional	362	1,414	118	118	300	469	2,162	175	262	553	1,253
% seasonal	4.1%	57.5%	30.1%	23.4%	37.3%	73.4%	83.5%	20.9%	36%	57.4%	96.8%

Source: US Census Bureau, 2010 Census, http://factfinder.census.gov

Economy and Unemployment. Major employment sectors in the eleven study area towns include educational services, and health care and social assistance; Management, and administrative and waste management services; and Arts, entertainment, and recreation, and accommodation and food services. After high unemployment rates in Rhode Island during the economic crisis of 2008 – 2009, many parts of Rhode Island had high unemployment rates of 10% to 12%. However, in recent years the economic recovery has taken hold and the October 2021 unemployment rate in all eleven towns was 5.4%.

Providence is the capital city of Rhode Island and is home to the largest labor force within the study, 85,817, along with the highest unemployment rate, 5.1%, and the lowest median household income at $50,097. The primary employment industry is educational services, and health care and social assistance followed by management, and administrative and waste management services. This is an accurate representation as there are multiple colleges, hospitals within the city along with having the highest population needing the most municipal services. Although, the city is close to water, the docks are used for cargo ships and not fishing boats.

Newport is a city in Rhode Island known for its rich history associated with yachting and large mansions, some of which have been converted to museums. Newport is one of the top tourist destinations in New England. The most popular employment industry is educational services, and health care and social assistance followed by Arts, entertainment, and recreation, and accommodation and food services. Like Providence the popular employment industries relate to what is offered within the city.

Barrington is a residential town southeast of Providence that borders the Massachusetts state line. This town has the highest median household income of the study at $125,431. The popular industries in town are educational services, and health care and social assistance followed by management, and administrative and waste management services. The least popular being agriculture, forestry, fishing and hunting, and mining. The town of Barrington does not have a lot of large areas of vegetation and the few have been set aside as state parks.

Warren is another small town that borders Massachusetts. Warren has the second smallest labor force of all the areas in the study, 5,607, and the second lowest median household income, $59,926. The most popular industries are educational services, and health care and social assistance followed by retail Trade with agriculture, forestry, fishing and hunting, and mining being the least popular. Warren is home to a town beach, Haile Farm Preserve and Audubon Touisset Marsh Wildlife Refuge.

Bristol is a peninsula south of Warren and Barrington. Bristol is home to Roger Williams University as well as museums and Colt State Park. The most popular employment industry in Bristol is educational services, and health care and social assistance followed by arts, entertainment, and recreation, and accommodation and food services. For a town with a university and numerous tourist sights, this would be an accurate description of workers. The least popular industry is once again agriculture, forestry, fishing and hunting, and mining.

Jamestown is the second largest island in Narragansett Bay and is in between Newport and North Kingstown. Jamestown has the second highest median household income of $111,110 and the lowest rate of unemployment at 2.4%. The most popular employment industry is educational services, and health care and social assistance followed by management, and administrative and waste management services with the least popular being agriculture, forestry, fishing and hunting, and mining. Jamestown is home to Fort Getty Park, Fort Wetherill State Park, Beavertail Lighthouse Museum and the Windmill Hill Historic District.

Narragansett is a town that borders Long Island Sound. This town’s population doubles in the summer; however, still has the second lowest unemployment rate of the towns in this study at 2.5%. The most popular employment industry is educational services, and health care and social assistance followed by Arts, entertainment, and recreation, and accommodation and food services with Information being the least popular.

Warwick is the third largest city in Rhode Island and is a few miles south of Providence. This city has the second largest labor force, 45,188. The most popular employment industry is educational services, and health care and social assistance followed by manufacturing with Agriculture, forestry, fishing and hunting, and mining being the least popular. Warwick is home to the Rocky Point State Park, Goddard Memorial State Park and the Warwick Center for the Arts.

North Kingstown is a town west of Jamestown and north of Narragansett. North Kingstown has the fourth highest median household income of areas in this study, $91,796. The most popular employment industry is educational services, and health care and social assistance followed by Arts, entertainment, and recreation, and accommodation and food services with Information being the least popular. North Kingstown is also home to Smith's Castle, Wickford Village, Biomes Marine Biology Center and the Quonset State Airport.

Portsmouth is a town north of Newport while also containing an island off the coast to the west in Narragansett Bay. This town has the third highest median household income, $100,453. Portsmouth's most popular employment industry is educational services, and health care and social assistance followed by rts, entertainment, and recreation, and accommodation and food services with Information being the least popular. Portsmouth is known for Greenvale Vineyards, Green Animals Topiary Gardens, Prudence Island Lighthouse, and the Newport Car Museum.

Table 1-4: Employment Data

Income & Employment	Providence	Newport	Barrington	Warren	Bristol	Jamestown	Narragansett	Warwick	North Kingstown	Portsmouth
Unemployment rate (October 2021)	5.1%	2.9%	2.8%	3.8%	2.9%	2.4%	2.5%	3.5%	3.5%	2.7%
Labor Force	85,817	13,334	8,235	5,607	11,617	3,186	8,777	45,188	14,547	8,577
Median household income (2021 dollars)	$50,097	$67,102	$125,431	$59,926	$72,610	$111,110	$86,920	$75,384	$91,796	$100,453
Employment by industry										
Agriculture, forestry, fishing and hunting, and mining	6	178	0	26	58	0	73	321	73	136
Construction	3,374	2,666	254	265	557	135	257	2,938	257	231
Manufacturing	9,414	3,652	570	597	946	86	515	4,947	515	523
Wholesale Trade	1,327	587	231	86	245	66	155	1,025	155	55
Retail Trade	9,827	3,444	624	797	1,047	151	696	4,839	696	769
Transportation and warehousing, and utilities	3,919	1,866	177	266	318	108	101	3,071	101	139
Information	1,099	669	404	61	177	59	38	1,228	38	46

Income & Employment	Providence	Newport	Barrington	Warren	Bristol	Jamestown	Narragansett	Warwick	North Kingstown	Portsmouth
Finance and Insurance, and real estate and rental and leasing	3,153	2,909	796	392	756	344	533	3,337	533	473
Management, and administrative and waste management services	11,529	5,924	1,282	430	980	444	742	4,424	742	870
Educational services, and health care and social assistance	31,141	9,029	2,721	1,600	3,951	738	2,209	10,636	2,209	2,222
Arts, entertainment, and recreation, and accommodation and food services	9,166	7,825	629	586	1,360	137	1,177	3,200	1,177	1,484
Other services, except public administration	3,432	1,262	293	298	423	113	348	3,640	348	273
Public administration	1,756	2,367	278	275	439	75	290	1,978	290	256

http://www.dlt.ri.gov/lmi/laus/town/laus19.htm
https://www.census.gov/quickfacts/fact/table/US/PST045218

1.3.4 Storm History

A history of storm events that have impacted coastal Rhode Island, including both nor’easters and other storms, is shown **Table 1-5** below.

Table 1-5: FEMA Disaster and Emergency Declarations, RI

Disaster Number	Date	Incident Description	Declaration Type
3563	08/21/2021	Hurricane Henri	Emergency
4212	04/03/2015	Severe Winter Storm[2]	Major Disaster
4107	3/22/2013	Severe Winter Storm[2]	Major Disaster
4089	11/3/2012	Hurricane Sandy	Major Disaster
3355	10/29/2012	Hurricane Sandy	Emergency
4027	9/3/2011	Tropical Storm Irene	Major Disaster
3334	8/27/2011	Hurricane Irene	Emergency
3311	3/30/2010	Severe Storms and Flooding[1]	Emergency
1894	3/29/2010	Severe Storms and Flooding[1]	Major Disaster
	11/3/2007	Hurricane	Major Disaster
3255	9/19/2005	Hurricane Katrina Evacuation	Emergency
3203	2/17/2005	Snow	Emergency
3182	3/27/2003	Snowstorm[2]	Emergency

Disaster Number	Date	Incident Description	Declaration Type
1091	1/24/1996	Blizzard[3]	Major Disaster
3102	3/16/1993	Blizzard[3]	Emergency
913	8/26/1991	Hurricane Bob	Major Disaster
748	10/15/1985	Hurricane Gloria	Major Disaster
548	2/16/1978	Snowstorm[2]	Major Disaster
3058	2/7/1978	Blizzards[3] and Snowstorms[2]	Emergency
39	8/20/1955	Hurricane Diane, Flood	Major Disaster
23	9/2/1954	Hurricane Carol	Major Disaster

[1] This flood event was caused by a series of moderate to heavy rainfall events

[2] A storm where precipitation falls as snow is called snowstorm

[3] A blizzard is a severe snowstorm defined by the strength of its winds rather than the amount of snow it brings

2.0 http://www.fema.gov/disasters/grid/state-tribal-government/34

History of Nor'Easters. A nor'easter (also called northeaster) is a cyclonic storm that moves along the east coast of North America with continuously strong northeasterly winds blowing in from the ocean. These winter weather events are known for producing heavy snow, rain, and oversized waves that often cause beach erosion and structural damage. This type of storm is a primary concern for Rhode Island residents not only because of the damage potential, but because there is a frequent rate of recurrence. Nor'easters have an average frequency of 1 or 2 per year, with a storm surge equal to or greater than two feet. The comparison of hurricanes to nor'easters reveals that the duration of high surge and winds in a hurricane is 6 to 12 hours while a nor'easter's duration can be from 12 hours to 3 days. (RIEMA, 2011)

The blizzard of 1978 remains the worst winter storm on record for Rhode Island. It was a slow-moving nor'easter accompanied by astronomically high tides that caused serious coastal flooding, beach erosion, broken seawalls and massive property damages. Although not all damages were in the coastal areas, the state suffered 26 fatalities and damages in excess of $15 Million[1]. (Strauss, 2003)

The Halloween Storm of 1991 was another strong extended nor'easter that caused flooding in tidal areas and over wash of the dunes along the southern coast during times of high tide. This in turn caused flooding in Westerly that damaged many businesses and flooded approximately one third of the residential area (Westerly, 2010).

Additional nor'easters include the 2003 President's Day Storm, the 2005 Blizzard, and the March 2010 Nor'easter that caused significant coastal flooding, including road and bridge washouts, flooded homes and businesses, damaged utilities and major disruptions to utility services.

History of Major Hurricanes. Five hurricanes of category 3 or greater, occurring in 1635, 1638, 1815, 1869, and 1938, have made landfall on the New England coast since

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[1] Dollar damages are reported at the price level of the associated storm event in this section of the report

European settlement. (Jeffrey P. Donnelly, 2001) Based on National Weather Service records, Rhode Island has experienced approximately 30 hurricanes throughout recorded history with 14 occurring in the 20th century. (RIEMA, 2011)

The most notable storm to hit Rhode Island was the hurricane of September 21, 1938, which brought major devastation to the State, with 262 deaths and damage estimated at $100 million. (RIEMA, 2011) Another major hurricane occurred on September 14, 1944; no lives were lost, but property damage was over $2 million. The coastal area from Westerly to Little Compton experienced the heaviest damage.

Ten years later, Hurricane Carol hit Rhode Island resulting in 19 deaths and $200 million in property damage (RIEMA, 2011). Hurricane Carol arrived on August 31, 1954, shortly after high tide. Even though the storm arrived after high tide, resulting in a lower storm tide, Narragansett Bay received storm surge greater than 14 feet in the upper reaches of the bay. In the capitol city of Providence, the surge was recorded at 14.4 feet, surpassing that of the 1938 Hurricane (NOAA). Entire coastal communities were nearly wiped out from Westerly to Narragansett. (RIEMA, 2011).

The next major storm to warrant a FEMA Major Disaster Declaration was Hurricane Diane in August 1955 which caused $5 Million in property damages when its 6-foot tidal surge hit Rhode Island. (RIEMA, 2011)

Hurricane Gloria, which was downgraded to a tropical storm over New England, caused two fatalities in Rhode Island and damages close to $20 Million when it struck on September 27, 1985. Fortunately, the storm arrived at low tide and reported surges were less than 5 feet in Rhode Island. (Grammatico, 2002)

On August 19, 1991, the eye of Hurricane Bob passed over Block Island and made landfall over Newport. Hurricane Bob caused a storm surge of 5 to 8 feet along the Rhode Island shore with approximate property damages of $115 million. (NOAA Coastal Services Center, 1999) Extensive beach erosion occurred from Westerly, eastward. Some south facing beach locations on Martha's Vineyard and Nantucket islands lost up to 50 feet of beach to erosion (NOAA).

Hurricane Irene made landfall on the RI coast during morning high tide on August 28, 2011, bringing storm surge values recorded at 2 to 4.8 feet with storm tides of 4.5 to 8.2 feet (NAVD88). (NOAA-US Dept. Commerce) The storm surge into Narragansett Bay caused some coastal damage, although Providence, at the head of the bay, was spared downtown flooding in part due to its hurricane barrier. (Wikipedia)

Hurricane/Post-tropical Cyclone Sandy was a late-season storm that came ashore in the U.S. near Brigantine, New Jersey on October 29 with 80 mph sustained winds and record storm tide heights. Its impact was felt along the entire East Coast of the United States from Florida northward to Maine, causing historic devastation and substantial loss of life.

The arrival of Hurricane Sandy, on October 29, 2012, was preceded by Coastal Flood Warnings and mandatory evacuations in Rhode Island for coastal towns, low lying areas and mobile homes. Major evacuations from Rhode Island towns along Narragansett Bay and the Southern Atlantic Coast included Bristol, Charlestown, Fall River Middletown, Narragansett, South Kingston, Tiverton and Westerly.

The storm surge of Hurricane Sandy destroyed houses and businesses, damaged pilings and deck supports, blew out walls on lower levels, and moved significant amounts of sand and debris into homes, businesses, streets, and adjacent coastal ponds. Propane gas tanks were dislodged from houses, septic systems were damaged and underground septic tanks were exposed, creating potential hazardous material exposure. The National Guard was called out to restrict entry to the community of Misquamicut (located in the town of Westerly) due to the devastation.

The Westerly Sun newspaper reported that “houses were ripped from their stilts and deposited in the streets while other structures appeared precariously perched over the ocean.” In some areas, roads were either flooded or covered in three feet of sand.

More than $39.4 million in support from four federal disaster relief programs is helping Rhode Island recover from Hurricane Sandy’s effects. FEMA’s website reports the National Flood Insurance Program (NFIP) has paid more than $31.1 million for more than 1,000 claims. In addition to NFIP claims, Federal aid also included more than $5.3 million in Public Assistance (PA) grants for state and local agencies and private nonprofits, and more than $423,000 in Individual Assistance grants paid directly to eligible individuals and families to meet basic needs for housing and cover other essential disaster-related expenses. The U.S. Small Business Administration has provided approximately $2.6 million in low-interest disaster recovery loans to Rhode Island homeowners, renters and business owners of all sizes. (FEMA, 2013)

FEMA’s PA program has approved more than 260 projects to reimburse local and state agencies in Rhode Island for 75 percent of eligible Sandy-related costs that include emergency response, debris removal, and repair or replacement of facilities or infrastructure. (FEMA, 2013) The US Department of Housing and Urban Development allocated $3.24 million in Community Development Block Grant Disaster Recovery funding to support projects that address the impacts of Hurricane Sandy in Rhode Island. (RIHCD, 2013)

Figure 1-3 below shows the coastal areas at risk of flooding during Category 2 and category 4 Hurricanes.

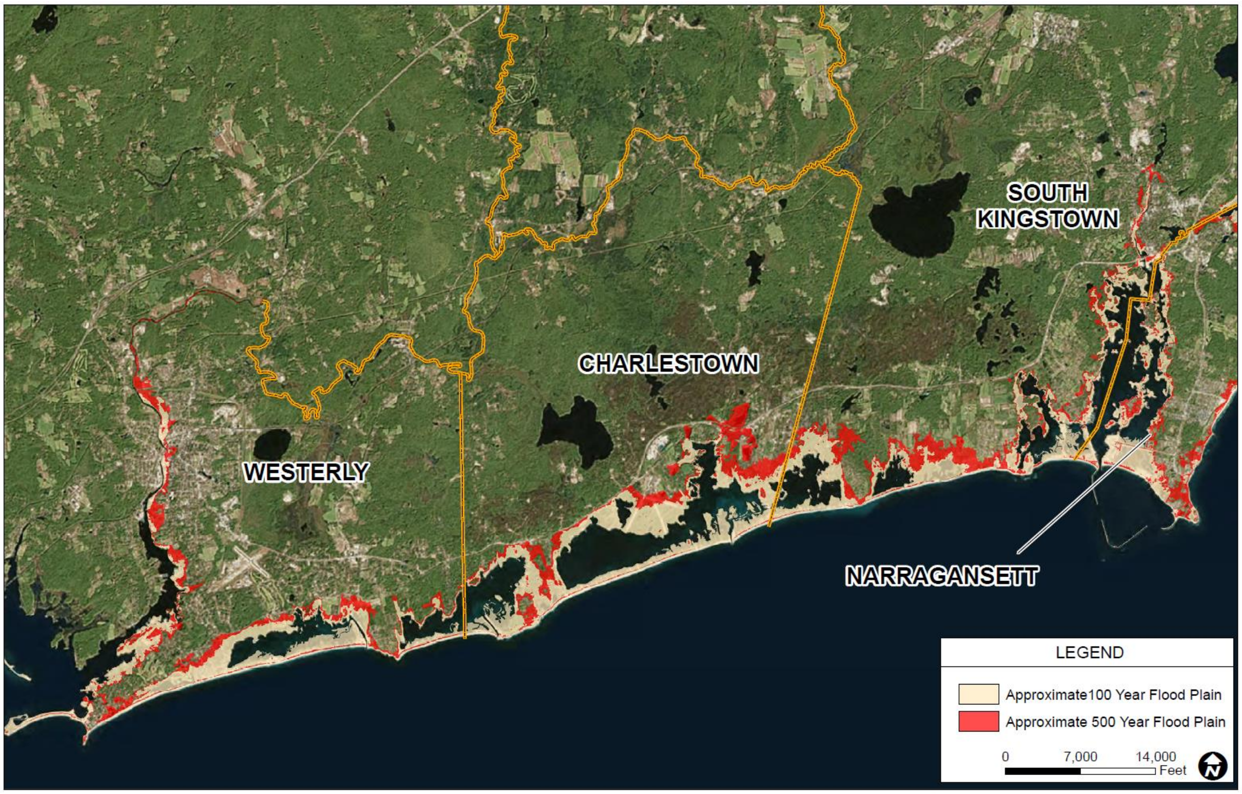

Figure 1-3: Category 2 and Category 4 Inundation Areas

In Narragansett, the storm surge from Hurricane Sandy caused shoreline erosion and damage to buildings, roads and a section of the seawall. One home was totally destroyed, and 6 other residences had major damage. Several low-income housing authority units and four town-owned single-family residences were also damaged. NFIP claims for Sandy damage for the entire town were in excess of $4.1 million. (RIHCD, 2013) The Coast Guard House Restaurant, a historic landmark overlooking the ocean, was severely damaged. A low-lying segment of Col. John Gardner Road in the Bonnet Shores neighborhood was significantly damaged, and a section of approximately 1,000 feet was undermined and washed away. (RIHCD, 2013) A section of sidewalk from State Pier No. 5 to the town beach was also damaged and 200 feet of seawall was overturned. The state was awarded $3.0 million by the US Department of Transportation quick release emergency relief funds to address the damages. (RIDOT, 2012)

In South Kingstown, Hurricane Sandy destroyed a recreational facility in the basement of the Green Hill Beach Club, but the elevated portion of the clubhouse remained. The building finally collapsed after consecutive days of large post-storm surf that took out the last remaining support pilings. The club had been built 51 years ago and had served 225 families. (SRIN, 2013) Structures damaged or lost included the South Kingstown Town Beach pavilion, a local tavern, and three of the historic Browning Cottages, which were built over 100 years ago. The on-going erosion and storm threat also prompted the South Kingstown Zoning Board to permit the relocation of 28 first and second row cottages at Roy Carpenter's Beach on Cards Pond Road.

In Charlestown, Hurricane Sandy altered the shoreline, damaged and destroyed buildings and infrastructure, spread debris, and caused utility interruptions. Damage to the Charlestown breach-way, the inlet to Ninigret Pond, resulted from the pounding of storm waves against the east side of the inlet channel. A number of rocks lining the channel were pushed into the channel causing parts of the bank to be nearly underwater at high tide, and the stone embankment was no longer safe to walk on. Charlestown and the State of RI are also applying for federal aid to repair the inlet.

In Westerly, damages from Hurricane Sandy were especially severe in the Misquamicut Beach area, in the vicinity of Atlantic Avenue. FEMA has reported multiple repetitive loss properties in Westerly; properties that have had two or more claims exceeding $1,000 over a ten-year period.

In August of 2021 Hurricane Henri made landfall in the state of Rhode Island. It was the first tropical cyclone to do so since 1991 and Hurricane Bob. Henri started as a low-pressure system off the northeast coast of Bermuda. Henri made landfall in Westerly, Rhode Island on August 22nd. Throughout the state of Rhode Island, primarily in Washington County, there were over 58,000 people without power. There were tree limbs and power lines downed from the 70 mile per hour winds. For the entirety of the northeast, damages and economic loss was estimated at $8 billion to $12 billion. (usatoday.com)

2.0 NATIONAL ECONOMIC DEVELOPMENT: COASTAL STORM RISK REDUCTION

2.1 NED Benefit Categories Considered

The NED procedure manuals for coastal and urban areas recognize four primary categories of benefits for coastal storm risk management measures: inundation reduction, intensification, location, and employment benefits. Generally, most of the benefits attributable to a project alternative result from the reduction of actual or potential damages caused by inundation. Benefits include the reduction of physical damages to structures and associated contents.

Physical Flood Damage Reduction. Physical flood damage reduction benefits include the decrease in potential damages to residential, commercial, industrial, or public structures, their contents, and associated vehicles, as well as loss of land value. Vehicles and land value were initially considered for this study, but ultimately not included in the modeling and economic analysis. While future population growth was projected for the study area, a future development structure inventory was not included in the damage calculations due to the limited remaining available land and the expectation that future growth will more likely be accomplished through redevelopment. As the analysis does not appreciate structure and content value over the 50-year economic analysis, it is reasonable to, also, not consider the potential reduction in future damages by the redevelopment to higher standards beyond what is reduced through the raising process in G2CRM.

Non-Physical Flood Damage Reduction. Non-physical flood damage benefits, eligible for inclusion if an alternative reduces the chances of inundation in a study area, include emergency costs incurred by the community during and immediately following a major storm. This can include the costs of emergency measures, such as evacuation and reoccupation activities conducted by local governments and homeowners, repair of streets, highways, and railroad tracks, debris removal and the subsequent cleanup and restoration of private, commercial, and public properties. Non-physical benefits could also include reduction in cost of future planned protective measures, transportation delay costs, reduced maintenance on existing structures, and intensification benefits. For this study, only the costs foregone is planned to be included for critical infrastructure in the study area as determined appropriate.

2.2 Economic Analysis Methodology

A Federal project is considered economically justified if the benefits of the project equal or exceed the costs. The economic benefits of a coastal storm damage reduction project are measured by the degree to which the project reduces expected annual storm damages. Damages in the without- and future with-project conditions were calculated using the approved USACE modelling tool, Generation 2 Coastal Risk Model (G2CRM) Version 0.4.564. A summary of the model's key components and the uncertainty surrounding the data elements is provided in the following sections.

G2CRM was used to estimate the inundation damages for project alternatives within the study area. G2CRM is distinguished from other models by virtue of its focus on probabilistic life cycle approaches. This allows for examination of important long-term issues including the impact of climate change and avoidance of repetitive damages. Additionally, G2CRM allows for incorporation of time-dependent and stochastic event-dependent behaviors such as waves, tides, and structure modifications. The model is based upon driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas (model areas) of different types that may interact hydraulically and may be defended by coastal defense elements that serve to shield the areas and the assets they contain from storm damage.

Within the specific terminology of G2CRM, the important modeled components are:

- **Driving forces** - storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE;
- **Modeled areas** (MAs) - areas of various types (coastal upland, unprotected area) that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area.
- **Protective system elements** (PSEs) - the infrastructure that defines the coastal boundary be it a coastal defense system that protects the modeled areas from flooding (levees, pumps, closure structures, *etc*.), or a locally developed coastal boundary comprised of bulkheads and/or hardened shoreline.
- **Assets** – spatially located entities that can be affected by storms. Damage to structure and contents is determined using damage functions. For structures, population data at individual structures allows for characterization of loss of life for storm events.

The model deals with the engineering and economic interactions of these elements as storms occur during the life cycle, areas are inundated, protective systems fail, and assets are damaged, and lives lost. Within the study, G2CRM is used to calculate the reduction in structure and contents damage, and life loss for different project alternatives.

Life-Cycle Approach

The possible occurrences of each variable were derived using Monte Carlo simulation, which used randomly selected numbers to simulate the values of the selected variables from within the established ranges and distributions. For each variable, a sampling technique was used to select from within the range of possible values. With each sample, or iteration, a different value was selected. At each iteration, different variables are sampled to allow for representations of uncertainty in variables, such as the number of storms in a year. Over many iterations, the overall results should return values representative of the input variability. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean value and probability distributions formed a comprehensive picture of all possible outcomes.

Assumptions and Run Conditions

G2CRM accuracy is not only dependent upon inputs but also requires consideration of the parameters (*i.e.*, assumptions) under which the model is bound. This section describes key assumptions of the G2CRM model and specific parametric assumptions made for the evaluation for this study.

Start year. The year in which the simulation begins is 2021. This year determines the starting structure inventory which will evolve through raising and rebuilding efforts throughout the period of analysis.

Base year. The present value basis and the year in which the benefits of a constructed federal project would be expected to begin accruing is 2030. This is based on the expected signing of the Chief’s Report in 2023, 3 years of funding appropriation and preconstruction engineering/design (PED), and 5 years of construction.

Basis year. G2CRM makes a distinction between base year and basis year. While the base year parameter specifies the temporal reference to any monetary related statistics, the basis year parameter specifies the temporal reference to any sea level calculation within the model. The basis year was selected to be 1992, the midpoint of the utilized National Tidal Datum Epoch (NTDE) (1983-2001).

Sea Level Change Rate. The mean sea level trend of 2.77 mm/year, or 0.00909 feet/year, with 95% confidence rating +/- 0.16 mm/year, as published for Newport RI as of 2019, was used as the sea level change rate using the USACE Intermediate Curve. Water level elevations at year 2030 are expected to be between 0.35 and 0.88 feet higher than the current NTDE. Water elevations at year 2080 are expected to be between 0.80 and 3.67 feet higher than the current NTDE.

Period of Analysis. The period of analysis is 50 years, from 2030 to 2079. Note that the model duration will be 58 years, from the start year (2021) to 2079. The additional time allows the structure inventory to become damaged and raised prior to the federal project being in place. This limits the available flood risk damages to be reduced by the federal project. However, for purposes of economic evaluation only the period from the base year will be used in benefit calculation.

Iterations. G2CRM model runs used 100 iterations for the FWOP and the final array of alternatives. The moving average of FWOP damages stabilized by this point and was determined as an adequate threshold. Within this appendix, the term iteration can also be referred to as life cycle.

Discount Rate. The analysis was conducted using the most current discount rate available at the time of the modeling, 2.5% federal water resource project evaluation discount rate for fiscal year 2021.

Calculate Depreciation. As discussed, structure values were calculated as depreciated replacement values. Therefore, additional depreciation was not considered.

Raise Structure. Base Flood Elevations (BFE) were identified, according to the preliminary Flood Insurance Rate Map, dated December 31, 2019. It is assumed that if a structure within the Special Flood Hazard Area is damaged by 50% of the structure's value prior to the event, that structure will be required to be brought up to code. Its first-floor elevation will be raised to the BFE plus one foot of freeboard in accordance with the Rhode Island Building Code.

Calculate Assets. Selecting "yes" directs G2CRM to use the uploaded assets.

Use Benefit Bases. The Water Resource Development Act (WRDA) of 1990, Section 308, FLOOD PLAIN MANAGEMENT. States that:

> (a) Benefit -Cost Analysis. --The Secretary shall not include in the benefit base for justifying Federal flood damage reduction projects——
>
> > (1)(A) any new or substantially improved structure (other than a structure necessary for conducting a water-dependent activity) built in the 100-year flood plain with a first-floor elevation less than the 100 -year flood elevation after July 1,1991; or
> >
> > (B) in the case of a county substantially located within the 100-year flood plain, any new or substantially improved structure (other than a structure necessary for conducting a water –dependent activity) built in the 10-year flood plain after July 1, 1991; and

> > (2) any structure which becomes located in the 100-year flood plain with a first floor elevation less than the 100-year flood elevation or in the 10 -year flood plain, as the case may be, by virtue of constrictions placed in the flood plain after July 1, 1991.
>
> (b) Counties Substantially Located Within 100-Year Flood Plain. --For the purposes of subsection (a), a county is substantially located within the 100-year flood plain——
>
> > (1) if the county is comprised of lands of which 50 percent or more are located in the 100 -year flood plain; and
> >
> > (2) if the Secretary determines that application of the requirement contained in subsection (a)(1)(A) with respect to the county would unreasonably restrain continued economic development or unreasonably limit the availability of needed flood control measures.
>
> Selecting “no” for this parameter directs G2CRM to assume all structures are in the benefit base. There are ten localities within the Rhode Island study area that currently participate in FEMA’s Community Rating System (CRS) and have Class ratings ranging from 7-9; therefore, structures are assumed to comply with the Flood Insurance Rate Map effective at the time of their construction.

Cumulative Damage Removal. Logic may suggest that a structure would be removed or acquired once the cumulative damage exceeds its present value or at a minimum, brought up to code once exceeded the 50 percent substantial damage (according to 44CFR 59.1). However, there are no current FEMA or USACE guidelines that require the removal or acquisition of a structure once damage has exceeded its present value. Additionally, tracking cumulative damages or improvements is a higher standard not often implemented by communities. Research on the study area found significant evidence that people overwhelming favor rebuild-in-place as opposed to other forms of mitigation. That’s backed up by actual experience when it comes to repetitive damage properties in the NFIP. Many homes have been damaged and rebuilt in place many (sometimes dozens) of times over the years. For those reasons, this option was not used.

Life Loss. This parameter allows the user to toggle life loss calculations on or off. For this study, life loss was calculated. Associated model and parameter assumptions for life loss are also covered in the Future Without-Project Condition section below.

Auto-Generated Waves. Waves were included in the H5 files imported into each study area; therefore, auto-generated waves were not used.

2.3 Modeling Variables

2.3.1 Economic Inputs

Structure Valuation. Depreciated replacement value per square foot was calculated for residential and non-residential structures using values for the Rhode Island area using data from Gordian's 40th edition of "Square Foot Costs with RSMeans Data" and updated to 2021 price levels. Various structure characteristics such as occupancy type, type of material, square footage, number of floors, basement, and garage were included in the structure value estimate for each individual structure. Structures were assumed to be built with average construction material. Type of material (stucco/wood, or solid masonry) was accounted for in each estimated value per square foot. In addition, those structures with basement foundations included an additional value per square foot as indicated in the RSMeans Data.

Square footages, number of floors, and foundation type for structures were obtained from parcel data when possible. However, since square footage was not available for most structures, to determine a square footage per building, the polygon area of the building footprint was calculated in ArcGIS and multiplied by 0.9 to allow for unusable space such as doors, walls, etc. This area was multiplied by the number of floors, not to exceed the number of floors within the depth-damage function for the occupancy type of the structure

According to the RSMeans residential depreciation schedule, each individual residential structure was depreciated based on the effective age for each structure obtained from either the 911 data set or the assessors database. An average condition depreciation rating was assumed for all structures, as opposed to good or poor. This equates to a percentage depreciation equivalent to the effective age for structures 10 years and older, with a cap at 50% for any structure 50 years or older. For non-residential structures, the appropriate construction material and effective age was used to determine the depreciation rate from the RSMeans non-residential depreciation schedule, which varies depending on material, but remains constant for structures 60 years or older. The age of structures for each occupancy type in the study area can be seen in the following table.

Table 2-1: Number of Structures by Age by Occupancy Type

Occupancy Type	50 year	40 year	30 year	20 year	10 year	Total
COM-2NP	542	153	9	9	4	717
COM-2P	114	31	5	7	1	158
COM-3NP	179	110	9	9	1	308
COM-3P	25	3	0	0	0	28
RES-1A1	200	39	7	2	1	249
RES-1A3	833	47	26	18	14	938
RES-4A	1	1	0	0	0	2
RES-4B	1	0	0	0	0	1
RES-5A	1595	402	103	73	33	2206
RES-5B	742	309	77	91	55	1274
RES-6A	1580	241	59	24	21	1925
RES-6B	3425	378	168	150	56	4177
RES-7A	40	31	28	33	4	136
RES-7B	5	5	0	1	0	11
Total	**9282**	**1750**	**491**	**417**	**190**	**12130**

This depreciated value was then adjusted by a percentage to equal a regional adjustment of 107% for residential and 104% for commercial, as determined by RS Means for the Rhode Island area. This process was used to calculate a most-likely cost per square foot for each structure. The most-likely depreciated cost per square foot was then multiplied by the square footage calculated for individual structures in each occupancy to obtain a total depreciated cost or value for each structure.

The resulting Depreciated Replacement Values (DRV) are in FY2021 values, which was the most current value at the time the analysis was originally completed. Each structure was also classified into different structure occupancies as required.

Content-to-Structure Value Rations. Content-to structure value ratios (CSVRs) used in this feasibility study were obtained from the Southwest Coastal Louisiana: Depth Damage Relationships for Structures and Contents, and Vehicles, and Content-to-Structure Values Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana Feasibility Study. and the Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013 (IWR 2013). Given the lack of a site specific CSVRs for this study area, various sources were considered rather than a single source. As shown in **Table 2-1**, a CSVR was computed for each residential and non-residential structure in the study as a percentage of the total depreciated replacement value. A triangular distribution was used to estimate the error.

Table 2-2: Content to Structure Value Ratios

Occupancy Type	Occupancy Type Description	C_Value P1 (Min)	C_Value P2 (ML)	C_Value P3 (Max)	Source Prototype
RES-1A1	Apartment 1 Story No Basement	0.075	0.099	0.135	Multi-Family Residence
RES-1A3	Apartment 3 Stories No Basement	0.075	0.099	0.135	Multi-Family
COM-2NP	Commercial-Engineered-Non-Perishable	0.365	0.45	0.525	Professional Business
COM-2P	Commercial-Engineered-Perishable	0.365	0.45	0.525	Professional Business
COM-3NP	Commercial-Non/Pre Engineered-Non-Perishable	0.365	0.45	0.525	Professional Business
COM-3P	Commercial-Non/Pre Engineered-Perishable	0.365	0.45	0.525	Professional Business
RES-4A	Urban High Rise	0.14	0.18	0.24	
RES-4B	Beach High Rise	0.075	0.099	0.135	Multi-Family
RES-5A	Residential 1 Story No Basement	0.25	0.5	0.75	Average Residential 1 and 2 story
RES-5B	Residential 2 Story No Basement	0.25	0.5	0.75	Average Residential 1 and 2 story
RES-6A	Residential 1 Story with Basement	0.25	0.5	0.75	Average Residential 1 and 2 story
RES-6B	Residential 2 Story with Basement	0.25	0.5	0.75	Average Residential 1 and 2 story
RES-7A	Building on Open Pile Foundation	0.365	0.45	0.525	Professional Business
RES-7B	Building on Pile Foundation with Enclosures	0.365	0.45	0.525	Professional Business

First Floor Elevation. Lowest adjacent ground elevations were obtained from Light Detection and Ranging (LiDAR) digital elevation model (DEM) downloaded from the National Elevation Dataset. The DEM is sourced from 2016 USGS CoNED Topobathymetric Model with resolution of 1 meter, and the vertical accuracy of approximately 7 cm. The coordinate system and pdt matches between the DEM and the structure inventory (both Rhode Island State Plane foot NAD83 and NAVD88 feet respectively). The vertical accuracy of the 2016 Topo Model data varies depending on the input source. In the area used for the Rhode Island project, the source was the 2011 USGS Lidar collection, which required LiDAR to be collected on *1.0-meter* GSD or better and processed to meet a bare earth vertical accuracy of 15 centimeters RMSEz or better to support 2' contour.

Foundation type was obtained from parcel data, and Google StreetView. For structures updated using Google StreetView, the foundation height was estimated by summing up the number of steps, assuming each to be 7.5 inches high. The foundation height was added to the ground elevation to determine the first-floor elevation of each structure in NAVD88. Structures with ground elevations below zero, often adjacent to waterbodies, were updated to reflect positive ground elevations adjacent to the boundary of the structure.

Structure point locations were based on the 911 point GIS layer obtained from Rhode Island GIS. When building the dataset, Rhode Island GIS located the points on the structure in the center of the building or very close to it. Since they were already located on the structure there was no refining necessary to account for adjacent lower ground from offset points.

Damage Functions. Depth-damage relationships developed for the North Atlantic Coastal Comprehensive study were used for all structures in the inventory. These depth-damage functions estimate the likely degree of damage to structure and contents at each elevation of flooding relative to the first floor, expressed as a percentage of structure and content value, based on actual damages experienced during Hurricane Sandy in the northeast. Structure values are based on depreciated replacement value of the building.

Uncertainty Surrounding the Economic Inputs. The uncertainty surrounding the four key economic variables (structure values, contents-to-structure value ratios, first floor elevations, and depth-damage relationships) was quantified and entered into the economic model. The G2CRM model used the uncertainty surrounding these variables to estimate the uncertainty surrounding the stage-damage relationships.

> *Structure Values.*
> A triangular probability distribution based on the depreciated replacement costs derived for the three quality of condition ratings (good, average, poor) was used to represent the uncertainty surrounding the residential structure values in each occupancy category. The most-likely depreciated value was based on the average quality, the minimum value was based on the poor quality, and the maximum value was based on the good quality, as seen in the following table. For non-residential

structures, the distribution was based on adjustment to observed age as well as type of material which equated to 10% less or more than the most likely depreciation. The triangular probability distributions were entered into the G2CRM model to represent the uncertainty surrounding the structure values in each residential occupancy category.

Table 2-3: Residential Structure Value Depreciation Uncertainty Range

Age	Good	Average	Poor
0	0	0	0
1	0.5%	0.5%	0.5%
2	2%	3%	10%
5	4%	6%	20%
10	7%	10%	25%
15	10%	15%	30%
20	15%	20%	35%
25	18%	25%	40%
30	24%	30%	45%
35	28%	35%	50%
40	32%	40%	55%
45	36%	45%	60%
50	40%	50%	65%

Content-to-Structure Value Ratios.
A triangular probability distribution was used to represent the uncertainty surrounding the contents-to-structure value ratios (CSVRs) for residential structures. The minimum CSVR value, 25 percent, most-likely CSVR value, 50 percent, and the maximum CSVR value, 75 percent, were all based on an estimated range found from various sources including USACE Engineering Manual 1110-2-1619, a survey of homes in coastal Louisiana and resulting report "Southwest Coastal Louisiana: Depth Damage Relationships for Structures and Contents, and Vehicles, and Content-to-Structure Values Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana Feasibility Study", and other CSRM studies with similar study area characteristics. Given the lack of a site specific CSVRs for this study area, various sources were considered rather than a single source due to the variance found in residential CSVRs, which is highly dependent on the method or derivation as well as many site specific factors.

A triangular probability distribution was also used to represent the uncertainty surrounding the CSVRs for the non-residential occupancies. The minimum, maximum and most-likely values were based on data obtained from either the Physical Depth Damage Function Summary Report published as a part of NACCS study or the 2013 Draft Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation, depending on the type of non-residential occupancy.

First Floor Elevations.

The uncertainty surrounding the first-floor elevations was captured in a triangular probability distribution due to the uncertainty associated with the used of LiDAR data, instrument, and measurement. The vertical accuracy of the 2016 Topo Model data varies depending on the input source. In the area used for the Rhode Island project, the source was the 2011 USGS Lidar collection, which required LiDAR to be collected on 1.0-meter GSD or better and processed to meet a bare earth vertical accuracy of 15 centimeters RMSEz or better to support 2' contour. Considering this, the uncertainty surrounding first-floor elevations was calculated by taking the standard deviation of the foundation height for each occupancy type, then combining the 15-centimerater (0.492 feet) uncertainty associated in lidar. The final uncertainty value was determined by taking the sum of squares of those combined values. The results of these calculations for each occupancy type are shown in the following table.

Table 2-4: First Floor Elevation Uncertainty by Occupancy Type

Occupancy Type	Count	Average of Uncertainty
COM-2NP	717	1.91
COM-2P	158	1.67
COM-3NP	308	1.85
COM-3P	28	1.00
RES-1A1	249	1.83
RES-1A3	938	1.87
RES-4A	2	1.50
RES-4B	1	N/A
RES-5A	2,206	1.28
RES-5B	1,274	1.94
RES-6A	1,925	1.79
RES-6B	4,178	1.42
RES-7A	136	2.29
RES-7B	11	4.70
Total	**12,131**	**1.61**

Depth-Damage Relationships.

A triangular probability density function was used to determine the uncertainty surrounding the damage percentages associated with each depth of flooding for the various residential and non-residential occupancy categories. A minimum, maximum, and most-likely damage estimate for each depth of flooding was obtained from the Physical Depth Damage Function Summary Report published as a part of NACCS study.

2.3.2 Engineering Inputs

Sea Level Change Rate. The mean sea level trend of 2.77 mm/year, or 0.00909 feet/year, as published for Newport RI as of 2019, was used as the sea level change rate. More details on the source for this sea level change rate can be found in the main report.

Stage-Probability Data. Stage-probability relationships were provided for the existing without-project condition through future without project conditions, based on the USACE Intermediate Sea level change curve. The intermediate rate was selected to balance the risk of over or under designing a project using the high or low curves. Further, the study area was not considered to be an abnormally high or low consequence risk area. Water surface profiles were provided for eight annual exceedance probability (AEP) events at various confidence limits. Water surface profiles were provided for eight annual chance exceedance (ACE) events at various confidence limits: fifty percent flood (2-year flood), twenty percent flood (5-year flood), ten percent flood (10-year flood), five percent flood (20 year flood), two percent flood (50 year flood), one percent flood (100 year flood), 0.50 percent flood (200 year flood), and 0.20 percent flood (500 year flood). The without-project water surface profiles were extracted from USACE North Atlantic Coast Comprehensive Study (NACCS) hydrodynamic model output data points through the USACE Coastal Hazards System (https://chs.erdc.dren.mil/) at selected ADCIRC nodes or “Save Points” throughout the study area. These ACE event water surface profiles were not used as a direct input in the G2CRM model. Rather, they were used to define floodplains within the study area, to formulate alternatives.

Storms. The probabilistic storm suite for the G2CRM model was developed from the NACCS hydrodynamic model output data at selected ADCIRC nodes or Save Points throughout the study area. Storm hydrographs from the NACCS coupled ADCIRC and STWAVE models were used to force the G2CRM model. ADCIRC is a two-dimensional hydrodynamic model that conducts short- and long-term simulations of tide and storm surge elevations and velocities in deep-ocean, continental shelves, coastal seas, and small-scale estuarine systems. ADCIRC uses the finite element method to solve the reformulated, depth-averaged shallow water equations. The model runs on a triangulated mesh with elevations derived from a seamless bathymetric/topographic DEM that includes both offshore and overland areas. The triangulated format of the mesh allows variation in the element size, so the study area can have a high concentration of nodes while fewer nodes (with higher element areas) can be placed farther away to make the mesh more efficient without compromising accuracy. STWAVE is a steady-state, finite difference, spectral model based on the wave action balance equation. Using the Coastal Storm Modeling System (CSTORM-MS), the ADCIRC and STWAVE models are two-way coupled.

For each MA, storms were sampled from the NACCS suite of 1050 synthetic tropical storms using a radius of 200 km about each model area save point. This storm sampling resulted in a range of 469 to 495 tropical storms per model area. In addition to the sampled tropical storms, the 100 historical extratropical storms from the NACCS were included in the storm suite for each MA, resulting in a total of 569 to 595 storms per model area.

Save Points:

NACCS water level and wave outputs are provided at save points throughout the study area as both annual exceedance probabilities and storm timeseries.

Sea Level Change:

For each of these AEP events, the water surface profiles for the years 2030 to 2079 were determined by adding relative sea level rise, as determined by the USACE Sea Level Rise Calculator at Newport, RI using the USACE Intermediate Curve to the Save Point elevations. The mean sea level trend of 2.77 mm/year, or 0.00909 feet/year, with 95% confidence rating +/- 0.16 mm/year, as published for Newport, RI as of 2019, was used as the sea level change rate.

Uncertainty Surrounding the Engineering Inputs:

The uncertainty surrounding three key engineering parameters was quantified and entered into the G2CRM model. These engineering variables include ground elevations, stage probability relationships, probabilistic storm suites, and sea level rise. The models used the uncertainty surrounding these variables to estimate the uncertainty surrounding the elevation of the storm surges for each study area reach. The following paragraphs detail the uncertainty surrounding individual input data.

Ground Elevations:

The elevation data for the study area was derived from the 2016 USGS CoNED Topobathymetric Model. The vertical accuracy of the 2016 Topo Model data varies depending on the input source. In the area used for the Rhode Island project, the source was the 2011 USGS Lidar collection, which required LiDAR to be collected on 1.0-meter GSD or better and processed to meet a bare earth vertical accuracy of 15 centimeters RMSEz or better to support 2' contour.

Probabilistic Storm Suites:

The probabilistic storm suite for the G2CRM model was developed from the NACCS hydrodynamic model output data at selected ADCIRC nodes or “Save Points” throughout the study area. To develop the NACCS storms, data from historical storms was used to develop a statistical description of the hurricane storm climate of the area in terms of parameters such as central pressure deficit, radius to maximum winds, forward speed of the storm, azimuth of the storm track, etc., allowing for the probabilistic characterization of the occurrence and characteristics of potential hurricanes that may cause significant flooding along the Rhode Island coast. While the NACCS storm suite included 1050 synthetic storms for the area from Virginia to Maine, the storm suite used in the G2CRM model was generated by sampling storms which came within 200 km of each G2CRM model area’s save point. This sampling resulted in storm suites ranging from 469 to 495 tropical storms. In addition to the sampled tropical storms, the 100 historical extratropical storms from the NACCS were included in the storm suite for each MA, resulting in a total of 569 to 595 storms per model area.

Stage-Probability Relationships:
The uncertainty is incorporated into the modeling of storm stage probabilities through the range of water levels associated with various confidence levels for each of the defined return periods specified in the previous section on stage-probability relationships. More detail on this can be found in the engineering appendix describing the H5 files used in the G2CRM model. As an example, the range of water levels associated with the 100-year return period ranges from approximately 2 feet for the 16% and 84% confidence levels to almost 4 feet for the 2% and 98% confidence levels.

Sea Level Change:
For each of these AEP events, the water surface profiles for the years 2030 and 2080 were determined by adding relative sea level change, as determined by the USACE Sea Level Change Curve Calculator for Newport, RI using the USACE Intermediate Curve to the Save Point elevations. The use of the intermediate curve was made after assessing historical trends of Sea Level Change and to balance the risk of over- or underestimating future SLC. Additionally, the mean sea level trend of 2.77 mm/year, or 0.00909 feet/year, with 95 percent confidence rating +/- 0.16 mm/year, as published for Newport, RI, was used as the sea level change rate in the G2CRM model. Performance of the selected plan under alternate SLC scenarios will be conducted following the TSP and will be detailed in the final feasibility report.

3.0 EXISTING CONDITIONS

This section of the appendix includes detailed information about the existing conditions in the study area, including the inventory of property potentially subject to storm damage. It also includes information about the economic evaluation approach and how that approach utilizes existing data.

3.1 Description and Characteristics

Under existing conditions, coastal Rhode Island is subject to significant risk from coastal storms as described in the preceding paragraphs. There are currently more than 650,000 people residing in the 19 towns included in the study area in Rhode Island and approximately 75 percent of the state population resides in a 40-mile long urban/suburban corridor along the shores of Narragansett Bay. About 20% of the existing population would be expected to require additional time and resources to assist in evacuation due to a storm event due to age. Structures in the area consist of a mix of single-family homes, apartment buildings, and commercial buildings; there are a considerable portion of buildings in the area that have basements and are over 50 years old.

The shoreline and coastal tributaries of southeastern Rhode Island from Narragansett Bay to the Massachusetts border experiences recurring and significant coastal flooding, due to inundation caused by storm events. This flooding contributes to risk to public safety and property in the region. The effects of inundation are anticipated to increase due to future sea levels rise.

3.2 Coastal Hydrology

3.2.1 Model Areas

In G2CRM, damages were estimated for 16 model areas (MAs), as detailed in the following Table and Figure. Model areas are established to reflect the area of influence of the ADCIRC save points identified to best represent various parts of the study area. The model areas can be defined as unprotected or upland. Based on guidance from G2CRM developers, all model areas within G2CRM were specified as upland. An upland model area is a polygonal boundary within G2CRM that contains assets and derives associated stage from the total water level calculated for a given storm. The stage is calculated as the storm surge plus wave contribution plus sea level change contribution plus tide contribution). The area is mediated by a protective system element such as a bulkhead/seawall that must be overtopped before water appears in the model area. It can also have an associated volume-stage relationship to account for filling behind the bulkhead/seawall during the initial stages of overtopping.

Table 3-1: Model Area Geographical Reference

Model Area	Description	Localities
BI1	Block Island	New Shoreham (Block Island)
BI2	Block Island	New Shoreham (Block Island)
BRI	Bristol	Bristol, North Kingstown, Portsmouth, Tiverton, Warwick
CRA	Cranston	Barrington, Cranston, East Providence, Providence, Warwick
GB	Greenwich Bay	East Greenwich, North Kingstown, Warwick
SAKS	Sakonnet South	Little Compton, Middletown, Portsmouth
SAKM	Sakonnet Middle	Little Compton, Portsmouth, Tiverton
SAKN	Sakonnet North	Portsmouth, Tiverton
PVD	Providence	Cranston, East Providence, Pawtucket, Providence
MTHB	Mt. Hope Bay	Bristol, Warren
NPT1	Newport	Jamestown, Middletown, Newport
NPT2	Newport	Jamestown, Middletown, Newport
LC	Little Compton	Little Compton, Middletown
NAR	Narragansett	Jamestown, Narragansett, North Kingstown, South Kingstown
WAR	Warwick	Barrington, Bristol, East Providence, Warren, Warwick
WICK	Wickford	Jamestown, Middletown, North Kingstown, Portsmouth

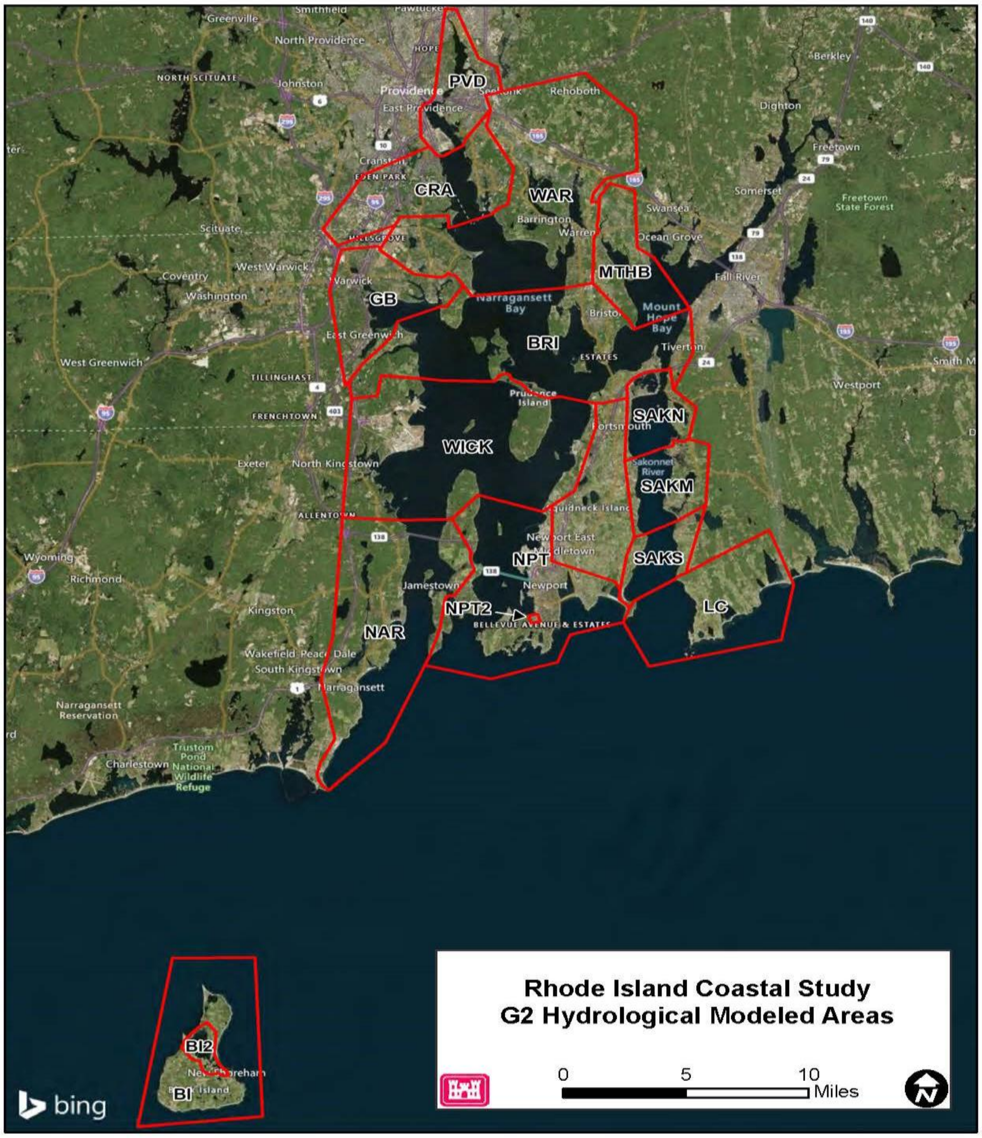

Figure 3-1: Model Area Geographical Reference

3.2.2 Protective System Elements (PSE)

Flood hazard manifested at the storm location is mediated by the associated bulkhead PSE for each model area. The PSE prevents transmission of the flood hazard into the model area until the flood hazard exceeds the top elevation of the bulkhead. When the flood hazard exceeds the top elevation the flood hazard is instantaneously transmitted into the model area if it is not associated with any volume-stage function (VSF).

If a volume-stage function was specified for the model area, it turns into a reservoir and becomes inundated over time during each storm event. The function calculates the storm stage (*i.e*. the water level) using accumulated volume at every timestep. Volume-stage functions were used in all areas under consideration for structural measures. Functions were manually calculated in ArcGIS using the cut/fill tool.

Based on guidance from the model developers, “upland” model area were employed for both the structural and nonstructural analysis. For areas under the structural analysis, PSEs were entered using a line shapefile generated in ArcMap to represent proposed constructions and existing dunes. PSEs are defined in G2CRM to capture the effect of built CSRM infrastructure (bulkhead/seawall). The infrastructure is present in both future without project and future with project condition. In the future without project, the top elevation of all PSEs are set consistent with ground elevation to eliminate any potential impedence to the water source. Similarly, the waterside ground elevation was set as zero-ft NAVD88 for all scenarios.

3.3 Asset Inventory

The asset inventory was compiled using geospatial data available from the state of Rhode Island. All processing was done with ArcGIS 10.1 using RI State Plane NAD83 feet as the horizontal projection and NAVD88 feet as the vertical datum, consistent with the vertical datum used for hydrologic and hydraulical modeling used for this analysis. The 911 database is in the format of a point shapefile with each point overlaying a structure location. A ground elevation was determined using 2011 USGS Lidar (U.S. Geological Survey). Most structures were viewed individually in either in Google Earth or online real estate sites to determine the type of construction, type of foundation and the first-floor elevation relative to the ground elevation.

3.3.1 Structure Values and Occupancy Types

The structure inventory was developed from a combination of 911 data for the state of Rhode Island and real estate data provided by various localities within the study area. The asset inventory is valued at the 2021 depreciated replacement cost, originally derived from 2019 square footage values available in the tax database and Gordian’s 40th edition of “Square Foot Costs with RSMeans Data” and updated to 2021 values using the historical adjustment factor appropriate for the study area.

Most structures near the coastline were found to consist of average construction material with an average effective age of about 70 years for both residential and commercial. Given the age of structures, a considerable number of structures in the study area may be considered historic. For this analysis, no adjustment was made to account for the potential added value that may be associated with historic structures, such as rare and higher priced building materials. As more information is able to be obtained on individual structures included in the plan, adjustments to structure values may be made.

Within G2CRM, structures are modeled as single point assets. Assets are spatially located entities that can be affected by storm surges. For this analysis, assets consist of structures and associated contents located within the 16 model areas. The following tables show the count and aggregated value distribution across occupancy types and model areas respectively.

Table 3-2: Average Depreciated Replacement Value by Occupancy Type

Occupancy Type	Count	Average Structure Value ($)	Average Contents Value ($)	Average Total Value ($)
Commercial-Engineered-Non-Perishable (COM-2NP)	717	638,000	287,000	925,000
Commerical-Engineered-Perishable (COM-2P)	158	632,000	285,000	917,000
Commercial-Non/Pre Engineered-Non-Perishable (COM-3NP)	308	1,205,000	542,000	1,747,000
Commercial-Non/Pre Engineered-Perishable (COM-3P)	28	279,000	126,000	405,000
Apartment 1 story No Basement (RES-1A1)	249	177,000	17,000	194,000
Apartment 3 stories No Basement (RES-1A3)	938	351,000	35,000	386,000
Urban High Rise (RES-4A)	2	19,687,000	3,544,000	23,231,000
Beach High Rise (RES-4B)	1	22,000	2,000	24,000
Residential 1 Story No Basement (RES-5A)	2,206	105,000	52,000	157,000
Residential 2 Story No Basement (RES-5B)	1,274	149,000	74,000	223,000
Residential 1 Story with Basement (RES-6A)	1,925	115,000	58,000	173,000
Residential 2 Story with Basement (RES-6B)	4,177	138,000	69,000	207,000
Building on Open Pile Foundation (RES-7A)	136	216,000	97,000	313,000
Building on Pile Foundation with Enclosures (RES-7B)	11	198,000	89,000	287,000
Grand Total	12,130	214,000	90,000	304,000

Value estimates are rounded, FY 2022 price levels

Table 3-3: Average Depreciated Replacement Value by Model Area

Row Labels	Count	Average Structure Value ($)	Average Contents Value ($)	Average Total Value ($)
MA_BI1	8	462,000	211,000	674,000
MA_BI2	52	278,000	128,000	406,000
MA_BRI1	535	202,000	90,000	292,000
MA_CRA1	1,019	307,000	129,000	436,000
MA_GB1	756	131,000	61,000	191,000
MA_LC1	50	275,000	128,000	403,000
MA_MTHB1	620	156,000	69,000	226,000
MA_NAR1	1,644	133,000	61,000	194,000
MA_NPT1	496	730,000	251,000	981,000
MA_NPT2	249	136,000	54,000	190,000
MA_PVD1	119	1,170,000	485,000	1,655,000
MA_SAKM1	77	104,000	51,000	156,000
MA_SAKN1	756	103,000	50,000	152,000
MA_SAKS1	1	216,000	97,000	313,000
MA_WAR1	5,167	184,000	77,000	262,000
MA_WICK1	581	269,000	117,000	386,000
Grand Total	12,130	214,000	90,000	304,000

Value estimates are rounded, FY 2022 price levels

Table 3-4: Average Depreciated Replacement Value by Locality

Locality	Count	Average Structure Value ($)	Average Contents Value ($)	Average Total Value ($)
Barrington	3,555	165,000	82,000	247,000
Bristol	345	221,000	105,000	326,000
Cranston	522	407,000	181,000	588,000
East Greenwich	16	586,000	250,000	836,000
East Providence	90	366,000	126,000	492,000
Jamestown	56	207,000	100,000	307,000
Little Compton	58	241,000	114,000	355,000
Middletown	30	740,000	166,000	906,000
Narragansett	1,333	139,000	68,000	207,000
New Shoreham	60	273,000	125,000	398,000
Newport	680	490,000	183,000	673,000
North Kingstown	548	244,000	114,000	358,000
Pawtucket	2	600,000	270,000	870,000
Portsmouth	892	114,000	56,000	170,000
Providence	84	1,185,000	534,000	1,719,000
South Kingstown	293	111,000	55,000	166,000
Tiverton	196	125,000	61,000	186,000
Warren	2,025	211,000	101,000	312,000
Warwick	1,345	134,000	65,000	199,000
Grand Total	12,130	206,000	95,000	301,000

Value estimates are rounded, FY 2022 price levels

3.3.2 First Floor Elevations

The first-floor elevations were calculated by estimating the height from the ground to the first floor that would experience damages during a flood. Lowest adjacent ground elevations were obtained from Light Detection and Ranging (LiDAR) digital elevation model (DEM) downloaded from the National Elevation Dataset. Foundation type was obtained from 911 data and Google StreetView. Foundation heights were estimated for each structure by visual inspection using Google StreetView, summing up the number of steps, assuming each to be 6 inches high. The foundation height was added to the ground elevation to determine the first-floor elevation of each structure in NAVD88. Structures with ground elevations below zero, often adjacent to waterbodies, were updated to reflect positive ground elevations adjacent to the boundary of the structure. Most elevations on structures with pier foundations were very low while structures with basement or pile foundations had much higher first floor elevation values.

Table 3-5: Average Ground Elevations and First Floor Elevations by Foundation Type

Foundation Type	Average Ground Elevation	Average First Floor Elevation	Foundation Height
BASEMENT	13.7	17.6	3.9
CRAWL	6.7	9.4	2.7
PIER	5.1	8.9	3.8
PILE	7.9	17.9	10
SLAB	12.4	14.4	2

3.3.3 Elevating, Rebuild, and Removal Assumptions

Elevating. When a structure is rebuilt after exceeding the 50 percent threshold, it is Elevated to reduce future flood damage if it has a compatible occupancy type as shown in. For this study, only single-family structures were modeled to be raiseable within the G2CRM model. The base first-floor elevation was developed based on the 1% AEP NACCS water level + wave contribution + 1 ft + sea level change (intermediate through 2080). A limit for raising a structure was considered, however this was not applied due to uncertainty in factors needed to determine limits on individual structures and since there were minimal structures beyond the typical elevation limit of 12-15 feet. When a structure is raised in G2CRM, the structure is rebuilt in kind. The only changed parameter is the first-floor elevation. The structure/contents values were set to be equal to the original values. For the rebuild that includes raising, the time to rebuild will be the maximum value from the pre-raised structure.

The cost of elevation is set as zero for all modeling scenarios as a conservative assumption. The ability to elevate a structure depends on several considerations that are outside the scope of this feasibility study including, but not limited to, site characteristics such as soil bearing capacity and building condition.

Rebuilding. The rebuilding parameter within G2CRM restricts the amount of monetary investment allocated to structural repair for any specific building type to reflect real-world behavior most accurately. Allowing for an unlimited amount of rebuilding in the period of analysis may be unrealistic for a CSRM study and can potentially overstate damages. As a result, the number of rebuilds has been limited to 5x, approximately once every 12 years of model runtime. The rebuilding parameter is only designated for single family homes as this assumption is consistent with state code and FEMA policy for single family structures. The rebuilding parameter is not used for other types of structures since there are not specific policy requirements in place for multi-family residential or non-residential structures with regard to rebuilding.

Significant Rebuild Damage Threshold. Each study has a significant rebuild damage threshold associated with it, which is automatically set within G2CRM as 50 percent for all model areas. This is consistent with 44CFR 59.1 of the National Flood Insurance Program (NFIP) that defines substantial improvement as any reconstruction, rehabilitation, addition or other improvement to a structure, the total cost of which equals or exceeds 50 percent of the market value of the structure before the start of the construction of the improvement. Additionally, if structures are damaged, or improved, to a value equal or greater than the pre-modification value, the structure must, then, be brought up to code which includes elevating a structure to the existing floodplain ordinance. After the number of rebuilds is exceeded, the structure is removed from the asset inventory for the remainder of the life cycle.

Removal. There are three ways for G2CRM to remove a structure from inventory:

- After a raising event was attempted, but the height required to raise the asset was greater than the inputted maximum raise height, or 12 feet NAVD88 for this study (see Main Report Section 6.7.5 Engineering Risk. Maximum Height for Elevating Structures for a description of the 12-foot engineering constraint on elevation which is addressed in the main report.)
- After a user-defined number of significant damage events is exceeded
- After a user-defined percentage threshold for cumulative damage within an iteration is exceeded

Each structure has a base first-floor elevation, a first-floor elevation distribution, and an occupancy type with a maximum raising height. If a structure is scheduled to be raised (see “Asset Raising” above) then the currently drawn first-floor elevation will be compared to the base first-floor elevation. If this comparison exceeds the maximum feet to be raised, then the structure will be removed from inventory.

The structure-specific setting for number of rebuilds will be compared throughout the iteration to the rebuild count for that structure. If a rebuild is due to damage that is greater than the study’s significant rebuild threshold, then the number of rebuilds will be incremented. Whenever the structure is damaged and cannot be rebuilt due to exceeding the allowed rebuild count, then the structure will be removed from inventory.

G2CRM also allows for structures to be removed once a percentage cumulative damage threshold is met or exceeded. As discussed earlier, a cumulative damage threshold was not employed in this study.

3.4 Life Risk

In addition to physical inundation damage, risk to human life is a vital component of defining the existing conditions in a study area. Historically, there have been several coastal storm events that have resulted in loss of life within the coastline of Rhode Island, as noted in the Storm History section of this appendix. Within the state of Rhode Island, two deaths resulted from Hurricane Gloria (September 1985), one death resulted from the Northeast Winter Storm (December 1992), and one death resulted from Hurricane Floyd (September 1999). Most storm significant storm events from the 1950’s to present, including Hurricane Sandy, have resulted in no deaths, most likely largely due to the mandatory evacuations implemented in the area.

While inundation levels vary throughout the study area, several points are presented here to provide an overview of the magnitude of inundation as it relates to life risk in the study area. These water levels are shown in the following table.

Table 3-6: Water levels in the Study Area

AREA	Return Period	2% CL	16% CL	Mean	84% CL	98% CL
Block Island	50	4.64	6.42	8	9.58	11.35
	100	4.99	6.86	8.59	10.31	12.18
Bristol	50	6.89	8.83	10.75	12.67	14.61
	100	8.18	10.12	12.05	13.98	15.92
Cranston	50	8.56	10.51	12.45	14.39	16.34
	100	10.18	12.13	14.08	16.03	17.98
Greenwich Bay	50	7.44	9.39	11.33	13.28	15.23
	100	8.88	10.84	12.8	14.76	16.71
Little Compton	50	5	6.93	8.82	10.71	12.63
	100	6.01	7.94	9.87	11.79	13.72
Mt Hope Bay	50	7.68	9.63	11.56	13.5	15.45
	100	9.09	11.04	12.98	14.92	16.87
Narragansett	50	5.45	7.34	9.14	10.93	12.82
	100	6.32	8.24	10.13	12.02	13.94
Newport	50	5.34	7.25	9.07	10.9	12.81
	100	6.12	8.05	9.95	11.86	13.79
Providence	50	9.32	11.28	13.24	15.2	17.16
	100	11.13	13.09	15.05	17.02	18.98
Sakonnet Mid	50	6.8	8.73	10.66	12.58	14.51
	100	8.11	10.04	11.97	13.9	15.84
Sakonnet North	50	7.61	9.56	12.93	13.44	15.38
	100	9.05	10.99	14.41	14.88	16.82
Sakonnet South	50	5.88	7.8	9.69	11.58	13.51
	100	6.98	8.91	10.83	12.76	14.69
Warren	50	7.68	9.61	11.54	13.47	15.41
	100	9.13	11.07	13.01	14.95	16.89
Wickford	50	5.98	7.9	9.77	11.63	13.55
	100	7.03	8.96	10.89	12.81	14.74

Since the save points used for this analysis are located over water, velocity is not a significant contributing factor as it relates to these inundation water levels and resulting life risk in this coastal analysis. As such, from the inundation levels listed in the table, it can be seen that areas that are estimated to receive higher water levels, and thus relatively higher concern for life risk, include Bristol, Cranston, Greenwhich Bay, Mt Hope Bay, Providence, Sakonnet North, and Warren. These areas all expected to experience over 10 foot of water level for both the 50-year and 100-year AEP storm even.

The other important variables that affect life risk beyond inundation levels are warning times, evacuation planning zones, available evacuation routes, and the resulting population at risk. These variables and findings for the Rhode Island study area are discussed in the following paragraphs.

3.4.1 Population at Risk

The number of people living within each structure were derived using census data. According to the U.S. Census Quick Facts, dated July 2019, there is an average of 2.55 persons per household. In addition, 32.2% of the population is 65 or older. For a single-family residence, 2.55 people are assumed to inhabit the structure with 1.7289 people under the age of 65 and 0.8211 people are 65 or older. The nighttime population for under 65 is assumed to be 1.7289. The daytime population for under 65 assumes one person works outside of the home and is therefore, half or 0.86445. The daytime and nighttime populations over the age of 65 are assumed to be the same. For multiple family residences, the same assumptions were applied to the number of apartments on the first two floors, or the limit of the depth damage functions.

In order to model for loss of life in the Rhode Island study, the inventory data of residential structures needs to be supplemented with population information. This was obtained from the U.S. Census Quick Facts dated July 2019 and consists of the average number of inhabitants per household for each town. Assuming each structure from the inventory is occupied, in the event of a storm surge there is lethality function associated with it. The G2CRM software can be utilized to make predictions from this data. The buildings are not homogeneous as the number of floors range from one to six. The software cannot determine how many people reside in a high-rise, so it assumes all residents are on the first floor. In previous studies, using this assumption, thousands of people were incorrectly categorized as being at risk. For this study it is assumed that any population above the first floor would not be at risk unless there was total destruction of the building. By integrating the population data into every occupancy type this issue was taken into account. Additionally, assumptions for vertical evacuation as an option to reduce risk were made. The data population was divided into four categories, population under 65 daytime & nighttime and over 65 daytime & nighttime and the tables below show the conditions.

The Rhode Island Emergency Management Agency (RIEMA) has a notification system to keep citizens informed in advance of a potential natural disaster event. In addition, REIMA has developed a State Emergency Operations Plan (SEOP) to protect the population potentially at risk. SEOP focuses on the management of any large-scale disaster which would require immediate response. The RIEMA External Affairs office indicated the warning notifications with details and magnitude are activated at least 5-6 days before a storm event. At the same time, RIEMA works in conjunction with the local municipalities and the national weather service to keep citizens properly informed. With this information, it is assumed that authorities will enforce business closures to prevent life risk during a storm. It is expected that the commercial buildings will be closed and unoccupied resulting in 0 fatalities as shown in the table below which includes the four population categories.

Condition for commercial buildings:

Pop U65 nighttime	Pop O65 nighttime	Pop U65 daytime	Pop O65 daytime
0	0	0	0

Condition for residential buildings:

Assuming the population U65 can more easily escape to a roof vs the population O65 who would likely find it more difficult and not survive.

Structure	Pop U65	Pop O65
Floors >= 2	0 This means no life loss. It is assumed that the water will rise but it will not to the second level and above.	All People over 65 will be unable to escape vertically during a storm surge and not survive.
Floors < 2	All All people under 65 will not survive because the water will rise and there are no more floors above for vertical evacuation.	All All people over 65 will not survive.

3.4.2 Evacuation Planning Zones

Based on documentation from prior studies and behavioral analysis, people do not usually behave in the way emergency warning authorities would expect. For example, potentially impacted residents do not comply in large numbers when evacuation orders are issued during a hurricane surge inundation warning. In order to calculate the loss of life using the G2CRM software certain inputs are required in the evacuation section including a shapefile polygon and the triangular distribution surrounding the remaining population assumed to be within each evacuation planning zone. The polygon will determine the evacuation planning zone which is a spatial area defined by a geographic boundary. The triangular distribution applied to the remaining population is a continuous probability distribution with a lower limit of $a = 0.1$, upper limit $b = 0.5$ and a most likely or mode $c = 0.25$, where $a < b$ and $a <= c <= b$. The variables a, b, c are the variables used by G2CRM where a is the minimum value, b is the maximum value and c is the most likely. This distribution is utilized because the actual percentage of the population who will follow evacuation orders during a potential storm surge is uncertain.

3.5 Critical Infrastructure and Socially Vulnerable Areas

Other considerations for the existing conditions within the study area include critical infrastructures as well as socially vulnerable areas. The study area includes significant critical infrastructure at risk of damage from future flooding and coastal storms including police, fire and emergency support service facilities; schools; energy production facilities; water and wastewater facilities; and nursing homes and assisted living facilities. There are also portions of the study area that are considered highly socially vulnerable. The CDC defines social vulnerability as “the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. A Social Vulnerability Index (SVI), that was developed by the Centers for Disease Control (CDC) to identify social vulnerability within communities (CDC 2021) was initially used to identify these areas within Rhode Island. The locations of critical infrastructure and various levels of social vulnerability study area are shown in the following figures.

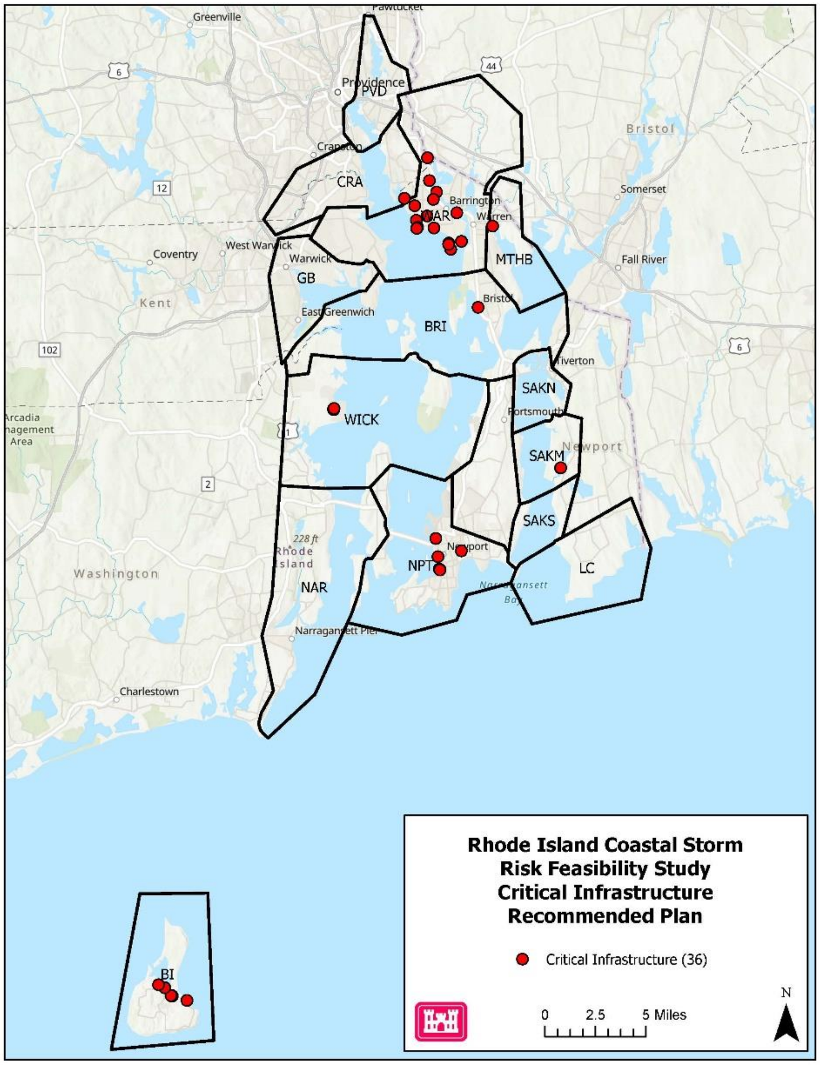

Figure 3-2: Critical Infrastructure in the Study Area

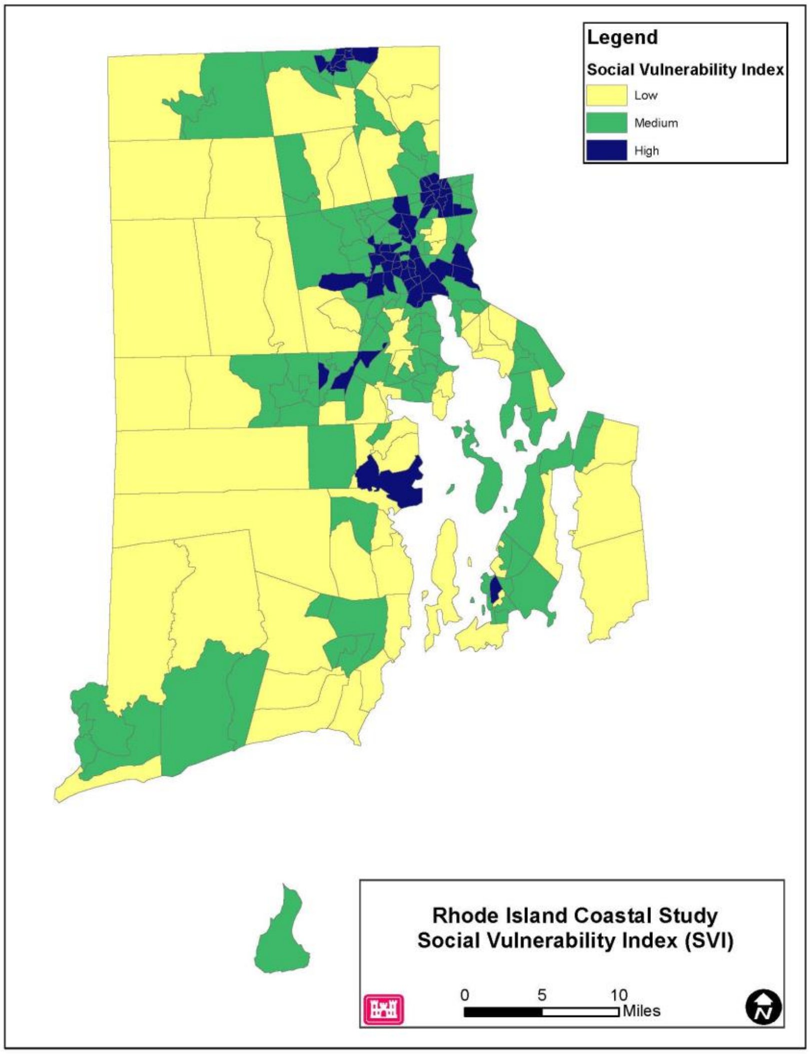

Figure 3-3: Social Vulnerability in the Study Area

4.0 FUTURE WITHOUT-PROJECT CONDITION

The future without project condition serves as the base condition to use as a comparison for all other alternatives. In the absence of a Federal project, homeowners and businesses will continue individual efforts to repair damages after coastal storms, using emergency funding or personal resources when available. In the event a residential or commercial structure sustains damage equal to or greater than 50% of its depreciated replacement cost, it is assumed that the structure will be elevated in accordance with NFIP and local rules. The future without project condition within the period of analysis (2030-2079) is identified as continued damages to coastal floodplain structures and property from future storm events.

Limited future growth or development in the study area was projected for this analysis, therefore structure inventory and values were kept the same as those under existing conditions. Much of the coastal floodplain in the study area is already developed, and there are limited opportunities for new expansion.

4.1 Description

Planning efforts were conducted using the intermediate Sea Level Change scenario for all modeling and formulation. The FWOP damages was modeled as a “no action” scenario to identify the risk and damage potential to Rhode Island infrastructure in the absence of any action and also to provide a commensurable baseline for comparative purposes.

As discussed previously, model areas were developed based on location of save points that were determined to have the appropriate environmental forcings. For the economic analysis, 16 model areas, shown in **Table 3-1** were evaluated as individual studies in G2CRM. The model areas are required to be separated within the modeling analysis due to the unique hydrodynamic characteristics and resulting water levels associated with each separate area. Each study was defined as an upland model area with a bulkhead PSE. The waterside ground elevation is used by the model to diminish wave action as water overtop the beach system and inundate the area. The bulkhead top elevation is set to existing ground elevation and kept consistent throughout the life cycle for the FWOP scenario.

The damages assigned to each model area were estimated in G2CRM using economic and engineering inputs to generate expected present value (PV) damages for each asset throughout the life cycle (i.e., the period of analysis). The possible occurrences of each economic and engineering variables were derived using Monte Carlo simulation and a total of 100 iterations were executed by the model. The expected PV damages was calculated as the average of PV damages across all iterations. The figure below demonstrates the stability prior to 100 iterations for a sample model area (MAX) and the convergence of PV damages after each iteration.

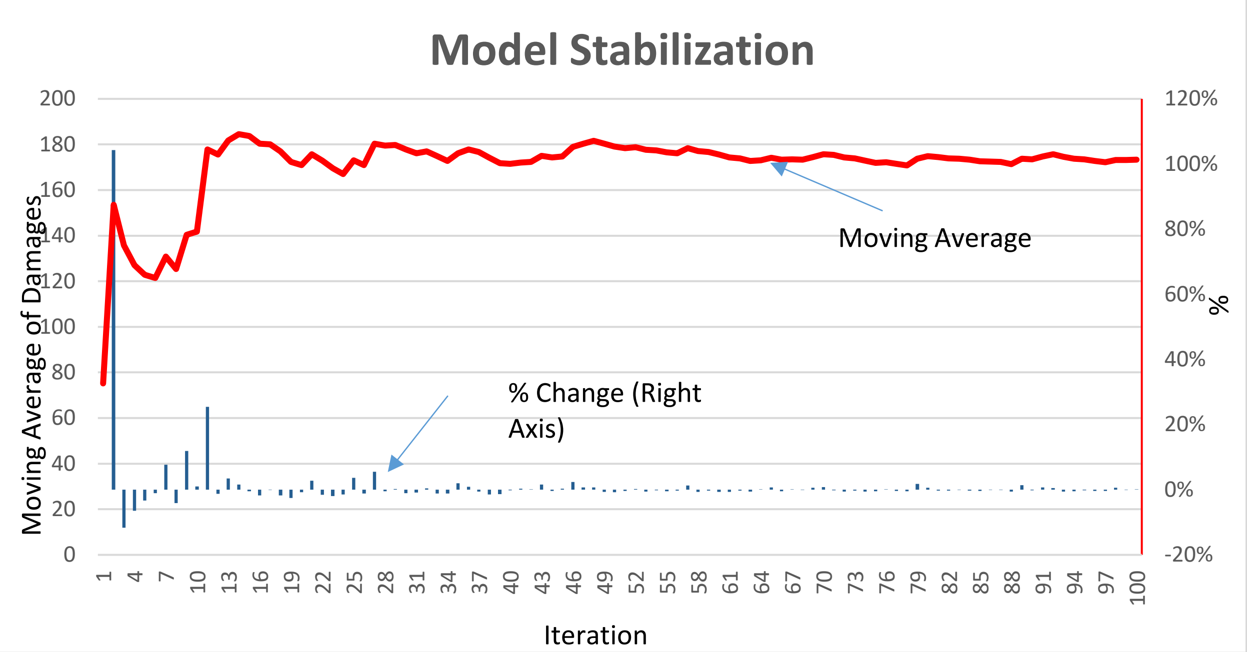

Figure 4-1: Model stabilization for sample model area

4.2 FUTURE WITHOUT PROJECT MODELING RESULTS

4.2.1 Distribution of Damages

The table below displays the estimated present value (PV) and average annual damages of each model areas for the FWOP condition. And the following figure shoes the damages geographically over the study area.

Table 4-1: Future Without Project Estimated Damages by Modeled Area (50-year, 2.5% discount rate)

Model Area	Present Value Damages ($)	Average Annual Equivalent Damages ($)	% of Total
MA_BI1	4,479,564	150,148	0.3%
MA_BI2	39,069,376	1,309,541	3.0%
MA_BRI1	65,960,749	2,210,896	5.0%
MA_CRA1	23,548,323	789,301	1.8%
MA_GB1	94,392,180	3,163,871	7.2%
MA_LC1	7,159,624	239,979	0.5%
MA_MTHB1	17,631,223	590,970	1.3%
MA_NAR1	36,577,074	1,226,003	2.8%
MA_NPT1	583,397,650	19,554,532	44.3%
MA_NPT2	16,306,912	546,581	1.2%
MA_PVD1	67,798,247	2,272,486	5.2%
MA_SAKM1	4,100,053	137,427	0.3%
MA_SAKN1	51,639,237	1,730,862	3.9%
MA_SAKS1	0	0	0.0%

Model Area	Present Value Damages ($)	Average Annual Equivalent Damages ($)	% of Total
MA_WAR1	164,895,326	5,527,021	12.5%
MA_WICK1	139,278,472	4,668,386	10.6%
Total	1,316,234,009	44,118,004	100.0%

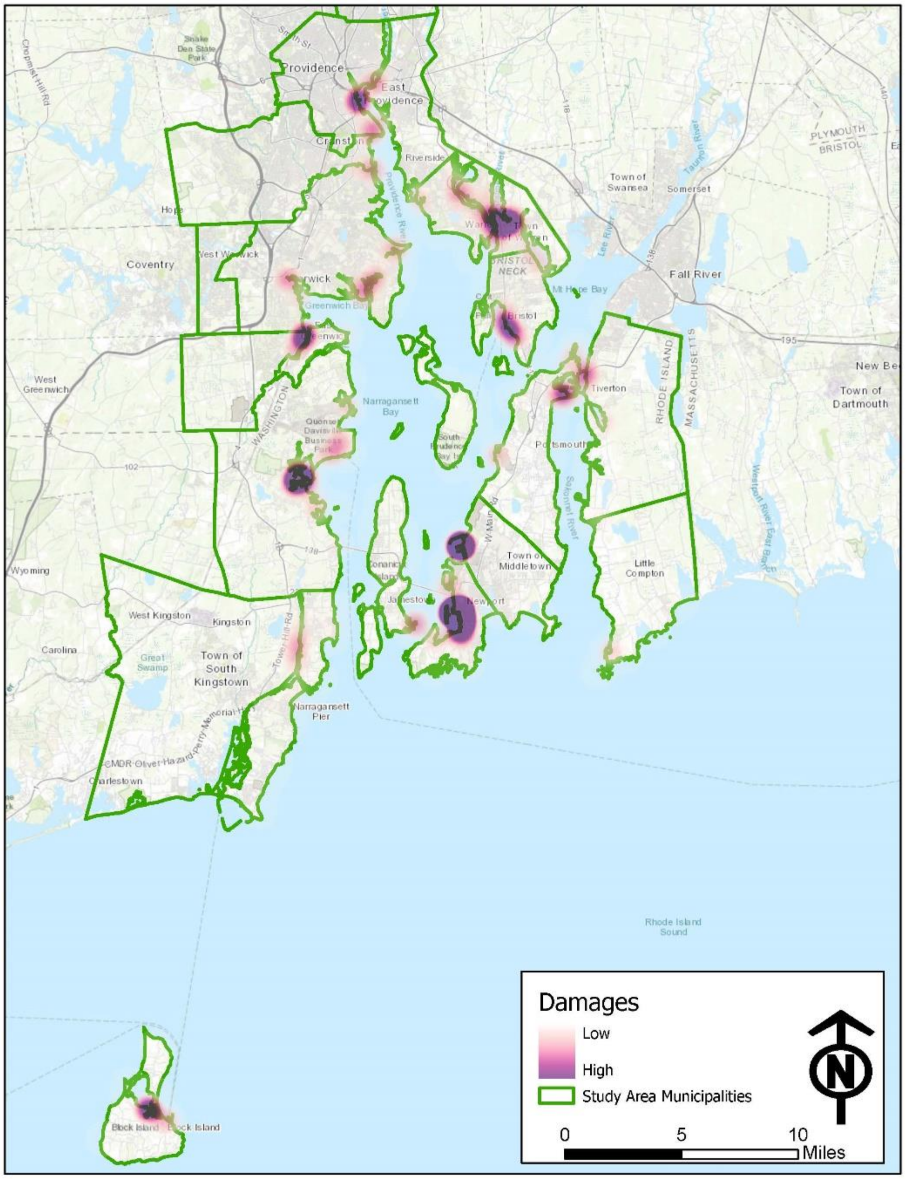

Figure 4-2: Geographic display of damages over the study area

The following figures display the PV damages for each structure foundation type within each model area as well as the PV damages compared to structure value for each model area, respectively.

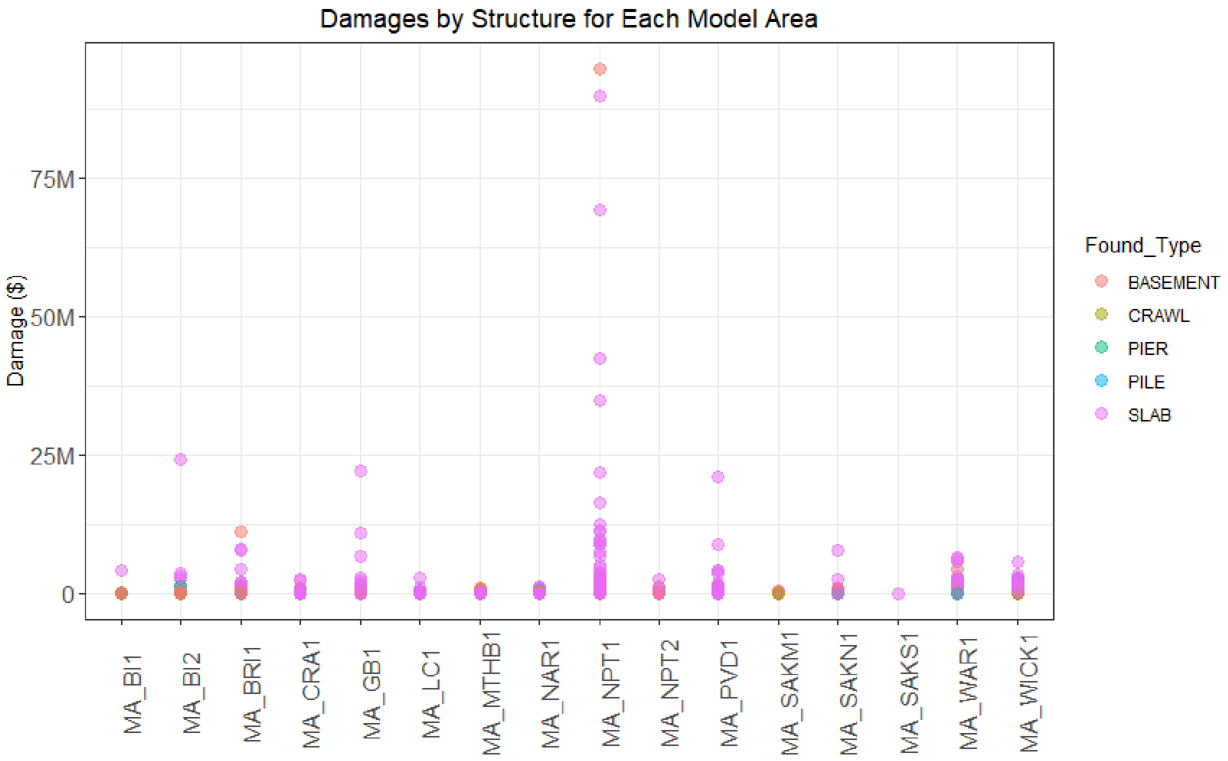

Figure 4-3: FWOP estimated PV damages by structure foundation for each model area

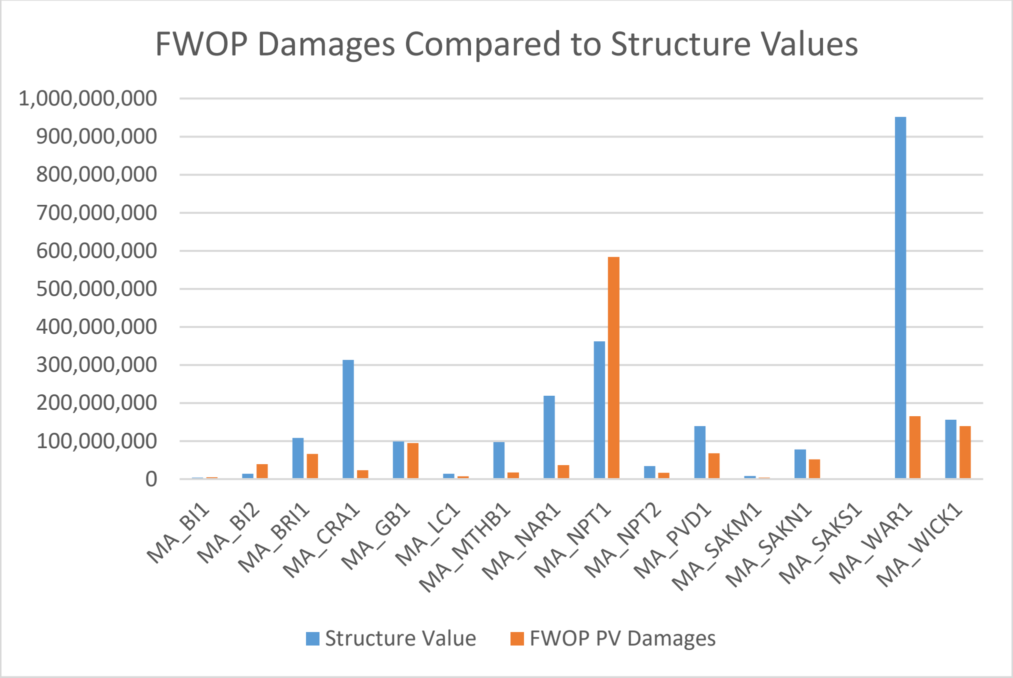

Figure 4-4: FWOP PV Damages compared to structure values for each model area

Most damages in the study area are estimated to occur in the Newport, Warwick, and Wickford modeled areas. In present value terms, accumulated damages to 2079 was estimated up to $1.3 billion for the entire study. These accumulated damages might be considered low relative to the value of the entire study area. This is due to most damage being concentrated in particular geographic locations. In addition, most of the damage in this study area results from repetitive loss from higher frequency storm events with relatively lower associated water levels. Damages per structure are estimated to be highest in in Block Island, Providence, and Newport modeled areas where damages per structure were estimated to be as much as $500,000 to over $1 million per structure.

Residential structures dominate the Rhode Island coastline, making up 80 percent of all structures in the inventory. The primary residential building type is a two-story single-family residence with basement (RES-6B); there are almost 4,200 such residences. However, there are also over 1,200 commercial buildings and 2,400 multi-family buildings accounting for a substantial portion of the inventory as well. Commercial structures are the greatest source of damage in the study area, accounting for almost 30% percent of all damages. The estimated present value damage by occupancy type and by foundation type for the future without project is shown in the following tables respectively.

Table 4-2: Future Without Project Estimated Damages by Occupancy Type (50-year, 2.5% discount rate)

Model Area	Present Value Damages ($)	Total Structure Value ($)	PV Damage % of Structure Value
COM-2NP	373,670,195	457,140,384	82%
COM-2P	199,983,129	99,928,429	200%
COM-3NP	184,123,864	371,124,450	50%
COM-3P	12,346,464	7,821,123	158%
RES-1A1	7,408,921	44,000,148	17%
RES-1A3	77,049,700	328,984,990	23%
RES-4A	129,617,364	39,374,185	329%
RES-4B	37,337	22,042	169%
RES-5A	69,436,871	230,560,153	30%
RES-5B	62,409,682	189,752,584	33%
RES-6A	42,638,052	221,748,974	19%
RES-6B	152,417,456	575,329,953	26%
RES-7A	4,449,272	29,366,053	15%
RES-7B	1,465,124	2,173,901	67%
Total	1,317,053,432	2,597,327,370	51%

Table 4-3: Future Without Project Estimated Damages by Foundation Type (50-year, 2.5% discount rate)

Model Area	Basement Present Value Damages ($)	Crawl Present Value Damages ($)	Pier Present Value Damages ($)	Pile Present Value Damages ($)	Total Present Value Damages ($)
MA_BI1	93,698	41,476	171,974		4,172,416
MA_BI2	648,064	53,871	1,442,321	1,550	36,923,569
MA_BRI1	22,713,308	830,123		326,567	42,090,751
MA_CRA1	11,937,466			110,878	11,499,979
MA_GB1	16,993,624	2,604,632		2,189,735	72,604,189
MA_LC1	188,739	37,503	339,923		6,593,460
MA_MTHB1	9,310,572	3,512,985		113,230	4,694,437
MA_NAR1	11,184,911	4,908,255	1,021,808		19,462,099
MA_NPT1	110,448,418	2,653,760		22,485	470,272,987
MA_NPT2	9,689,544				6,617,364
MA_PVD1	598,260				67,199,987
MA_SAKM1	1,153,057	546,747	59,764	1,478	2,339,007
MA_SAKN1	23,276,773	1,347,395	380,284	456,063	26,178,722
MA_SAKS1					0
MA_WAR1	65,612,919	5,037,969		3,823,580	90,420,858
MA_WICK1	50,211,734	1,181,390	4,185,942	11,732	83,687,674
Total	**334,061,086**	**22,756,106**	**7,602,015**	**7,057,298**	**944,757,501**

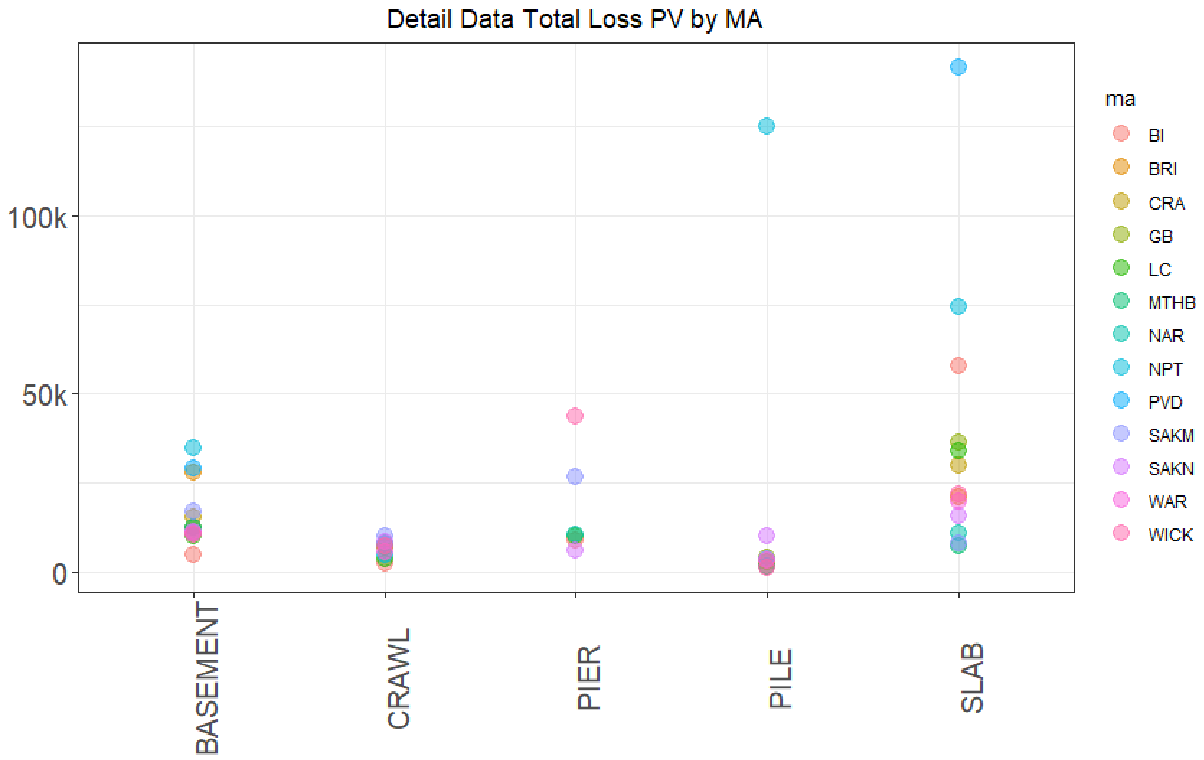

Figure 4-5: FWOP PV Damages total loss by foundation type for each model area

Temporally, no additional development within the study area is anticipated since it was assumed that new development would most likely be built to higher standards and less vulnerable to future flood risk during the period of analysis. However, accounting for the sea level rising, assets within the study area are expected to suffer increasing damages as the model move toward the end of each life cycle. The estimated damages in the study area are averaged for all iterations run in the model, for each year in the period of analysis, and are shown below in **Figure 4-6**. Estimated damages are presented here, rather than present value damages, in order to hold constant the decreasing value over time that would otherwise offset the increasing damages due to sea level change.

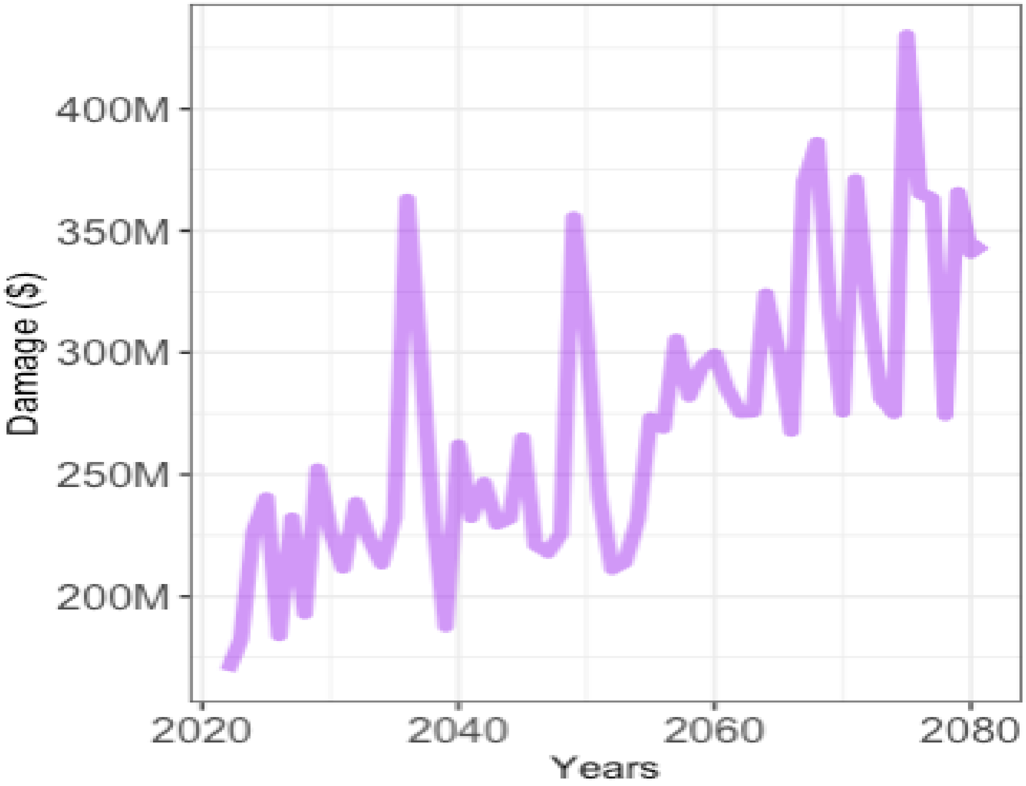

Figure 4-6: Estimated damages, average of all iterations by year

While the figure above displays the damages over time for the study area as a whole, the figure below shows average total loss for each MA to compare variability of damages over time within each MA. Damages in each MA, when looked at on average are increasing similar and each MA appears to have similar low variability, with the exception of Newport.

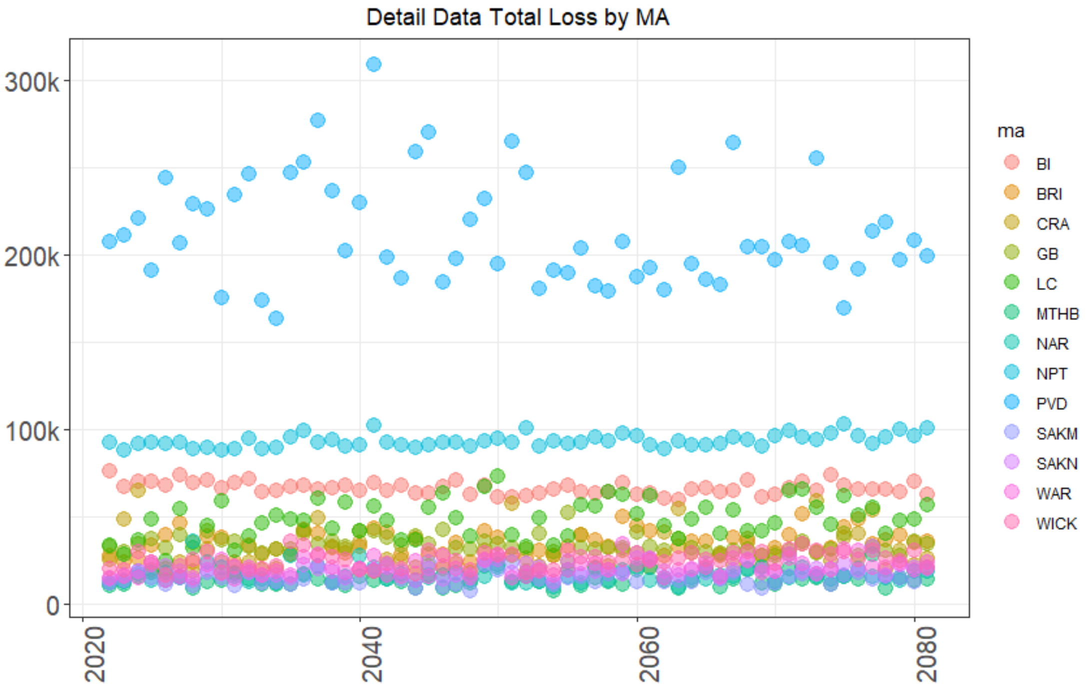

Figure 4-7: Estimated damages, average of all iterations by year

Water levels causing most damages are estimated to be between 0 to 10 feet for most of portions of the study area, with the exception of Newport. In general, it appears that when water is from 0 to 10 the damages go up and then gradually decrease for most of the modeled areas when the water is 10 to 20. The following figures show the damages associated with water level above the first floor within each MA and the damages associated with each storm stage within each MA respectively.

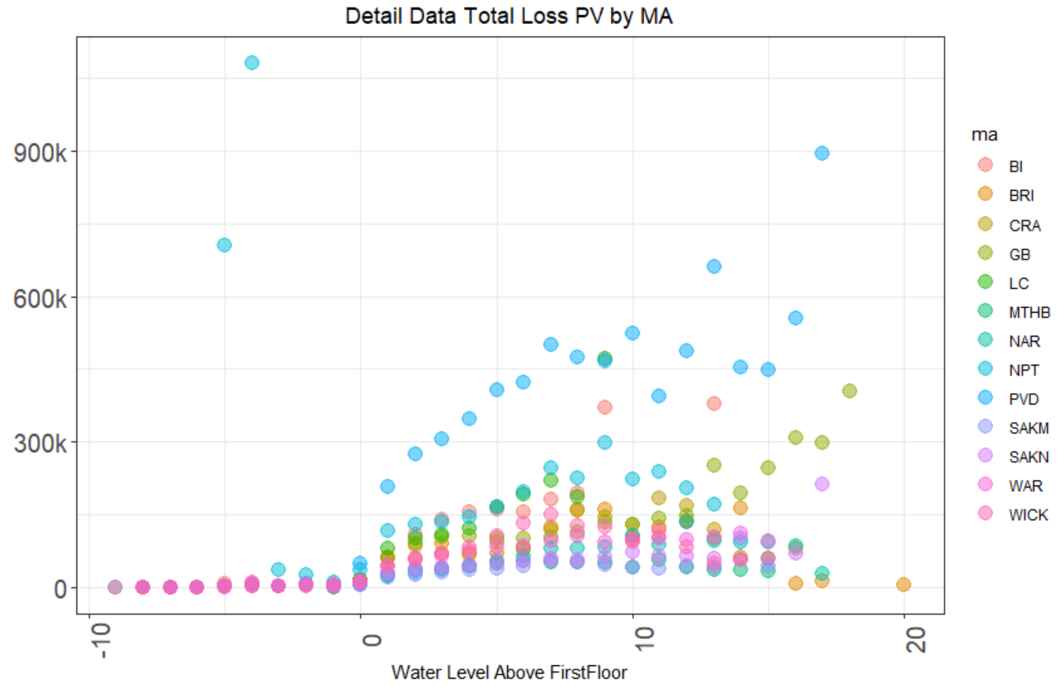

Figure 4-8: Estimated damages by water level above first floor for each MA

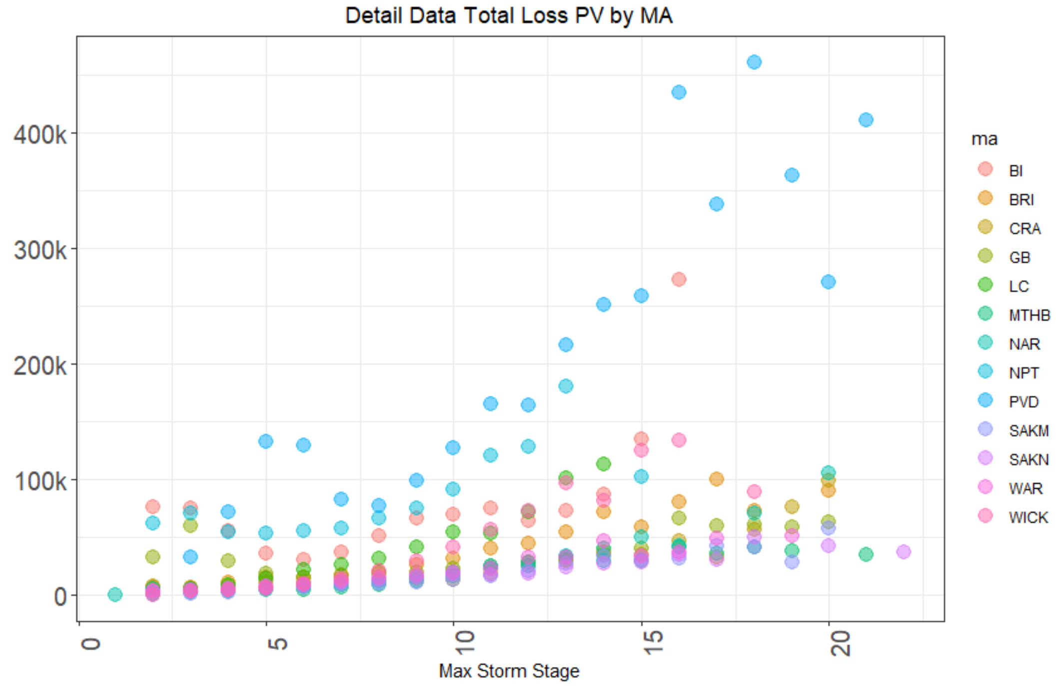

Figure 4-9: Estimated damages by maximum water level for each MA

Damages modeled in the study area for the FWOP condition can also be looked at in comparison to the water levels associated with various storm events. To do this, the estimated present value damages from the G2CRM model were incrementally totaled for each level of water assumed for each annual exceedance probability (AEP) storm event for each separate modeled area. These separate totals by modeled area were then combined by AEP storm event to represent the total estimated present value damages by AEP storm event for the entire study area, as shown in the following table.

Table 4-4: Estimated PV Damages by AEP Storm Event

Annual Exceedence Probability Storm Event	Total Estimated Present Value Damages
2-Year (50% AEP)	505,469,844
5-Year (20% AEP)	213,402,295
10-Year (10% AEP)	122,877,871
20-Year (5% AEP)	103,091,211
25-Year (4% AEP)	25,115,454
50-Year (2% AEP)	89,618,005
100-year (1% AEP)	71,681,827
200-Year (0.5% AEP)	57,511,888
500-Year (0.2% AEP)	57,286,222
>500-Year (50% AEP)	70,824,835

Consideration was given to the magnitude of the G2CRM modeled damages due to storms equivalent to the 2-year AEP and whether homeowners and businesses would realistically mitigate for these damages. These modeled results appear to be consistent with the historical storm damages in the study area and identified problems of repetitive loss due to higher probability/low level storm events. While these damages appear high when considered for the entire study area as a whole, the amount of damage per structure for each of these events is relatively low as it is spread out over a large geographic area. There is no evidence that suggest homeowners would self-mitigate for these types of damages unless the cost to elevate or floodproof would offset the damages received. To account for homeowners self-mitigating, the model is set up to automatically raise a structure to the base flood elevation if that structure receives damage equivalent to 50% of the structure's value. As discussed previously in **Section 2.2.1**, it is assumed that if a structure within the Special Flood Hazard Area is damaged by 50% of the structure’s value prior to the event, that structure will be required to be brought up to code. Its first-floor elevation will be raised to the BFE plus one foot of freeboard in accordance with the Rhode Island Building Code.

It is recognized that damages from these lower-level storm events may accumulate over time. And, logic may suggest that a structure would be removed or acquired once the cumulative damage exceeds its present value or at a minimum, brought up to code once exceeded the 50 percent substantial damage (according to 44CFR 59.1). However, as discussed previously in **Section 2.2.1**, there are no current FEMA or USACE guidelines that require the removal or acquisition of a structure once damage has exceeded its present value. Additionally, tracking cumulative damages or improvements is a higher standard not often implemented by communities. Research on the study area found significant evidence that people overwhelming favor rebuild-in-place as opposed to other forms of mitigation. That’s backed up by actual experience when it comes to repetitive damage properties in the NFIP. Many homes have been damaged and rebuilt in place many (sometimes dozens) of times over the years.

4.2.2 Damages for Alternative Sea Level Change

Evaluating sea level change (SLC) is a vital component in the planning process to ensure alternatives are selected based on risk-informed analysis. To incorporate risk into the analysis the FWOP condition must be run assuming three distinct future rates of SLC. EC 1165-2-211 provides both a methodology and a procedure for determining a range of SLC estimates based on the local historic rate, the construction (base) year of the project, and the design life of the project. While the project is formulated to the USACE intermediate curve, the high and low curves are evaluated in the FWOP condition. The table and figure below provide an overall summary of the damages for each curve.

Table 4-5: Impacts of sea level change on PV damages

	PV Damages by Sea Level Change Curve			% Change from Int SLC curve	
Modeled Areas	**High**	**Int**	**Low**	**High**	**Low**
MA_BI1	17,699,359	4,479,564	2,670,758	295%	-40%
MA_BI2	67,179,190	39,069,376	33,527,263	72%	-14%
MA_BRI1	114,649,975	65,960,749	55,804,925	74%	-15%
MA_CRA1	38,414,320	23,548,323	20,546,693	63%	-13%
MA_GB1	137,085,158	94,392,180	84,750,221	45%	-10%
MA_LC1	26,245,924	7,159,624	4,853,750	267%	-32%
MA_MTHB1	29,106,615	17,631,223	15,145,876	65%	-14%
MA_NAR1	87,101,318	36,577,074	27,928,206	138%	-24%
MA_NPT1	1,000,762,724	583,397,650	492,832,212	72%	-16%
MA_NPT2	35,077,638	16,306,912	12,545,428	115%	-23%
MA_PVD1	104,789,775	67,798,247	59,324,018	55%	-12%
MA_SAKM1	6,110,681	4,100,053	3,639,450	49%	-11%
MA_SAKN1	75,192,583	51,639,237	45,670,017	46%	-12%
MA_SAKS1	33,141	16,616	13,615	99%	-18%
MA_WAR1	299,692,397	165,000,097	136,865,480	82%	-17%
MA_WICK1	267,308,760	139,993,124	114,760,636	91%	-18%
Total	**2,306,416,418**	**1,317,053,432**	**1,110,878,549**	**75%**	**-16%**

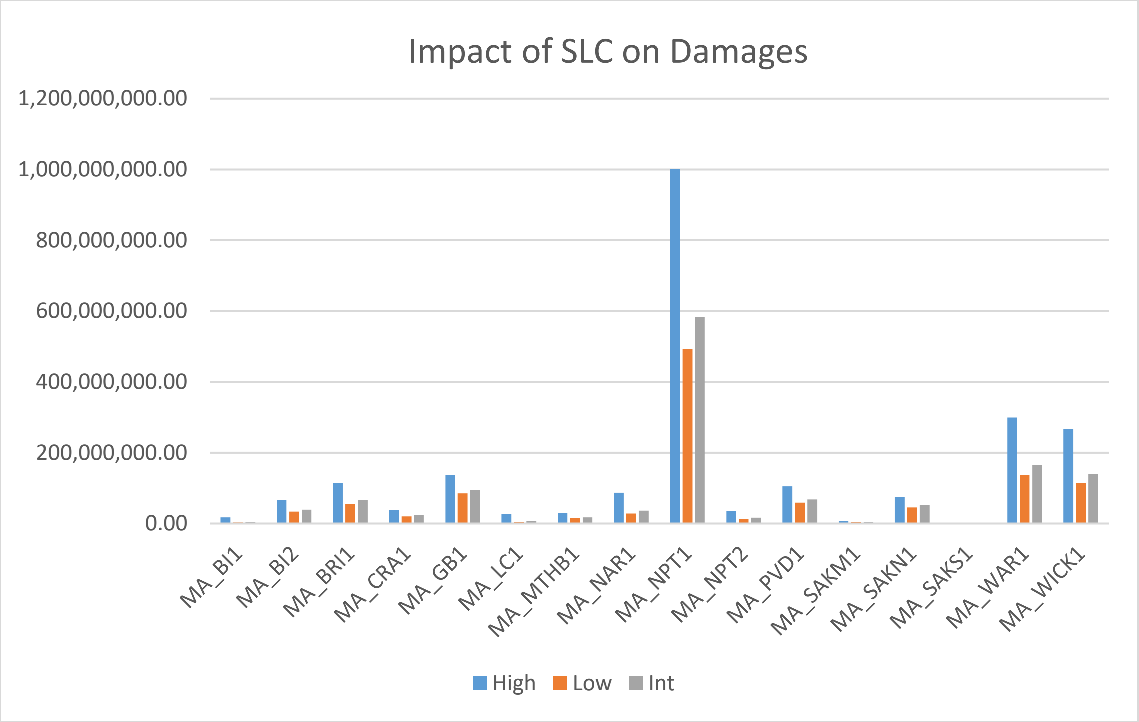

Figure 4-10: FWOP damages by sea level change scenario across the study area

4.2.3 Life Loss

G2CRM is capable of modeling life loss using a simplified life loss methodology. The Risk Management Center was coordinated with prior to the TSP to ensure the use of G2CRM was adequate for the assessment of life loss given the level of life loss risk associated with his particular study area. Since there is a high level of uncertainty in modeling life loss, the future without project condition was modeled to serve as a baseline. When compared to the future with project condition, any increase or reduction of life loss from the baseline would serve as a proxy in identifying impacts to life safety for each alternative.

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. Each structure has an occupancy type, which has an associated storm surge lethality. For this study, only structures being occupied as residential buildings were assigned lethality functions. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, although safe does not imply that there is no life loss. Chance would have the highest expected life loss. During each storm, the model cycles through every active structure. For each structure, the model defaults the lethality function to safe and check for the maximum lethality function such that the model area stage is greater than the sum of the first flood elevation of the structure and the lethality function’s surge above the foundation. This will be checked separately for under and over 65, as these two age groups can have different lethality functions depending on the age-specific surge above foundation for that occupancy type.

Using the proper lethality function, a random number is generated and interpolated using the Lethality Function Values to get the expected fraction of life loss. The way the default lethality functions are formed is that the smaller the random number, the higher the life loss. This interpolation from the lethality function is multiplied by the nighttime population for the corresponding age range and the remaining population fraction in order to calculate the life loss under 65 and life loss for 65 and older. This is recorded in fractions of lives, so depending on the level of output, there exists small rounding differences. The total estimated life loss is then simply the sum of estimated life loss under 65 and over 65 age groups.

For each structure, G2CRM calculates the statistics across 100 iterations and aggregates all outputs into structure distributions using the life-cycle method. The structure distributions are then aggregated for each model area and used to carry out an analysis on the impact to life safety of the TSP.

Two key inputs contribute to the calculation of life loss, the number of people living within each structure and hurricane evacuation zones. The assumptions on these inputs are specified in the existing conditions, life risk section of this appendix.

The following table shows the expected life loss estimated in G2CRM over the 50-year period of analysis for each model area in the future without project. As can be seen in the table, the life loss for the study area is estimated to be relatively low. The greatest expected life loss is estimated to occur in MA SAKN. It is important to note that the numbers listed here are approximations to give an understanding of the overall magnitude of expected life loss in an area. The life loss modeling performed in G2CRM is not precise enough to give detailed quantities related to life loss.

Table 4-6: Estimated Life Loss in the Future Without Project

Names	Model Area	FWOP Total life loss average
Block Island/New Shoreham	BI	0
Bristol	BRI	1.1
Cranston	CRA	0.6
Greenwich Bay	GB	4.1
Little Compton	LC	0.1
Mount Hope Bay	MTHB	1.6
Narragansett	NAR	3.4
Newport	NPT	0.5
Providence	PVD	0.1
Sakonnet Mid	SAKM	1.2
Sakonnet North	SAKN	6.9
Sakonnet South	SAKS	0
Warren	WAR	3
Wickford	WICK	2

4.2.4 FWOP Condition Conclusion

- The majority of the damage in the Rhode Island coastline is structural damages due to inundation on both residential and commercial structures with slab and basement foundations in flood zones AE and VE. Damages are more evenly distributed throughout the study area among buildings with basements, crawl spaces, or piers.
- Total damages increase over the period of analysis throughout the study area. And, over time there is similar variability of damages within each model with the exception of Newport.
- The highest damages in monetary terms occur within the areas of Newport, Warwick and Wickford. Likewise, when considering structures on an individual basis, some of the highest damages to individual structure occurs in Newport
- Approximately 55% of the total FWOP damages occur at or below the 20% AEP (5-year) event and approximately 86% of the FWOP damages occur at or below the 1% AEP event.
- Overall damages in the FWOP increase in each SLC scenario, increasing by 16% from the low to intermediate scenario and increasing by 75% from the intermediate to high scenario. This increase is relatively consistent among modeled areas from the low to intermediate scenario. Whereas, the increase is much higher for some modeled areas, such as BI1, LC1, NAR1, and NPT2, changing from the intermediate to high scenario.
- Life loss for the study area is estimated to be relatively low with the greatest expected life loss estimated to occur in SAKN.

5.0 FUTURE WITH PROJECT

The future with project (FWP) condition is the most likely condition expected to exist in the future if a specific project is undertaken. The conditions were evaluated within G2CRM for both structural and nonstructural scenarios. The final array of alternatives included 4 alternatives considered for the structural analysis and 3 for nonstructural analysis.

5.1 Formulation of Alternatives

The Feasibility Study plan formulation considered a range of structural and nonstructural measures to reduce the risk of storm damage in the study areas. Coastal storm risk management measures were developed to address problems and to capitalize upon opportunities described in the main report. They were derived from a variety of sources including prior studies, the public scoping process, and the Project delivery Team (PDT). The following management measures were considered:

- No Action
- Nonstructural
    - Acquisition/Relocation
    - Floodproofing
    - Structural Raising
    - Land Use Development Regulations

- Structural
    - Storm Surge Barriers
    - Breakwaters
    - Groins
    - Shoreline Stabilization
    - Road Raisings
    - Levees/Floodwalls
    - Seawalls
    - Tide Gates
- NNBF
    - Coastal Wetlands
    - Reefs
    - Beach Renourishment

Through an iterative planning process, potential coastal storm risk management measures were identified, evaluated, and compared. Net benefits and benefit-to-cost ratios (BCR) were reviewed to determine the viability of each alternative based on an economic justification.

5.2 Initial Alternatives Screening

Due to the size and complexity of the assessment, initial and secondary screenings were conducted toward the beginning of the study to rule out unsuitable measures that clearly would not contribute to study objectives. The initial screening was strictly qualitative. The second screening, while mostly qualitative, did include development of rough costs and benefits for the measures that were bought forward from the initial screening. NACCS parametric costs were used to develop project costs and NSI structure data was used to develop rough BCRs. The AAB was calculated using the, then current, Federal project evaluation discount rate for fiscal year 2020 of 2.75 percent, a price level of FY2020, and a period of analysis of 50 years. **Table 5-1** summarizes the estimated AAC and AAB for considered measures.

Table 5-1: Initial Alternatives Screening Summary

Initial Array of Measures			
ID #	**Description**	**Location**	**Management Measure**
NAA	No Action	Entire Study Area	N/A
NS	Nonstructural	Entire Study Area	Structure Raising/Floodproofing
R3	3-Segment Narragansett Bay Barrier	Entire Study Area	Storm Surge Barrier
R4	2-Segment Narragansett Bay Barrier	Entire Study Area	Storm Surge Barrier
J1	No Action	Jamestown	N/A
J2	Newport Bridge Approach Protection	Jamestown	Levee/Floodwall
ND1	No Action	Newport Downtown	N/A
ND2	Nonstructural	Newport Downtown	Structure Raising/Floodproofing
ND3	Point Area Perimeter	Newport Downtown	Point Area Floodwall
ND4	Wellington Perimeter	Newport Downtown	Wellington Area Floodwall/Levee

Initial Array of Measures			
ID #	**Description**	**Location**	**Management Measure**
NR1	No Action	Newport Reservoirs	No Action
NR2	Easton Pond Perimeter Only	Newport Reservoirs	Easton Pond Perimeter Levee
NR3	Memorial Boulevard Barrier Only	Newport Reservoirs	Memorial Boulevard Barrier Levee
NR4	Gardner Pond Barrier only	Newport Reservoirs	Gardner Pond Perimeter Levee
NR5	Sachuest Road	Newport Reservoirs	Sachuest Road Floodwall/Dune
BI1	No Action	Block Island	No Action
BI2	Corn Neck Road Raising	Block Island	Elevation of Corn Neck Road
BI3	Corn Neck Road Beach Nourishment	Block Island	Beach Nourishment
BI4	Corn Neck Road Stabilization (Hard)	Block Island	Rock Revetment
BI5	Corn Neck Road Stabilization (NNBF)	Block Island	Sill/Reef-based Coastal Wetlands
BI6	Corn Neck Road Stabilization & NNBF	Block Island	Combination of Revetment & NNBF
PO1	No Action	Portsmouth	No Action
PO2	Nonstructural	Portsmouth	Structure Raising/Floodproofing
PO3	Common Fence Perimeter	Portsmouth	Floodwall/Levee
PO4	Island Park Perimeter	Portsmouth	Floodwall/Levee
BW1	No Action	Barrington/Warren	No Action
BW2	Nonstructural	Barrington/Warren	Structure Raising/Floodproofing
BW3	Warren River Surge Barrier (Upper)	Barrington/Warren	Surge Barrier
BW4	Warren River Surge Barrier (Lower)	Barrington/Warren	Surge Barrier
BW5	Mathewson Road Protection	Barrington/Warren	Rock Revetment
BW6	Belchers Cove Perimeter	Barrington/Warren	Belchers Cove Levee/Floodwall
BW7	Route 114 Floodproofing	Barrington/Warren	Route 114 Levee/Floodwall
BR1	No Action	Bristol	No Action
BR2	Nonstructural	Bristol	Structure Raising/Floodproofing
BR3	Bike Path Levee	Bristol	Raise Existing Bike Path
PR1	No Action	Providence	No Action
PR2	Nonstructural	Providence	Structure Raising/Floodproofing
PR3	Providence Harbor Bulkhead	Providence	Bulkhead
PR4	Fields Point Levee/Bulkhead	Providence	Levee/Floodwall
WA1	No Action	Warwick	No Action
WA2	Nonstructural	Warwick	Structure Raising/Floodproofing
WA3	West Shore Road Barrier	Warwick	Bulkhead/Floodwall/Levee
NA1	No Action	Narragansett	No Action
NA2	Nonstructural	Narragansett	Structure Raising/Floodproofing
NA3	Pier Area Protection	Narragansett	Floodwall/Levee/Revetment
NA4	Middle Bridge Protection	Narragansett	Middle Bridge Barrier

Following this second screening, a third screening iteration was completed on all alternatives carried through from the previous screening iterations and the No Action Alternative were evaluated against the P&G criteria of completeness, effectiveness, efficiency, and acceptability. Additionally, the PDT took a more in-depth look at the remaining alternatives, again considering constructability, design, environmental impacts. The results of this screening resulted in the final array of alternatives which were carried forward for evaluation within G2CRM.

5.3 Final Array of Alternatives

The following alternatives were included in the final array of alternatives:

No Action Alternative: Under this Alternative, no Federal action would be taken to reduce flooding risk to the properties within the study areas. Implementation of the No Action Alternative (NAA) would result in the Future without project condition. Although the NAA provides no coastal storm risk management, is required to be included in the study by USACE regulations. The NAA serves as a baseline against which the proposed alternatives can be evaluated. Evaluation of the NAA involves assessing the economic and environmental effects that would result over the period of analysis if the proposed action did not take place.

Nonstructural Alternatives – Three nonstructural alternatives were developed that include elevation, floodproofing, and/or acquisition of structures throughout the entire study area.

Barrington/Warren – Lower Surge Barrier: This alternative is a surge barrier that includes 1,000 linear feet (LF) in-water structure and a 2,000 LF approach levee. The structure would start near Bourne Lane in Barrington, then it would cross Warren River and ending near Burrs Hill Park.

Barrington/Warren - Upper Warren Surge Barrier: This alternative is a surge barrier that consists of two (2) in-water structures and 5,800 LF of land-based levees/floodwalls. The structure would start at Bike Path/Shaws in Barrington, then run along Bike Path Bridges. The alternative would end in Warren near Tourister Mill building.

Narragansett – Middle Bridge Barrier: This alternative is a closure structure across Narrow River at Middle Bridge that includes 500 LF in-water structure and 2,000 LF approach levee.

Newport - Wellington Levee/Floodwall: This alternative consists of a 2,100 LF of Levee/Floodwall along Wellington Ave. High ground tie-ins at Wellington Ave and Columbus Ave.

Providence – The Port of Providence: The Port of Providence is New England’s second biggest deep-water port. The port includes 4,200 Ft of berthing space, 115 acres, 20 acres of open laydown area and 40 feet alongside water depth. The primary exports are scrap metals, automobiles and project equipment and materials. This port is part of an intermodal transportation system in Rhode Island that includes two major highways that are less than one (1) mile away from the port, railway capable of supporting double stack service and the deep-water port itself.

Early in the planning process, it was determined that the port area is an extremely complicated system with diverse facilities and stakeholders. Many challenges were discovered which led to the recommendation of this study that Port of Providence should be the subject of its own study.

5.4 Structural Analysis

Structural measures analyzed include the following: Barrington/Warren – Lower Surge Barrier, Barrington/Warren - Upper Warren Surge Barrier, Narragansett – Middle Bridge Barrier, and Newport - Wellington Levee/Floodwall.

For each structural simulation, the waterside ground elevation is maintained as zero-ft NAVD88. The PSEs setup in the FWOP scenarios for each model area are elevated using the plan alternative adjustment input. The PSE online dates are set to October 2025, which is when the measure would be expected to come online assuming 9 months of construction.

5.4.1 Barrington/Warren – Lower Surge Barrier

A lower surge barrier was considered to protect the Warren/Barrington study area. The primary feature of this alignment was a surge barrier crossing the Warren River. This barrier would include 1,000 linear feet (LF) of in-water structures and a 2,000 LF approach levee. The design elevation selected for this alignment was the 0.2-percent AEP NACCS water level for the year 2080 under the intermediate SLC scenario.

Within G2CRM this alignment was represented using the flood barrier PSE, with a stage-volume relationship for the interior area. The top elevation of the PSE was set to the 0.2-percent AEP water elevation for the year 2080 assuming intermediate SLC, 16.5 feet NAVD88. In addition to specifying a top elevation for each PSE, the flood barrier PSE also requires inputting a closure threshold to define the water level necessary to deploy the flood barrier. If the closure threshold is exceeded during a storm event, the barrier is closed and protects the assets in the interior up to the top elevation of the PSE. Anticipating sea level change, the closure threshold for surge barriers was set to 5 ft NAVD88. This value was based off a 2080 MHHW of 3.86 feet NAVD88 under the intermediate sea level change scenario plus a buffer of approximately 1 foot to ensure that the closure structures would not need to operate daily to protect against tidal flooding within the 50-year economic period of analysis.

The Barrington/Warren Lower Surge Barrier would protect approximately 2380 structures as shown in the following figure. The total present value damages modeled for this area over the period of analysis are estimated to be $483,330,000 for the FWOP and $58,547,000 FWP, resulting in damage reduction of $424,783,000.

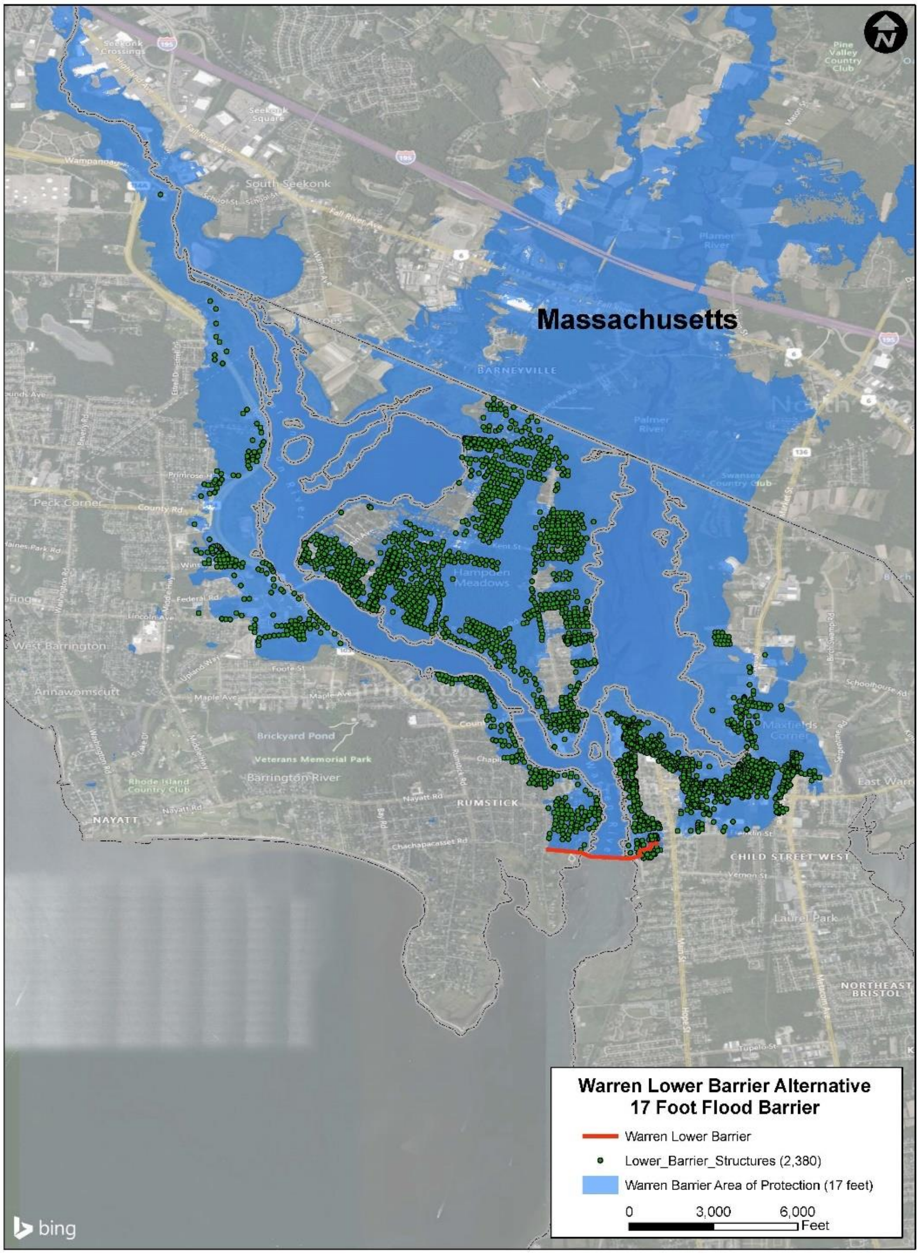

Figure 5-1: Warren Lower Barrier Structural Alternative Area of Protection

5.4.2 Barrington/Warren – Upper Surge Barrier

A hurricane barrier system was also considered for the upper reach of the Warren River. Alignments that provided protection from a 100-yr storm (1.0% chance) and 500-yr storm (0.2% chance) were investigated. The design that provided the greatest amount of protection (i.e., the 500-yr storm) was developed. This system, utilizing a combination of existing infrastructure and the construction of new structures, would result in a structure that would extend for 6,350 feet (1.2 miles) between Barrington and Warren.

Within G2CRM this alignment was represented in the same manner as the Barrington/Warren Lower Surge Barrier.

The Barrington/Warren Upper Surge Barrier would protect 2043 structures as shown in the following figure. The total present value damages modeled for this area over the period of analysis are estimated to be $483,330,000 for the FWOP and $107,651,000 FWP, resulting in damage reduction of $375,679,000.

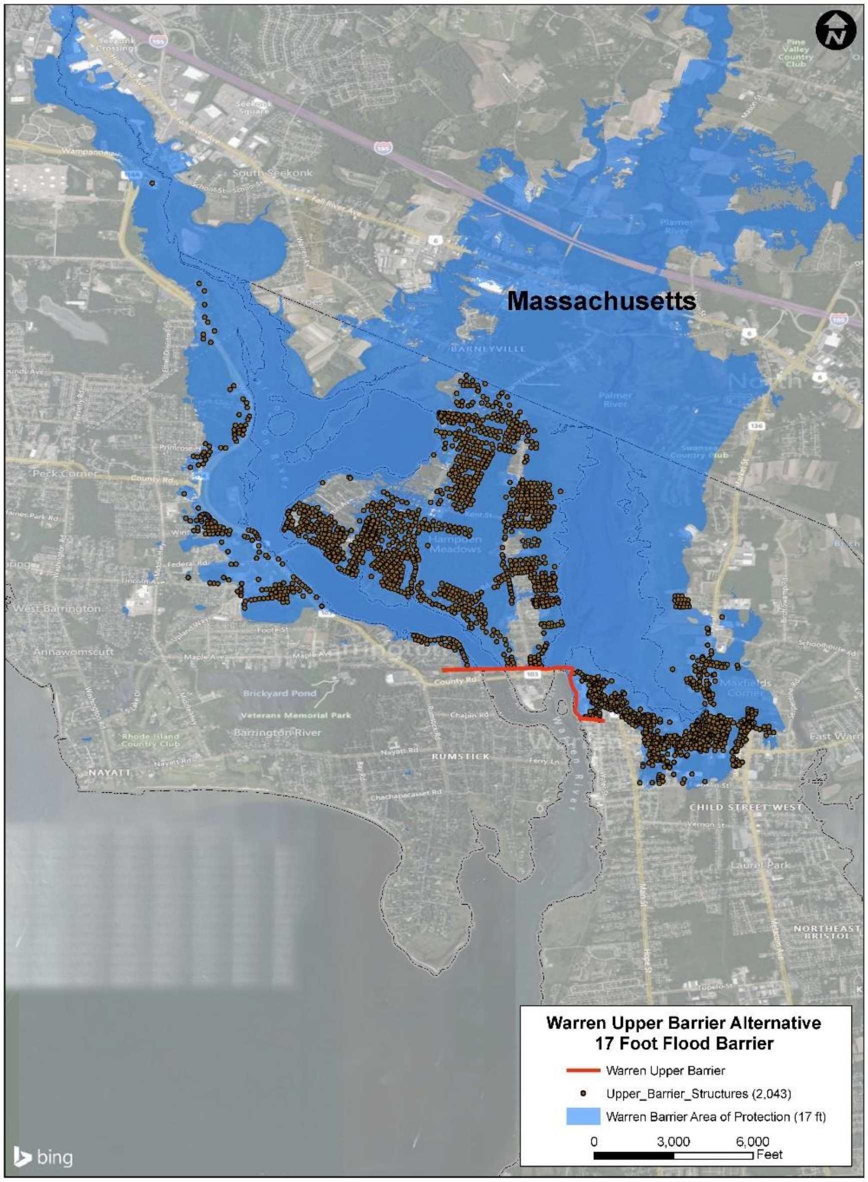

Figure 5-2: Warren Upper Barrier Structural Alternative Area of Protection

5.4.3 Narragansett – Middle Bridge Surge Barrier

A surge barrier across the Narrow River at Middlebridge Road in South Kingstown and Narragansett was designed to prevent surge from propagating up the Narrow River and flooding the low-lying residential neighborhoods to the north. A flood protection system for this area would consist of a floodwall to either side of the Narrow River Bridge and a stop log structure underneath the existing bridge. The in-water structure would be approximately 500 LF in length, with 2,000 LF of on-land approach levees. The existing bridge was built to withstand the 1-percent AEP storm water elevation levels. Therefore, the proposed surge barrier system was designed for the same event with a base elevation of 10.13 feet NAVD88.

The Middlebridge surge barrier was represented in G2CRM using a flood barrier PSE with a stage-volume relationship for the interior area. The top elevation of the PSE was set to the 1-percent AEP water elevation for the year 2080 assuming intermediate SLC, 10.1 feet NAVD88. In addition to specifying a top elevation for each PSE, the flood barrier PSE also requires inputting a closure threshold to define the water level necessary to deploy the flood barrier. If the closure threshold is exceeded during a storm event, the barrier is closed and protects the assets in the interior up to the top elevation of the PSE. Anticipating sea level change, the closure threshold for surge barriers was set to 5 ft NAVD88. This value was based off a 2080 MHHW of 3.86 feet NAVD88 under the intermediate sea level change scenario plus a buffer of approximately 1 foot to ensure that the closure structures would not need to operate daily to protect against tidal flooding within the 50-year economic period of analysis.

The Narragansett Middle Bridge Surge Barrier would protect 309 structures as shown in the following figure. The total present value damages modeled for this area over the period of analysis are estimated to be $53,795,000 for the FWOP and $26,723,000 FWP, resulting in damage reduction of $27,073,000.

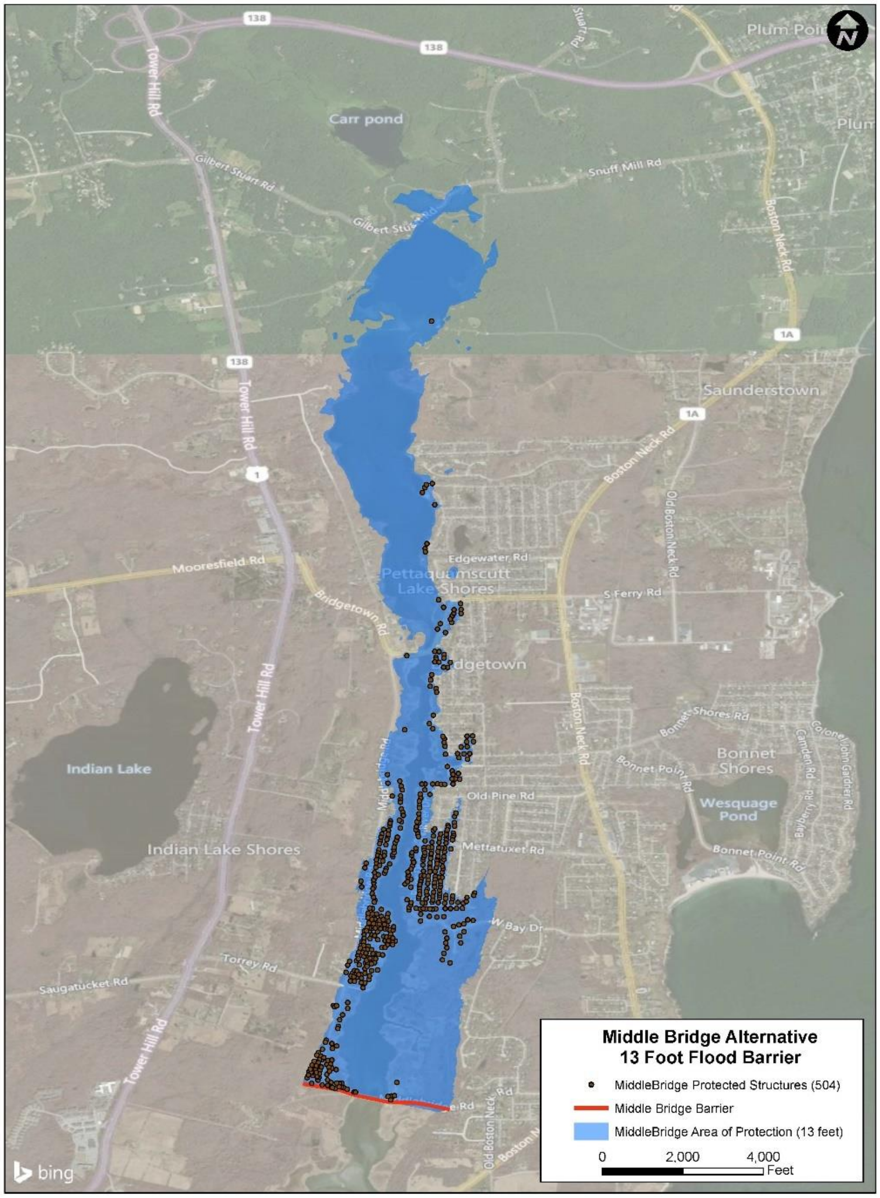

Figure 5-3: Middle Bridge Structural Alternative Area of Protection

5.4.4 Newport - Wellington Levee/Floodwall

A floodwall and levee system along Wellington Avenue between Thames Street and Columbus Avenue was investigated to reduce flood risk within the area south of Wellington Avenue known as the Fifth Ward. This structural measure was designed to reduce coastal storm risk in this area consisted of a 2100 LF concrete floodwall and earthen levee system located along the westbound side of Wellington Avenue. Kings Park, which is a public recreational area and includes ball fields, two beaches, and public meeting areas borders Wellington Avenue to the north along Newport Harbor. A structural measure for the area would consist of a concrete floodwall and earthen levee system located along the westbound side of Wellington Avenue, with a vehicle barrier required to cross from the north side of Wellington Avenue to the high ground along Columbus

Avenue. The design elevation for the floodwall and levee system was the 1-percent AEP water level for the year 2080 under the intermediate SLC scenario. The elevation does not include a wave runup height which would incorporate the effects of waves.

The Wellington Avenue floodwall and levee system was represented in G2CRM using a floodwall PSE with a stage-volume relationship for the interior area. The top elevation of the PSE was set to the 1-percent AEP water elevation for the year 2080 assuming intermediate SLC, 10. feet NAVD88.

The Newport Wellington Levee/Floodwall would protect 312 structures as shown in the following figure. The total present value damages modeled for this area over the period of analysis are estimated to be $577,500,000 for the FWOP and $559,554,000 FWP, resulting in damage reduction of $17,947,000.

Figure 5-4: Wellington Avenue Structural Alternative Area of Protection

5.4.5 Structural Plans Comparison

The estimated present value damages are recorded for each of the PSE top elevation scenario discussed previously. The results are subtracted from the FWOP scenario damages and annualized using the capital recovery factor to estimate the expected average annual benefits.

Costs estimates were developed for each of the alternatives. Interest during construction was calculated based on total first costs and included as part of the total investment cost used to determine average annual costs for each alternative. The AAB, AAC, and resulting benefit-to-cost ratio can be seen in the following table for each structural measure evaluated.

Table 5-2: Economic analysis of the final array of structural alternatives
(October 2020 Price Level, 2.5% Discount Rate)

	Lower Barrier (Barrington/ Warren)	Upper Barrier (Barrington/ Warren)	Middle Bridge (Narraganset)	Wellington Ave (Newport Downtown)
Initial Construction	$496,112,000	$546,295,000	$100,166,000	$36,640,000
Total Mitigation[1]	$72,098,933	$68,335,940	$30,800,406	$0.00
Total First Cost	$568,210,933	$614,630,940	$130,966,406	$36,640,000
Total Maintenance[1]	$70,287,000	$110,935,000	$10,382,000	$0.00
Average Annual Cost	$24,142,000	$27,276,000	$5,138,000	$1,305,000
FWOP Present Value Damages[2]	$483,330,000	$483,330,000	$53,795,000	$577,500,000
FWP Present Value Damages	$58,547,000	$107,651,000	$26,723,000	$559,554,000
Average Annual Benefits	$14,977,023	$13,245,712	$1,075,000	$632,761
Average Annual Net Benefit	-$9,164,977	-$14,030,288	-$4,063,000	-$672,239
Benefit-to-Cost Ratio	0.6	0.5	0.2	0.5

1) Costs not estimated for Wellington Ave since this alternative was not justified based on first costs.
2) FWOP damages representative of applicable modeled area only, not the entire study area.

5.5 Nonstructural Analysis

Nonstructural measures are permanent or contingent measures applied to a structure and its contents that prevent or provide resistance to damage from flooding. Existing structures within the study area were identified and considered for either acquisition, floodproofing or elevation. Nonstructural measures differ from structural measures in that they reduce the consequences of flooding instead of reducing the probability of flooding.

Participation in elevation and floodproofing is voluntary, an outreach plan will be collaboratively developed with the NFS to ensure that all eligible owners are notified and have an opportunity to participate. For modeling and plan formulation purposes, the nonstructural economic analysis assumes full participation. However, a sensitivity analysis using varying participation rates will be conducted to ensure that the net benefit will be greater than zero and the BCR will be higher than unity for the Recommended Plan with less than full participation. Participation in acquisitions is mandatory in accordance with Planning Bulletin 2019-03.

5.5.1 Nonstructural Measures

Elevation was considered for single family residences. The elevation design height was determined separately for each structure based on the 1% AEP NACCS water level + wave contribution + sea level change (intermediate through 2080). Costs for elevation were estimated based on structure type and foundation heights, height of raising, as well as square footage. It is assumed there will be no fill added to the basements of structures being elevated. And, as such, no associated costs for fill are included for this measure.

Floodproofing was considered for non-residential structures and large multi-family structures not in a designated VE Zone and without a basement. For floodproofing, a 3 feet height was assumed for all measures. However, this assumes a watertight barrier of 3 feet around the structure. It should be noted that, where applicable, additional measures, such as closures for windows and doors, may be appropriate and may provide a higher-level protection than evaluated in this analysis. For the FWP, depth damage functions were adjusted to remove damage if the inundation depth is lower than 3 feet. Costs for floodproofing were estimated based on various ranges of structure square footage.

Acquisition was considered for single family residences expected to be inundated at the highest annual tide with the 2080 USACE Intermediate SLC scenario or have access roads which would be cutoff from utility access at this flood level. Acquisition benefits would alleviate the full estimated FWOP damages. Cost of acquisition were developed based on available city tax assessment data adjusted as necessary and included various cost components. More details on the methodology used to develop acquisition costs can be found in the **Appendix G**, *The Real Estate Plan*.

5.5.2 Baseline Structures

The selection of structures for nonstructural measures is an iterative process. Nonstructural investigation included the entire study area and were not limited to the eleven problem areas. The structures were initially considered if located within the 100-

year floodplain and aggregated into an initial inventory of approximately 12,000 buildings. The 1% AEP floodplain was chosen for the TSP analysis based on findings of similar previous studies in proximity to this study area which identified the majority of structures at risk for a nonstructural plan would all be contained within the 1% AEP zone. This is also consistent with building codes, to be compliant with FEMA floodplain standards. In addition, preliminary analysis was completed on higher frequency storm event aggregated floodplains, which resulted in higher net benefits, supporting the notion that aggregation at a lower frequency storm event floodplain than the 1% AEP is not warranted for this study area.

Since ground elevation was used to determine the initial inventory, FFE was examined to determine if it is estimated to be 1 foot or greater below a water level threshold. The threshold for existing first floor elevation was used to eliminate structures from consideration that were included in the structure inventory but were already at an elevation that provides sufficient protection. This threshold was calculated as the 1% or 0.5% AEP water level estimated for 2084 plus additional wave action according to the FEMA Special Flood Hazard Area to be consistent with guidance on guidance for Hurricane Sandy related vertical construction infrastructure and nonstructural mitigation projects funded by P.L. 113-2 which specifies "these must meet a single uniform flood risk reduction standard (FRRS) of one foot above the best available and most recent BFE information provided by FEMA. Where Federal, state and local standards exceed this standard, Federal agencies will be guided by the higher standard. The State of Rhode Island or local municipality BFE +X standard was compared and found to be lower than the elevation specified.

Structures in Zone VE or with a basement were also screened from consideration of floodproofing.

Lastly, a screening was applied by determining whether the future without project damages to was large enough to support the calculated cost of the nonstructural measure using a threshold of $125,000. This value was a considered a very conservative estimate since it was based on half of the lowest cost estimated for floodproofing in order to focus on structures receiving significant enough damage to warrant protection out of the over 12,000 structures under consideration. The lowest estimated cost estimate of $250,000, which the $125,000 was derived from, was based on nonstructural cost estimates from previous USACE studies and cost-estimates developed for floodproofing measures in areas comparable to this study area. It should be noted that structures that fell into this category were brought back into consideration if determined to be located in socially vulnerable areas in order to give consideration to structures that may be receiving inundation damage that is not appropriately captured fully by net NED benefits and instead should be other benefit beyond NED.

This aggregation resulted in a Baseline Inventory of 1033 structures, 757 that are single family residential and 276 which are non-residential. Non-residential structures include commercial properties and multi-family housing, such as apartment buildings. The FWOP and FWP present value damage associated with this baseline inventory in each model area can be seen in the following **Table 5-3**. The number of structures evaluated for elevations and floodproofing in each model area can be seen in **Table 5-4**.

Table 5-3: Nonstructural Analysis Present Value Damage Reduction

Model area	Present Value FWOP Damages	Present Value FWP Damages	Present Value Damages Reduction
MA_BI1	4,944,591	4,787,400	157,192
MA_BI2	34,321,052	20,339,971	13,981,081
MA_BRI1	73,654,364	57,606,477	16,047,887
MA_CRA1	26,048,528	18,923,714	7,124,814
MA_GB1	90,522,960	54,718,745	35,804,215
MA_LC1	5,885,510	4,048,260	1,837,250
MA_MTHB1	22,181,048	13,741,303	8,439,745
MA_NAR1	44,736,916	26,166,353	18,570,563
MA_NPT1	556,228,188	435,488,461	120,739,727
MA_NPT2	21,272,212	9,651,538	11,620,673
MA_PVD1	60,431,143	47,173,741	13,257,403
MA_SAKM1	5,306,033	3,145,843	2,160,190
MA_SAKN1	55,476,891	41,303,805	14,173,087
MA_SAKS1	16,616	16,616	0
MA_WAR1	173,312,760	101,615,690	71,697,070
MA_WICK1	159,995,332	84,144,638	75,850,694
Total	1,334,334,144	922,872,554	411,461,590

Table 5-4: Nonstructural Analysis Number of Structures by Measure and Model Area

Model Area	Elevation	Floodproof	Total
MA_BI1	1		1
MA_BI2	2	10	12
MA_BRI1	56	9	65
MA_CRA1	11	9	20
MA_GB1	63	25	88
MA_LC1	3	2	5
MA_MTHB1	42	1	43
MA_NAR1	76	5	81
MA_NPT1	55	47	102
MA_NPT2	39	3	42
MA_PVD1		41	41
MA_SAKM1	11		11
MA_SAKN1	79	1	80
MA_WAR1	161	66	227
MA_WICK1	158	57	215
Grand Total	**757**	**276**	**1033**

5.5.3 Community Groups

Structures included in the baseline inventory were divided into approximately 30 community groups using the following three criteria:

Town Boundaries - All but two (2) community groups were located within a single town and did not cross town boundaries. Town boundaries were considered important because structures within the same town share the same infrastructure and town governments.

Modeling Areas - Areas with similar water levels during storm events were developed for modeling purposes. Water levels can vary greatly depending on where location within the study area for a particular storm event, so it was necessary to delineate them by areas of similar water levels. Each community group fell within a single modeling group.

Structure Groups – Community groups were made up of structures that are located on proximity to other structures. Community groups consisted of anywhere from five (5) to 153 structures, both residential and non-residential. 74 structures were no located near any other structures, so were not part of any community group. These were identified as outliers and were removed from consideration. The number of structures included in each community group and locality can be seen the following table.

Table 5-5: Community Groups

Community Group Name	Town	Residential	Non-Residential
Barrington	Barrington	66	11
Block Island	Block Island	2	10
Bristol Downtown	Bristol	14	8
Common Fence Point	Portsmouth	25	0
Cranston Mall	Cranston	0	5
Downtown Warwick	Warwick	5	12
East Greenwich	East Greenwich	0	10
Fort Ave	Cranston	9	3
Island Park	Portsmouth	50	0
Laurel Park	Warren/Bristol	37	0
Little Tree Point	North Kingston	24	0
Nannaquaket Pond	Tiverton	13	1
Narragansett	Narragansett	26	3
Newport Downtown	Newport	85	38
Newport North	Newport	3	8
Oakland Beach	Warwick	28	2
Potowomut	Warwick	5	0
Port of Providence	Providence	0	35
Quonset Airport	North Kingston	0	9
Sakonnet	Little Compton	3	2
Sakonnet North	Tiverton	8	0
Sakonnet South	Tiverton	10	0

Community Group Name	Town	Residential	Non-Residential
Shawomet	Warwick	21	3
Shore Acres	North Kingston	7	0
South Kingston	South Kingston	38	0
The Hummocks	Portsmouth	7	0
Tiverton/Little Compton	Tiverton/Little Compton	9	0
Warren	Warren	64	49
Warwick Neck	Warwick	29	0
West Passage	North Kingston	9	0
Wickford	North Kingston	113	40
Outliers		47	27

It should be noted that, while the alternative plans were developed based on selection of aggregated community groups (not including outliers). However, after selection of the TSP, reconsideration for inclusion of outlier structures was completed as a refinement to the TSP.

5.5.4 Nonstructural Plans

Three nonstructural plans were developed for this analysis. For each plan, the estimated present value damages for the FWP were subtracted from the estimated present value damages for the FWOP to determine the total present value benefits for each community group. These were compared to the total estimated costs for each community group for the corresponding plan. Costs were developed as specified previously for each distinct nonstructural measure considered. And more detailed information on these costs is also discussed in the Cost Data section of **Section 6.0** of this appendix. For those structures identified to be included in nonstructural plans, more specific survey will be completed within the PED phase to verify assumptions made on structure characteristics as well as any previous mitigation that may already be in place.

Typically, a benefit-to-cost ratio is a comparison of average annual values, including the cost of interest during construction (IDC). However, since nonstructural cost estimates only include first costs and minimal IDC, the total present value compared to total costs results in a comparable BCR for decision making at the community group level. The present value benefits and total cost information presented in this section is later aggregated for the community groups chosen to be included in each nonstructural plan, then annualized for evaluation and comparison of each alternative.

Plan NS-A. For the first plan costs and benefits for elevations for residential properties and floodproofing for non-residential floodproofing were developed for each community group. Twelve community groups had a BCR >1.0, while the remaining community groups had a BCR <1.0. Three community groups had a BCR of 0.9. At this point, there is a large amount of uncertainty in this initial economic analysis, particularly due to large cost contingency and the preliminary nature of the cost analysis. For that reason, the three (3) community groups with a BCR of 0.9 were included with the 12 groups that have a BCR above 1.0 to create the NED Plan (blue highlights). Additional cost analysis will be completed after the TSP milestone meeting to reduce the uncertainty. Currently this plan includes 494 total structures – 313 residential recommended for elevation and 181 non-residential recommended for floodproofing.

Table 5-6: Economic analysis for Plan A

Community Group Name	Total Present Value Benefits ($)	Total Costs ($)	BCR
Barrington	19,926,663	27,429,240	0.7
Block Island	13,981,081	4,384,340	3.2
Bristol Downtown	6,175,878	8,097,265	0.8
Common Fence Point	4,997,412	9,282,420	0.5
Cranston Mall	999,216	2,246,801	0.4
Downtown Warwick	9,047,754	6,467,902	1.4
East Greenwich	16,110,150	3,737,150	4.3
Fort Ave	5,665,512	4,113,303	1.4
Island Park	8,820,825	16,892,371	0.5
Laurel Park	7,051,756	12,265,738	0.6
Little Tree Point	6,073,631	7,504,134	0.8
Nannaquaket Pond	2,053,799	4,492,056	0.5
Narragansett	7531400	9379882.949	0.8
Newport Downtown	123,300,197	47,593,332	2.6
Newport North	5,519,085	4,678,317	1.2
Oakland Beach	5,241,542	9,572,737	0.5
Potowomut	1,617,807	1,591,669	1.0
Port of Providence 1	12,095,014	19,758,065	0.6
Quonset Airport	11,033,142	4,498,113	2.5
Sakonnet	1,837,250	1,747,901	1.1
Sakonnet North	2,413,607	2,775,778	0.9
Sakonnet South	2,124,147	3,690,453	0.6
Shawomet	4,804,555	7,974,676	0.6
Shore Acres	2,163,717	2,542,409	0.9
South Kingston	7282201	12138881.68	0.6
The Hummocks	1,284,553	2,596,478	0.5
Tiverton/Little Compton	1,796,627	3,040,647	0.6
Warren	44,663,135	42,055,525	1.1
Warwick Neck	4,972,011	9,626,549	0.5
West Passage	2,797,581	3,187,718	0.9
Wickford	50,053,164	51,653,408	1.0

Plan NS-B – Vulnerable Communities. Plan NS-B addresses socially vulnerable populations within the project area that are at risk from coastal storms. The CDC Social Vulnerability Index (SVI). The CDC defines social vulnerability as "the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss." The index uses U.S. Census data to determine the social vulnerability of every census tract. The CDC SVI ranks each tract on 15 social factors, including poverty, lack of vehicle access, and crowded housing, and groups them into four related themes. These themes include Socioeconomic status, Household Composition, Race/Ethnicity/Language and Housing and transportation. A numerical ranking is assigned to each tract for each of the four (4) themes, in addition to an overall ranking. For the RI Coastline Study, the overall ranking was used to identify socially vulnerable communities.

Plan NS-B includes all of the community groups included in Plan NS-A, which were justified based on NED benefits and adds community groups that did not have a BCR above 1 but were identified as being socially vulnerable within the 100-year floodplain. The first part of the social vulnerability analysis involved the community groups that were developed from the Baseline Inventory. Four (4) community group are located in vulnerable communities. Two (2) communities (Quonset Airport 1 & Fort Ave – highlighted in blue in **Table 5-7**) had a BCR >1.0 so were already included in Plan A. The two (2) other communities (Oakland Beach & Port of Providence 1 – highlighted in white in **Table 5-7**) were not included in the Plan NS-A because their BCR is <1.0. Oakland Beach and Port of Providence 1 were included in the Plan NS-B, adding 28 residential properties and 37 non-residential properties into the plan.

The second step in the development of Plan NS-B involved the Initial Inventory, which included all structures located within the 100-year floodplain. The PDT reevaluate the approximately 12,000 structures included in the Initial Inventory to identify structures in vulnerable communities that weren't included in the Baseline Inventory. Only areas identified by the CDC SVI over with an index above 0.75 were evaluated. An index of 0.75 was chosen to be consistent with CDC developed County level mapping for the SVI which identifies census blocks with an index of 0.75 and above as having the 'high' vulnerability." 51 additional structures, not included in the community groups, were found. These properties were divided into three (3) additional community groups (Port of Providence 2, Newport NE & Quonset Airport 2) and added into the plan (**Table 5-7**).

Ultimately, Plan NS-B includes 348 residential properties that will be recommended for elevations and 262 non-residential properties that will be recommended for floodproofing.

Table 5-7: Socially vulnerable communities included in Plan NS-B.

Baseline Inventory			
Community Group	Total Present Value Benefits ($)	Total Costs ($)	BCR
Oakland Beach	$5,241,542	$9,572,737	0.55
Port of Providence 1	$12,095,014	$19,758,065	0.56
Quonset Airport 1	$11,033,142	$4,876,339	2.3
Fort Ave	$5,665,512	$4,113,303	1.4
Initial Inventory			
Community Group	Total Present Value Benefits ($)	Total Costs ($)	BCR
Newport Northeast	$365,414	$3,485,150	0.10
Port of Providence 2	$765,212	$9,574,358	0.08
Quonset Airport 2	$406,691	$5,542,725	0.07

Plan NS-C – Flooded and Isolated Structures. Plan NS-C considered Health and Safety of the residents living within the study area by assessing structures that would be cut off from essential services and utilities due to future flooding caused by SLR and storm flooding. This was done by mapping the inundation of the highest annual tide with the 2080 USACE Intermediate SLC scenario. Residential structures that were predicted to be inundated at this future flood level were recommended for acquisition, instead of elevations. Additionally, there are residential properties that would be cut off from essential services and utilities because all access (i.e., roads and bridges) would be inundated at this future flood level. The structures on these properties were also included for buy-outs. This element of Plan NS-C's rationale was that private properties experiencing consistent flooding would no longer be safe to inhabit because they would be cut off from essential services and utilities. Therefore, moving the buildings out of the floodplain, instead of elevating them, would reduce repetitive flooding, promote safety and increase community resiliency. The final element of Plan NS-C addressed non-residential structures. All non-residential structures that would be inundated at this future flood level would not be included in the plan. Because these properties would regularly experience flooding (at the highest annual tide), floodproofing measures would be insufficient to stop property damage. The state and property owners would have to consider other measures to address these properties.

This plan was developed using the community groups formulated in Plan NS-A. An economic analysis as completed, which included three (3) elements:

1. Acquisitions for residential properties that would be consistently flooded at the future flood level (i.e., Mean Higher High Water plus 1.5ft using the USACE intermediate SLC model),
2. Elevations for residential properties that would be flooded at the future flood level,

3. Floodproofing for non-residential properties that would not be consistently flooded at the future flood level.

Because the cost of acquisition is so much higher than the cost of elevations, only seven (7) of the original community 31 groups had a BCR greater than 0.9 (highlighted in blue in **Table 5-8**). Twenty-five (highlighted in gray in **Table 5-8**) had a BCR less than 0.9, so were not included in the plan. As a result, Plan NS-C is a much smaller plan. Plan NS-C includes 21 elevations, five (5) acquisitions and 41 floodproofings (highlighted in blue in **Table 5-8**).

Table 5-8: Economic analysis for Plan NS-C

Community Group Name	Total Present Value Benefits	Total Costs	BCR	Acquisition	Elevation	Floodproof
Barrington 1 (Warren)	$36,695,721	$74,145,862	0.49	48	44	36
Barrington 2	$11,275,182	$15,315,472	0.74	0	36	10
Block Island	$3,326,145	$3,267,706	1.02	0	2	6
Bristol Downtown	$6,175,878	$8,475,491	0.73	0	14	8
Common Fence Point	$5,872,950	$17,207,321	0.34	0	12	13
Downtown Warwick	$8,532,124	$8,635,518	0.99	3	2	11
East Greenwich	$3,003,178	$2,989,720	1.00	0	0	8
Fort Ave	$2,524,052	$4,510,793	0.56	1	8	1
Island Park	$9,894,835	$21,442,490	0.46	16	34	0
Laurel Park	$8,349,363	$19,069,709	0.44	11	26	0
Little Tree Point	$8,106,434	$25,060,387	0.32	24	0	
Cranston Mall	$999,216	$3,381,479	0.30	0	0	5
Nannaquaket Pond	$2,731,614	$7,498,215	0.36	0	0	
Nar/NK	$17,943,968	$40,293,237	0.45	36	29	3
Newport	$6,601,552	$20,016,634	0.33	17		
Newport Downtown	$65,309,458	$70,063,160	0.93	37	31	29
Newport North	$3,717,798	$4,372,113	0.85	1	2	7
North Kingstown	$1,042,338	$5,095,675	0.20	1		
Oakland Beach	$6,224,850	$11,583,918	0.54	5	23	2
Potowomut	$2,128,178	$4,521,580	0.47	3	2	
Provport 1	$12,095,014	$21,649,195	0.56	0	0	35
Quonset Airport	$11,033,142	$4,876,339	2.26	0	0	9
Sakonnet	$1,891,846	$2,248,749	0.84	1	2	2
Sakonnet North	$3,583,277	$8,458,327	0.42	7	1	
Sakonnet South	$3,378,462	$6,790,561	0.50	6	4	
Shawomet	$5,150,644	$10,831,255	0.48	6	15	3
Shore Acres	$2,163,717	$2,542,409	0.85	0	7	0
Sounth Kingstown	$7,282,201	$12,138,881	0.60	0	38	0
The Hummocks	$1,622,946	$4,594,010	0.35	4	3	0
Tiverton/Little Compton	$2,513,143	$7,450,163	0.34	9	0	0
Warren	$36,695,721	$74,145,862	0.49	48	44	36
Warwick Neck	$6,267,922	$16,081,207	0.39	17	12	0

Community Group Name	Total Present Value Benefits	Total Costs	BCR	Acquisition	Elevation	Floodproof
West Passage	$3,011,609	$3,502,615	0.86	1	8	0
Wickford	$46,539,575	$62,676,699	0.74	16	97	35
Outliers	$17,145,655	$34,113,396	0.50	7	38	27

5.6 Critical Infrastructure

Coastal storm risk management measures for critical infrastructure was analyzed as part of this study. A list of facilities, initially developed from the Rhode Island Emergency Management Office, the Department of the Interior, as well as various Rhode Island localities, were preliminarily identified as critical infrastructure. This included airports, communication sites, electrical substations, emergency facilities (EMS and fire stations, hospitals, police stations), HazMat facilities (e.g., wastewater treatment plants), nursing homes, and schools. There were a total of 73 facilities preliminarily identified as critical within the designated 100-year floodplain. The list was refined down to approximately 55 structures and/or sites to be considered for coastal storm risk management measures.

The formulation strategy was to provide coastal storm management measures for critical infrastructure as part of the nonstructural component of the alternative plan selected for recommendation, regardless of whether or not the critical infrastructure is located in a community group that is otherwise economically justified. As such, critical infrastructure could be incorporated throughout the study area, including those areas where no other nonstructural action is recommended.

Preliminary costs and benefits for providing coastal storm risk management for critical infrastructure was developed for those facilities identified to have associated buildings that could potentially be protected by dry floodproofing. Of the refined list discussed previously, there were 43 critical infrastructure sites that had identified buildings on the premises. The preliminary costs associated with those 43 structures totaled $18.9 million. The total present value benefit based on damage to a general commercial building was estimated to be $4.9 million. Due to the individualized characteristics associated with critical infrastructure, further investigation on both the costs and benefits is necessary prior to making a decision regarding inclusion in the recommended plan for this study. A summary of the number and types of critical infrastructure considered in the analysis and the preliminary costs and benefits estimated on average for buildings located at each type of critical infrastructure can be seen in the following table.

Table 5-9: Critical Infrastructure Included in Analysis

Type of Critical Infrastructure	Number of Sites	Number of Buildings	Average Total Present Value Benefit Floodproofing of Building ($)	Average Total Cost Estimated for Floodproofing of Building ($)
Airport	1	0		
Electrical Power Station	4	3	373,715	206,928
Energy Production	1	0		
Fire/police	5	5	373,715	212,315
FP - Chemical/Single Building	2	2	373,715	58,042
Nursing Home	4	4	804,143	121,842
School	9	9	522,991	201,818
Sewer	22	18	363,391	42,275
Structural - WWTF	1	0		
Tank Farm	2	2	373,715	6,404
Total	**51**	**43**		

6.0 NED BENEFIT COMPARISON

The final array of alternatives carried forward for evaluation includes the no action plan NAA; three (3) nonstructural alternatives (NS-A, NS-B, and NS-C) NS; a surge barrier in the upper portion of the Warren River BW3; a surge barrier in the lower portion of the Warren River BW4; and a barrier at Middle Bridge NA4.

Table 6-1: Final Array of Alternatives

Alternatives	Location	Measures	
NAA	No Action	Entire Study Area	N/A
NS	Nonstructural	Entire Study Area	Elevation of Residential Structures Acquisition of Residential Structures Floodproofing Non-Residential Structures
ND3	Wellington Perimeter	Newport Downtown	Wellington Area Floodwall/Levee
BW3	Warren River Surge Barrier (upper)	Barrington/Warren	Surge Barrier
BW4	Warren River Surge Barrier (lower)	Barrington/Warren	Surge Barrier
PR3	Providence Harbor Bulkhead	Providence	Bulkhead
NA4	Middle Bridge Protection	Narragansett	Middle Bridge Barrier

6.1 NED Benefits

Present value damage reduction estimated using the G2CRM model was annualized using the capital recovery factor for a 50-year period of analysis and the fiscal year 2021 discount rate of 2.5%, which was the most current at the time of the analysis was completed. Average annual benefits were calculated for each alternative in the final array.

6.2 Cost Data

The costs presented for the plan selection were developed using the USACE Micro-Computer Aided Cost Estimating System (MCACES), Second Generation (MII). The MII cost estimate used RS Means, MII Cost Libraries, and vendor quotations. The project contingency is assumed to be 30%. Prior to recommendation of the final recommended plan, this contingency will be further refined through use of the Abbreviated Risk Analysis (ARA) tool provided by the USACE Cost Center of Expertise. Detailed cost information is provided in the cost engineering sub-appendix.

Cost estimates were developed for all alternatives based on representative unit costs for similar construction projects in the area. All costs used in final comparison of alternatives are in October 2020 (FY 2021) price levels, the most current price levels at the time of the analysis. First cost developed for each alternative plan include estimation for construction, contingency, preconstruction engineering and design, construction management, real estate, and environmental mitigation. After first costs for each measure were determined, they were annualized to provide a basis for evaluation against the benefits.

Interest During Construction. IDC was calculated based on the estimated length of construction for each component of construction in each alternative. Implementation of nonstructural measures as a whole, including Critical Infrastructure are assumed to be spread out over the 5-year construction timeline. However, given that each individual nonstructural measure is expected to take only 3 months, IDC is calculated accordingly for all nonstructural measures.

The total cost is added to the costs of interest during construction to determine the investment cost of each alternative. The interest during construction associated with each measure for the recommended plan can be found in the tables below.

Operations, Maintenance, Relocations, Rehabilitation, and Repair Costs (OMRR&R). OMRR&R costs for each alternative were also estimated based on comparable projects constructed in the past. OMRR&R is expected to occur during the period of analysis for all structural measures.

Average Annual Costs. Using the total investment costs and annual OMRR&R, the average annual equivalent costs were calculated for each alternative based on a 50-year period of analysis, the fiscal year 2022 discount rate of 2.5%, and the most current price levels available at the time October 2020 (FY2021).

6.3 Benefit-Cost Analysis

Table 6-2 shows the total average annual costs, average annual benefits, and resulting average annual net benefits and benefit to cost ratios (BCR) for each alternative in the final array of nonstructural alternatives as compared to the structural alternatives shown previously. As shown in the table, nonstructural Plan A has the higher Average Annual Net Benefit of the plans under consideration.

Table 6-2: NED Net Benefit Comparison of Final Array Alternatives

Plan	Structure Count	Total First Cost ($)	Annual Average Benefit ($)	Annual Average Cost ($)	Average Annual Net Benefits ($)	BCR
Wellington Perimeter (Newport)	N/A	$36,640,000	$633,000	$1,305,000	-$672,000	0.5
Warren River Surge Barrier (Upper)	N/A	$614,631,000	$13,246,000	$27,276,000	-$14,030,000	0.5
Warren River Surge Barrier (Lower)	N/A	$568,211,000	$14,977,000	$24,142,000	-$9,165,000	0.6
Middle Bridge Protection (Narragansett)	N/A	$130,966,000	$954,000	$5,138,000	-$4,184,000	0.2
NS- A	494	181,000,000	9,730,000	6,500,000	3,220,000	1.5
NS-B	610	229,000,000	10,360,000	8,230,000	2,130,000	1.3
NS-C	67	29,000,000	1,170,000	1,040,000	130,000	1.1

6.4 Risk and Uncertainty

Risk and uncertainty were factored into the economic analysis through the use of statistical risk-based models.

6.5 Residual Risk

Residual risk (RR) is the risk that remains in the study area after the proposed coastal storm risk management project is implemented. Residual risk includes the consequence of capacity exceedance as well as consideration of the project flood risk reduction. The residual risk is the remaining risk that cannot be mitigated given the hydrological, environmental, and economic constraints. The residual risk is assessed here, as required by ER 1105-2-101, *Risk Assessment for Flood Risk Management Studies*, using remaining expected annual damages and remaining structures at risk. For each metric, the residual risk of the future with project condition can be calculated by subtracting the impact of the plan from the risk in the future without project condition.

The residual risk associated with implementation of each of the alternatives is estimated and shown in the following table. The number of structures listed as “protected by alternatives” is the number of structures with measures implemented that are intended to reduce the coastal storm risk and provide protection to varying degrees depending on the measure rather than full protection from coastal storm risk. As such, there are varying amounts of risk that remain for structures included in the FWP alternatives that are not included in the residual number of structures at risk.

Table 6-3: Residual risk of Alternative Plans

		FWOP		FWP		Residual**	
Locality	**Number of Structures at Risk**	**FWOP Total Present Value Damage ($)**	**Number of Structures Protected by Alternative**	**FWP Present Value Damage Reduced by Alternative ($)**	**Remaining Number of Structures at Risk**	**Total Remaining Present Value Damage ($)**	**Percent Damage Reduction**
Warren River Surge Barrier (Lower)	12,137*	1,334,334,000*	2380	424,783,000	9,757	909,551,000	32%
Warren River Surge Barrier (Upper)	12,137*	1,334,334,000*	2043	375,679,000	10,094	958,655,000	28%
Middle Bridge Protection (Narragansett)	12,137*	1,334,334,000*	309	26,723,000	11,828	1,307,611,000	2%
Wellington Perimeter (Newport)	12,137*	1,334,334,000*	312	24,467,000	11,825	1,309,867,000	2%
NS-A	12,137	1,334,334,000	494	290,203,000	11,643	1,044,131,000	22%
NS-B	12,137	1,334,334,000	610	309,077,000	11,527	1,025,257,000	23%
NS-C	12,137	1,334,334,000	67	34,788,000	12,070	1,299,546,000	3%

*Structural alternative residual risk damages adjusted to account for updated structure inventory used in nonstructural alternative modeling, for comparison purposes.

**Residual damage is overestimated as presented in this table due to damages in the years prior to project implementation that are included in both the FWOP and FWP modeled damage estimates. Residual Risk is defined as the flood risk that remains in the floodplain after a proposed coastal storm management project is implemented and would therefore be less than what is shown in the Table.

7.0 SENSITIVITY ANALYSIS

Prior to the final recommended plan, additional sensitivity analysis will be completed as necessary for variables and assumptions on benefits and costs that have considerable associated uncertainty.

8.0 REGIONAL ECONOMIC DEVELOPMENT

RED effects include the impact of project spending, either direct or induced, on the local economy. It is expected that with increased Federal spending on the selected plan, income and employment would show some modest temporary increase. The reduction in coastal storm damages will also help to maintain the current residential population and associated tax base.

8.1 Background

The Recommended Plan includes nonstructural measures selected to reduce coastal storm risk to Rhode Island. This system is being implemented in response to reoccurring hurricane storm damage and is designed to prevent to reduce flood damages. For this analysis, the Regional Economic Development (RED) effects of implementing the components of the structural alternatives will be estimated and compared to the RED effects of implementing the Recommended Plan.

8.2 RECONS Methodology

This RED analysis employs input-output economic analysis, which measures the interdependence among industries and workers in an economy. This analysis uses a matrix representation of a region’s economy to predict the effect of changes in one industry on others. The greater the interdependence among industry sectors, the larger the multiplier effect on the economy. Changes to government spending drive the input-output model to project new levels of sales (output), value added (GRP), employment, and income for each industry.

The specific input-output model used in this analysis is RECONS (Regional Economic System). This model was developed by the Institute for Water Resources (IWR), Michigan State University, and the Louis Berger Group. RECONS uses industry multipliers derived from the commercial input-output model IMPLAN to estimate the effects that spending on USACE projects has on a regional economy. The model is linear and static, showing relationships and impacts at a certain fixed point in time. Spending impacts are composed of three different effects: direct, indirect, and induced. The long-term spending module within RECONS allows for spending over a designated length of construction, so expenditures were able to be input for the 5-year construction period for this project starting in the year 2025. Direct effects represent the impacts the new federal expenditures have on industries which directly support the new project. Labor and construction materials can be considered direct components to the project. Indirect effects represent changes to secondary industries that support the direct industries. Induced effects are changes in consumer spending patterns caused by the change in employment and income within the industries affected by the direct and induced effects. The additional income workers receive via a project may be spent on clothing, groceries, dining out, and other items in the regional area.

The inputs for the RECONS model are expenditures that are entered by work activity or industry sector, each with its own unique production function. The production function “FRM Construction” was selected to gauge the impacts of the construction of the NED plan. The model results are expressed in 2025 dollars based on the first year of project expenditure.

8.3 Assumptions

Input-output analysis rests on the following assumptions. The production functions of industries have constant returns to scale, so if output is to increase, inputs will increase in the same proportion. Industries face no supply constraints; they have access to all the materials they can use. Industries have a fixed commodity input structure; they will not substitute any commodities or services used in the production of output in response to price changes. Industries produce their commodities in fixed proportions, so an industry will not increase production of a commodity without increasing production in every other commodity it produces. Furthermore, it is assumed that industries use the same technology to produce all of its commodities. For structural measures, “Construction or Major Rehabilitation of Concrete Floodwalls” was assumed as the work activity. Whereas, for nonstructural alternatives, “Construction or Major Rehabilitation of Residential Single-Family Structures or Multi-Family Structures was the assumed as the work activities for the analysis.

8.4 Description of Metrics

“Output” is the sum total of transactions that take place as a result of the construction project, including both value added and intermediate goods purchased in the economy. “Labor Income” includes all forms of employment income, including employee compensation (wages and benefits) and proprietor income. “Gross Regional Product (GRP)” is the value-added output of the study regions. This metric captures all final goods and services produced in the study areas because of the project’s existence. It is different from output in the sense that one dollar of a final good or service may have multiple transactions associated with it. “Jobs” is the estimated worker-years of labor required to build the project.

8.5 Recons Results

For the structural alternatives, the total regional economic development impact is estimated as the following:

Wellington Perimeter (Newport) the expenditures of $43,968,000 support a total of 390.6 full-time equivalent jobs, $29,215,250 in labor income, $39,374,336 in the gross regional product, and $66,597,357 in economic output in the local impact area. More broadly, these expenditures support 654.7 full-time equivalent jobs, $52,359,744 in labor income, $70,421,879 in the gross regional product, and $122,363,312 in economic output in the nation.

Warren River Surge Barrier (Upper) the expenditures $737,557,128 support a total of 6,552.0 full-time equivalent jobs, $490,081,792 in labor income, $660,499,044 in the gross regional product, and $1,117,161,469 in economic output in the local impact area. More broadly, these expenditures support 10,982.8 full-time equivalent jobs, $878,327,468 in labor income, $1,181,317,287 in the gross regional product, and $2,052,627,662 in economic output in the nation.

Warren River Surge Barrier (Lower) the expenditures $681,853,120 support a total of 6,057.2 full-time equivalent jobs, $453,068,360 in labor income, $610,614,848 in the gross regional product, and $1,032,787,840 in economic output in the local impact area. More broadly, these expenditures support 10,153.3 full-time equivalent jobs, $811,991,779 in labor income, $1,092,098,289 in the gross regional product, and $1,897,602,940 in economic output in the nation.

Middle Bridge Protection (Narragansett) the expenditures $157,159,687 support a total of 1,396.1 full-time equivalent jobs, $104,427,302 in labor income, $140,740,045 in the gross regional product, and $238,046,302 in economic output in the local impact area. More broadly, these expenditures support 2,340.2 full-time equivalent jobs, $187,155,225 in labor income, $251,716,712 in the gross regional product, and $437,376,725 in economic output in the nation.

For the Nonstructural alternative Plan A, for the study area, an initial construction stimulus of $181 million (FY2025 price level) would generate 1,860 full-time equivalence jobs, $133 million in labor income, $316 million in output, and $189 million in total value added. For the state of Rhode Island as a whole, the construction stimulus would generate approximately 1,951 FTE jobs, $156 million in labor income, $341 million in output, and $215 million in Gross Regional Product. More broadly, these expenditures support 2,446 full-time equivalent jobs, $190 million in labor income, $277 million in the gross regional product, and $473 million in economic output in the nation.

TABLE 8-1: Regional economic development summary Plan NS-A
(FY2025 Price level)

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$174,410,152	1,065.4	$84,578,338	$105,797,769
Secondary Impact		$141,416,262	794.2	$48,298,848	$82,872,612
Total Impact	$174,410,152	$315,826,413	1,859.6	$132,877,186	$188,670,381
State					
Direct Impact		$180,997,570	1,114.0	$97,457,183	$118,033,846
Secondary Impact		$160,749,444	837.2	$58,882,930	$97,269,360
Total Impact	$180,997,570	$341,747,014	1,951.1	$156,340,113	$215,303,206
US					
Direct Impact		$180,998,090	1,114.0	$97,929,897	$118,209,014
Secondary Impact		$292,313,681	1,332.1	$91,815,300	$158,859,456

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Total Impact	$180,998,090	$473,311,770	2,446.1	$189,745,197	$277,068,470

9.0 Environmental Quality

The environmental quality (EQ) account displays non-monetary effects on significant natural and cultural resources. The TSP does not currently include any specific positive EQ benefits. But, as shown in the Four Accounts Comparison **Table 11-1**, there is not anticipated to be a negative EQ impact as compared to the structural measures analyzed in the final array of alternatives.

Prior to selection of the final recommended plan, non-residential buildings in the 100-year floodplain that generate/store/transport HTRW will be reviewed to determine if the EQ benefit associated with floodproofing these structures warrants inclusion in the recommended plan. Floodproofing these structures would benefit the environment by preventing potential release of HTRW to the environment.

10.0 OTHER SOCIAL EFFECTS

10.1 Background

The four Principle and Guidelines “accounts” or categories have been part of federal guidance over the past decades. The importance of each account has its own specific focus. For example, the other social effects (OSE) category covers urban and community impacts on life, health and safety, among those that are not reflected in other or formulation “accounts”.

During a hurricane surge inundation or other flooding events, communities are impacted inconsistently. The effects are due not only to location, but also income, education and emergency preparedness. Residents in lower income, high unemployment areas will likely have a more difficult time escaping the impact of flooding and recovering from it. In addition, the household composition, minority status, language skills, housing quality and availability of transportation are considerations that fall under health and safety and are classified OSE. Residents older than 65 or under 17 years of age are considered more vulnerable as well and may require more lengthy and intensive government support. Studies of Katrina showed that it took longer to return these residents to their homes compared to higher income neighborhoods.

10.2 OSE Variables and Analysis

This OSE analysis used the residential and nonresidential inventory of 12,137 buildings to select a subset with certain characteristics. Structures selected were within the 100-year floodplain and were evaluated for elevation or floodproofing as economic measures for this project. In addition, they are part of a community group, so these "communities" were developed during the process. In order to develop these population clusters, political boundaries with similar hydrology and hydraulic characteristics during flood events were evaluated. These are part of the “Social Connectedness” consideration in this account.

Moreover, health and safety were evaluated on those community groups by protecting critical infrastructure. The assets that are essential for the functioning of a society and economy are labeled critical infrastructure. For these reasons, the groupings were examined to reassure access to indispensable services and utilities in the event of flooding. Finally, all residential and nonresidential structures based in the stressed locations were re-assessed as part of this aggregation methodology and communities were identified as vulnerable.

10.2.1 Life Loss/Life Safety

Formulation in this document is directed to the process of identifying potential management measures and combining them into alternative plans. As part of the OSE analysis, it was important to learn the risk to the individuals impacted during a flood event. In addition, vulnerable populations such as the elderly were taken into account. Therefore, during the G2CRM modeling the vertical evacuation of vulnerable groups was considered. In order to understand the increase or decrease of loss of life, the future without project (FWOP). A population of 670,000 was utilized for the study and it determined a total loss of life of 0.004% in the FWOP group.

There appears to be minimal life loss risk for this study area based on historical storm events as well as estimated modeling of FWOP life loss. Since life loss does not play a significant role in formulating and evaluating alternatives, and selecting the recommended plan for this study, a qualitative assessment was used to consider and explain changes to risk of life loss for structural alternatives that are not justified based on NED compared to implementation of a nonstructural alternative. As such, a comparative quantitative analysis was only completed on the nonstructural alternative. The nonstructural future with project (FWP) condition was modeled within G2CRM and resulted in a reduction of 28% loss of life when compared to the FWOP. Based on the number of structures protected and residual risk associated with the Middle Bridge and Wellington (Newport) structural alternatives, the reduction in life loss would be negligible. A similar comparison to both the Upper and Lower Warren River Alternatives, one could conclude a slightly higher reduction in loss of life compared to a nonstructural alternative. The results of the G2CRM estimated life loss associated with a nonstructural plan compared to the FWOP can be seen in the following figure.

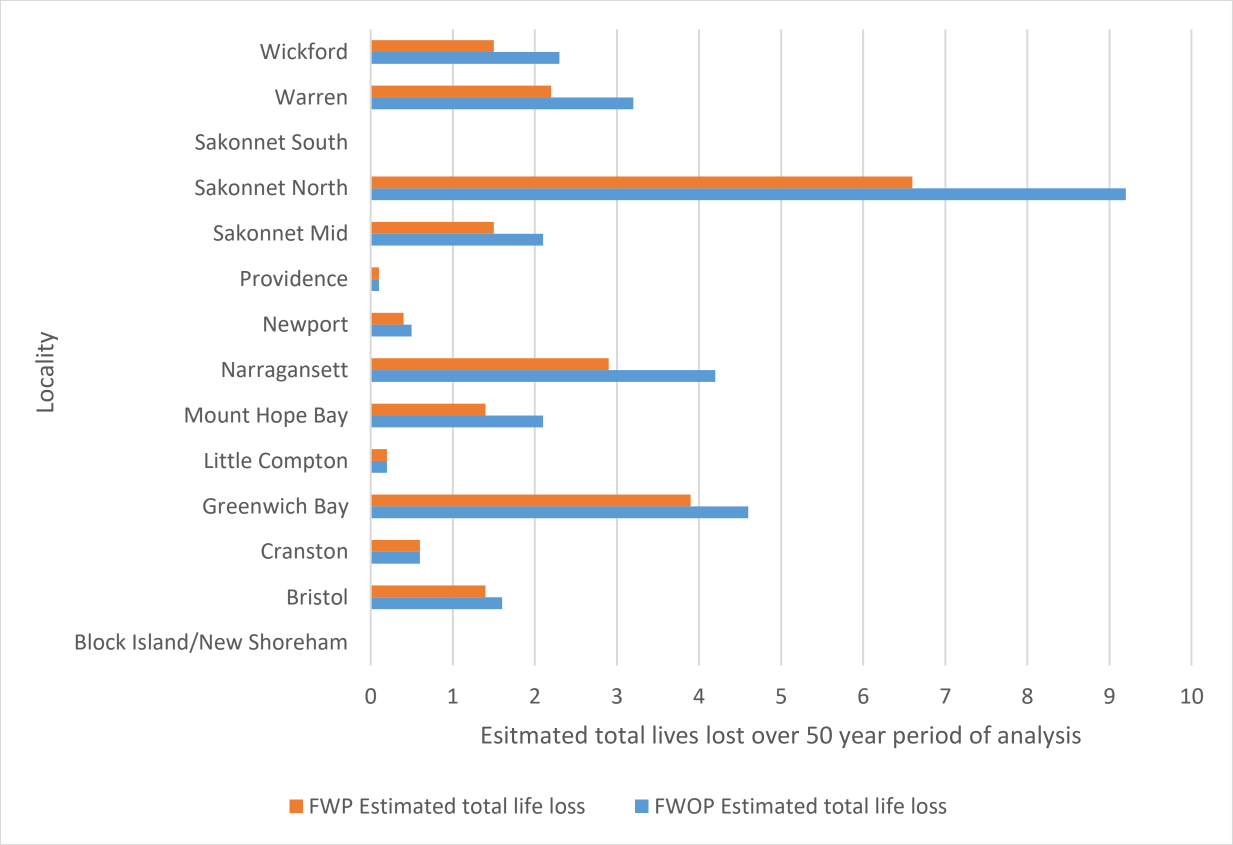

Figure 10-1: Life Loss G2CRM estimates for a Nonstructural Alternative Plan*

*These estimated values should be viewed as approximations to give an understanding of the overall magnitude of expected life loss in an area. The life loss modeling performed in G2CRM is not precise enough to give detailed quantities related to life loss.

10.2.2 Socially Vulnerable Communities

The OSE account helped to answer some key questions when evaluating the dynamics of social interaction in the regional area of Rhode Island, which included the economic and cultural aspects. Other studies revealed that vulnerable groups and families living in poverty were less resilient when a natural disaster occurs. In order to mitigate this issue, the formulation strategized its plan by collecting and evaluating data.

The Center for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry CDC/ATSDR social vulnerability index (SVI) data was utilized to identify the vulnerable geographic areas in Rhode Island. The SVI contains data from the 2018 census tracts which originally were downloaded in a geographic shapefiles form and then preprocessed in order to do the full analysis. These tracts were ranked for the entire United States with values ranging from 0 to 1. The higher value indicated greater vulnerability and for this study values of 0.75 and higher were selected. The 0.75 threshold used to identify socially vulnerable communities was chosen to be consistent with CDC developed County level mapping for the SVI which identifies census blocks with an index of 0.75 and above as having the 'high' vulnerability." It is acknowledged that the average for a census block may not be indicative of each individual structure. So, in an effort to err on the side of inclusion, those community groups having an average index of 0.65 (rated medium-high by the CDC) were also included in this analysis at this point in the study. Socially vulnerable community groups will reevaluated as the study progresses to determine if appropriate to include in the final recommended plan.

The structure inventory of 12,137 buildings was used to identify vulnerable locations. Seven out of 31 communities were identified as vulnerable as shown in the tables below.

Table 10-1: SVI Variables

SVI index group name	Variable name
Socioeconomic	Unemployment, income and no high school diploma
Household Composition/Disability	Aged 65 or older, aged 17 or younger, civilian with a disability, single parent households
Minority Status/Language	Minority, aged 5 or older who speaks English “less than well”
Housing Type/Transportation	Multi-unite structures, mobile homes, crowding, no vehicle, group quarters

Table 10-2: Community Groups identified as Socially Vulnerable

Community name
Quonset Airport 1
Fort Avenue
Oakland Beach
Port of Providence 1
Port of Providence 2
Newport NE
Quonset Airport 2

11.0 FINAL ALTERNATIVES FOUR ACCOUNTS COMPARISON

11.1 Overview Comparison of Alternatives

As discussed, and covered throughout this appendix, there are four accounts to facilitate and display the effects of alternative plans in the formulation of water resource projects while recognizing the importance of maximizing potential benefits relative to project costs. These accounts include National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). The results of the analysis for each of these accounts is summarized in the following table.
The NED account displays the average annual net benefit estimated for each alternative.

The RED account shows the total output associated with each alternative. “Output” is the sum total of transactions that take place as a result of the construction project, including both value added and intermediate goods purchased in the economy. More details associated with each alternative were discussed previously in **Section 8.0**.

The EQ and OSE accounts both list the positive and negative qualitative assessments for each alternative. These qualitative benefit assessments were then used to develop a scaled rating to compare alternatives. The scale used to evaluate the OSE account was between 3 (positive impacts) and 1 (negative impacts), while the scale used to evaluate the EQ account was between 3 (positive impacts) and -3 (negative impacts). These qualitative benefit assessments were used to develop a scaled rating to compare alternatives. Qualitative assessment was determined to be suitable for this comparison of alternatives since the only NED justified alternatives are all nonstructural. It is reasonable to conclude that any positive quantitative assessment of EQ and/or OSE would not outweigh the value of the NED benefits attained by the nonstructural alternatives as compared to the structural alternatives for this study. Likewise, it is not anticipated that the difference in EQ or OSE benefits would be substantial enough to warrant quantitative assessment of these accounts.

Table 11-1: Final Array of Alternatives Four Accounts Comparison

Alternative	NED[1] ($)	RED[2] ($)	OSE			EQ		
			Value	Pros	Cons	Value	Pros	Cons
Wellington Perimeter (Newport)	-672,000	122M	1	•Maintains communities, local roads and utilities.	•Localized Benefits •Does not protect socially vulnerable communities.	1	No Significant Impacts	•Effects to aesthetics
Warren River Surge Barrier (Upper)	-14,030,000	2B	1	•Maintains communities, local roads and utilities.	•Localized Benefits •Does not protect socially vulnerable communities.	-3	No Significant Impacts	•Effects to wetlands and fish passage.
Warren River Surge Barrier (Lower)	-9,165,000	1.9B	1	•Maintains communities, local roads and utilities.	•Localized Benefits •Does not protect socially vulnerable communities.	-3	No Significant Impacts	•Effects to wetlands and fish passage •Located adjacent to an Audubon Sanctuary •Impacts to Native American burial site.
Providence Harbor Bulkhead	N/A	N/A	2	•Maintains communities, local roads and utilities. •Located in a vulnerable community	•Localized Benefits •Does not protect socially vulnerable communities.	2	•Minimizes HTRW releases to Providence River	None
Middle Bridge Protection (Narragansett)	-4,184,000	437M	1	•Maintains Communities	•Localized Benefits •Does not protect socially vulnerable communities.	-3	No Significant Impacts	•Effects to wetlands, eelgrass, and fish passage. •Located near a wildlife sanctuary.
NS - Plan A	3,220,000	473M	2	•Benefits on regional scale •Maintain communities •Includes some vulnerable communities	•Does not reduce risk for local roads and utilities.	1	No Significant Impacts	No Significant Impacts
NS - Plan B	2,130,000	599M	2	•Benefits on regional scale •Maintain communities •Includes all vulnerable communities	•Does not reduce risk for local roads and utilities.	1	No Significant Impacts	No Significant Impacts
NS - Plan C	130,000	76M	1	•Benefits on regional scale •Maintain communities •Considers future access to critical services and utilities	•Highest residual risk of NS plans. •Does not reduce risk for local roads and utilities. plans	1	No Significant Impacts	No Significant Impacts

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[1] NED account displays average annual net benefits

[2] RED account displays total economic output estimated to result from project implementation expenditures

11.2 Selection of the Tentatively Selected Plan

There are no structural measures that have positive NED net benefits. Of the nonstructural alternatives, Plan A has the greatest average annual net NED benefit.

The Warren River Surge Barrier (Upper) alternative has the greatest Regional Economic Development benefit. However, this was not considered to outweigh the value of the positive NED net benefits associated with the other nonstructural alternatives.

The Providence Harbor Bulkhead and nonstructural alternatives NS-A, and NS-B, all have equivalent OSE assessment ratings of 2. However, the Providence Harbor alternative is being recommended for study outside the scope of this study, and thus not carried forward.

The Providence Harbor Bulkhead is anticipated to have the greatest positive EQ benefits. However, once again, this alternative is being recommended for study outside the scope of this study. The nonstructural alternatives are all found to have no associated negative benefits.

Nonstuctural Plan NS-A is selected as the Recommended Plan. This Plan has the greatest average annual net benefits, is one of the alternatives with the highest qualitative OSE assessment and has a neutral EQ benefit assessment.

11.3 Refinement and Optimization of the Selected Plan

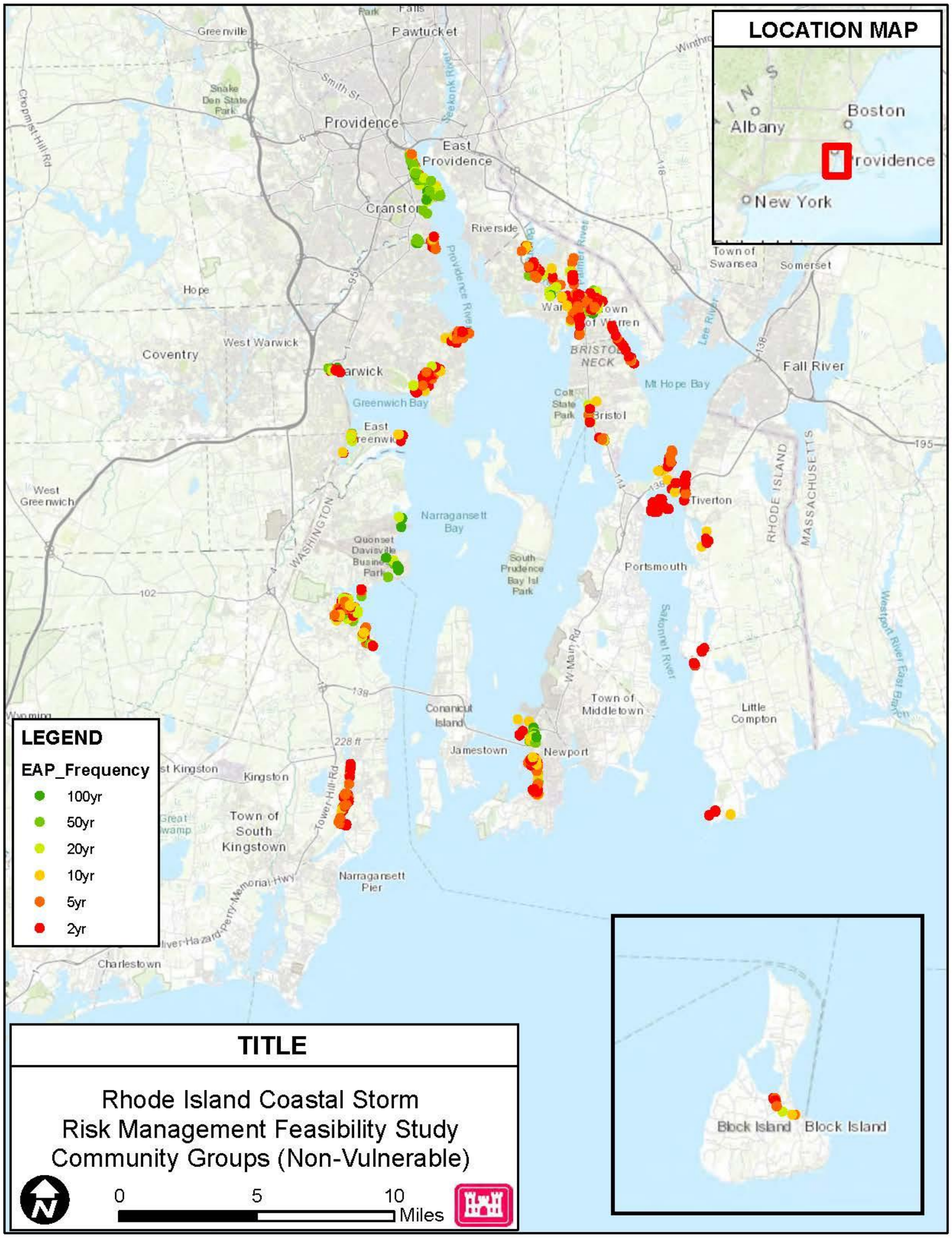
After the Plan NS-A was selected as the TSP, several refinements were made in order to be as inclusive as possible and reduce the greatest amount of flood risk in the study area. Two refinements were made to the initially selected Plan NS-A that resulted in Plan NS-A.1 as the TSP. Further refinements were subsequently made to Plan NS-A.1 and elevation design heights were optimized that ultimately resulted in the Recommended Plan for this study. These refinements and optimization are described in this section of the report.

11.4 Tentatively Selected Plan Refinement

Two (2) refinements were made to Plan NS-A that resulted in the inclusion of an additional 39 structures to the TSP. This plan will be referred to as NS-A.1.

Review of the following map shows the annual exceedance probability flooding risk associated with the structures that comprise community groups. Consideration was given to the community groups that were previously screened from Plan NS-A to determine if remaining flood risk could be mitigated in an economical efficient manner.

Figure 11-1: AEP Water Level Flood Frequency of Structures in Community Groups



The first refinement includes additional non-residential structures from four (4) community groups that were originally considered in Plan NS-A (Barrington, Bristol Downtown, Narragansett and Shawomet). Although these groups did not have an overall BCR less than 1.0 when both elevations and floodproofing were considered, the BCR for non-residential floodproofing alone was greater than 1.0. **Table 11-2** shows the economic analysist for the four (4) community groups. The rows highlighted in blue include the costs and benefits of non-residential floodproofing. As a result of this refinement, twenty-five additional non-residential properties were added in Plan NS-A.1 since it is shown through the economic analysis that these groups of non-residential structures face coastal storm risk.

Table 11-2: Community groups with BCRs above 1.0 for the non-residential floodproofing

Community Group Name	Total Present Value Benefits ($)	Total Costs ($)	BCR
Barrington	**19,926,663**	**27,249,240**	**0.7**
Elevation	**14,108,403**	**21,794,889**	**0.6**
Floodproof	**5,818,260**	**5,454,351**	**1.1**
Bristol Downtown	**6,175,878**	**8,097,264**	**0.8**
Elevation	**2,545,806**	**5,107,545**	**0.5**
Floodproof	**3,630,072**	**2,989,720**	**1.2**
Narragansett	**7,531,400**	**9,379,882**	**0.7**
Elevation	**5,945,377**	**8,258,737**	**0.6**
Floodproof	**1586023**	**1121145**	**1.4**
Shawomet	**4,804,555**	**7,974,676**	**0.6**
Elevation	**3,487,028**	**6,853,531**	**0.5**
Floodproof	**1,317,527**	**1,121,145**	**1.2**

The second refinement includes the outlier properties. As described previously in this report, 74 structures were not located near any other structures, so were not part of any community group. These were identified as “outliers” and were initially removed from consideration. Of the 74 structures, 6 were justified, with BCR’s greater than 1.0. These structures were added to the TSP plan.

11.5 Recommended Plan Refinement

Plan NS-A.1 was further refined to incorporate appropriate modeling updates and revisions to structure inventory based on a quality check of the entire baseline inventory. Some structures had to be removed from consideration if found to actually be commercial rather than residential and had a basement or were located in a VE zone, since these structures could not be floodproofed. Likewise, if residential structures were found to actually have first floor elevations higher than the base elevation height, these were removed from consideration. Structures were also removed from the baseline inventory as necessary if designated for floodproofing but located in a Coastal A zone or if found to be a Federal property. Costs Estimates were refined as well to incorporate adjustments based on actual implementation costs for a similar project in close proximity to this study area. Both costs and depreciated replacement values used to derive inundation damages were updated to October 2021 price levels for comparison at the current price level.

The updated G2CRM modeling results were used along with updated cost estimates to reevaluate inclusion of each community group in the plan based on NED benefits and the plan was adjusted accordingly. While a BCR of 0.9 was used to determine inclusion in the plan at the time of the TSP, a BCR of 1.0 was used to determine inclusion in the Recommended Plan. The refined estimated damages and costs are shown in the following table for each community group. Critical Infrastructure was included in total present value benefits and total costs shown here for those community groups that were justified with the inclusion of critical infrastructure.

Table 11-3: Economic analysis for Recommended Plan Community Groups

Community Group Name	Total Present Value Benefits ($)	Total Costs ($)	BCR
Block Island	5,084,853	2,276,000	2.2
Cranston Mall	19,628,559	3,683,000	5.3
Downtown Warwick	249,356,085	73,796,000	3.4
East Greenwich	7,075,514	5,135,000	1.4
*Newport Downtown	7,075,514	5,135,000	1.4
*Quonset Airport	19,628,559	3,683,000	5.3
Sakonnet	249,356,085	73,796,000	3.4

*****Includes Critical Infrastructure in Community Group Benefits and Costs

Table 11-4: Economic analysis for Recommended Plan Floodproofing Groups

Community Group Name	Total Present Value Benefits	Total Costs	BCR
*Barrington	9,991,468	9,748,000	1.0
*Bristol Downtown	1,898,677	1,842,000	1.0
Fort Ave	2,246,692	1,105,000	2.0
Nannaquaket Pond	409,799	368,000	1.1
Narragansett	785,395	737,000	1.1
Shawomet	348,316	337,000	1.0
Warren	24,680,711	16,369,000	1.5
Wickford	19,989,396	12,891,000	1.6

*****Includes Critical Infrastructure in Community Group Benefits and Costs

Additional community groups were added to the plan based on further review of areas designated as environmental justice areas of concern as well as areas with historical significance.

Table 11-5: Economic analysis for Recommended Plan Environmental Justice and Historically Significant Groups

Community Group Name	Total Present Value Benefits	Total Costs	BCR
Fort Avenue (Elevation)	3,053,102	5,272,000	0.6
Oakland Beach (Elevation and Floodproofing)	4,524,449	17,176,000	0.3
Warren(Elevation)	20,452,958	38,221,000	0.5
Wickford (Elevation)	26,585,338	48,215,000	0.6

Individual structures within community groups not included in the plan were reviewed and added to the plan if estimated BCR was over 1. There were 454 structures located within community groups that were not justified as a group. Of these individual structures, 14 were justified, with BCR's greater than 1.0. These structures were added to the Recommended Plan similar to individually justified outliers.

Lastly, additional critical infrastructure was added to the plan based on information collected, interviews with facility contacts, along with G2CRM modeling completed on these facilities. Due to the uniqueness of these facilities and content, associated inundation damages are difficult to estimate on a broad scale. Modeled estimates of frequency and depth of inundation at the location/elevation of the facilities was taken into consideration along with information regarding prior flooding, value/cost of replacing equipment, and impact to the community if a facility were to become inoperable due to flooding. There were 51 sites and 43 buildings initially carried forward for consideration. Further research updated these amounts to 55 total facilities which included 53 buildings, 10 underground facilities (pump, ejector, and grinder stations), and 8 electric substations. Additional information was collected on this updated list of facilities resulting in a total of 36 critical infrastructure structures or facilities identified that were determined appropriate to include in the recommended plan. Of these, 23 were located in community groups included in the Recommended Plan based on NED justification, 7 were in a justified community group but did not have a BCR above 1.0 with inclusion of the critical infrastructure, 3 were located in community groups not included in the Recommended Plan, and 3 were considered outliers not located in any community group. As shown in the following table, critical Infrastructure facilities in the recommended plan include fire stations, nursing homes, schools, electrical power station (substations and associated buildings), and sewer facilities (pump stations, grinder stations, ejector stations).

Table 11-6: Critical Infrastructure in the Recommended Plan

Type of Critical Infrastructure	Number of Dry Flood-proofing	Number of Wet Flood-proofing
Fire/police	4	1
Nursing Home	2	0
School	2	0
Electrical Power Station (substations and associated buildings)	6	0
Sewer (pump station, ejector station, grinder station)	3	18
Total	**17**	**19**

11.5.1 Optimization of the Recommended Plan

The elevation design height modeled for the Recommended Plan was determined separately for each structure based on the 1% AEP NACCS water level + wave contribution + sea level change (intermediate through 2080). From the G2CRM User's Manual (USACE, 2018b) and per FEMA guidance, the wave contribution was computed as 0.705* (the smaller of the 1% wave height or 0.78* water depth). For optimization of the plan, costs were updated and damages were modeled in G2CRM for an elevation of plus one foot (if possible based on an engineering constraints of 12 feet maximum elevation) and minus one foot to the base elevation used for the Recommended Plan. Net benefits were then compared for each to determine where benefits would be maximized, which will determine the optimized design elevation to be used in the Recommended Plan.

The results from the comparison of net benefits associated with three design heights (Base, Base-1, and Base+1) showed in increase in net benefit (2.2%) moving from the Base-1 to Base elevation. The results also showed a slight increase in net benefit (0.7%) moving from the Base to Base+1 elevation. However, since the increase from Base to Base+1 is increasing at a lower rate than the increase from Base-1 to Base, it was determined that benefits are reasonably maximized at the Base elevation design height used for the main analysis. These results were consistent for the majority of model areas, so it was determined that this design height would be appropriate for the entire recommended plan.

Table 11-7: Optimization of the Recommended Plan Net Benefit Comparison

Elevation Height	PV Benefits	PV Cost	Net Benefit	% Increase in Net Benefit
Base -1 foot	334,936,000	212,728,000	122,208,000	n/a
Base	338,324,000	213,339,000	124,985,000	2.2%
Base +1 foot	339,811,000	213,950,000	125,861,000	0.7%

12.0 DESCRIPTION OF THE RECOMMENDED PLAN

The Recommended Plan for coastal storm risk management in the Rhode Island Coastline CSRM Project is Plan NS-A.1, which is a refinement of the selected Plan NS-A. Plan NS-A.1 is an entirely nonstructural plan that includes 497 total structures – 295 residential recommended for elevation and 207 non-residential (which includes 36 critical infrastructure) recommended for floodproofing. The average annual cost of this plan is $9.6 million with a benefits-to-cost ratio of 1.5.

The Recommended Plan includes seven (7) community groups with both elevations and floodproofing measures, eight (8) community groups with only floodproofing, as well as 6 additional structures that were not included as part of an identified community group and 14 additional structures that had a BCR greater than one but were located in an unjustified community group. Within this plan three (3) community groups (Quonset Airport, Fort Ave, and Warren) that are considered socially vulnerable, but were included in the plan based on justified BCRs (Fort Ave and Warren had justified floodproofing only). Elevations for Fort Ave and Warren as well as the entire community group for Oakland Beach were added to the plan based on environmental justice consideration, and elevations in Wickford were added to the plan based on historical significance consideration. Within the Recommended Plan there are twenty-three (23) facilities identified a critical infrastructure, included as part of community groups with justified BCRs, and thirteen (13) additional critical infrastructure facilities added based on additional benefits associated with these critical facilities.

Table 12-1: Structures in the Recommended Plan

Community Group	Total Costs ($)	Elevations	Flood-proofing	Critical Infra-structures (Flood-proofing)	Total Structures
PLAN NS-A					
Block Island	2,276,000	2	3	0	5
Cranston Mall	1,940,000	0	5	0	5
Downtown Warwick	7,966,000	5	12	0	17
East Greenwich	3,683,000	0	10	0	10
Newport Downtown	73,796,000	83	36	4	123
Quonset Airport	5,135,000	0	7	3	10
Sakonnet	1,836,000	2	2	0	4
Plan Refinement - Floodproofing only					
Barrington	9,748,000	0	9	15	24
Bristol	1,842,000	0	4	1	5
Fort Avenue	1,105,000	0	3	0	3
Nannaquaket Pond	368,000	0	1	0	1
Narragansett	737,000	0	2	0	2
Shawomet	337,000	0	1	0	1
Warren	16,369,000	0	37	0	37
Wickford	12,891,000	0	35	0	35
Plan Refinement – Environmental Justice					
Fort Avenue	5,272,000	9	0	0	9
Oakland Beach	17,176,000	28	1	0	29
Warren	38,221,000	62	0	0	62
Plan Refinement – Historical Significance					
Wickford	48,215,000	82	0	0	82
Plan Refinement – Outliers and Additional from Unjustified Groups					
Outliers	3,121,000	3	3	0	6
Individuals with BCR's > 1 from unjustified groups	6,774,000	14	0	0	14
Additional critical infrastructure	7,729,000	0	0	13	13
TOTAL	**266,541,000**	**290**	**171**	**36**	**497**

*Total may be off due to rounding

12.1 Costs of the Recommended Plan

The total estimated project costs for the Recommended Plan at the October 2021 (FY 2022) price level can be found in **Table 12-2** below. In accordance with ECB No. 2007-17, dated 10 September 2007, "Cost risk analysis methods will be used for the development of contingency for the Civil Works Total Project Cost estimate. It is the process of identifying and measuring the cost and schedule impact of project uncertainties on the estimated total project cost. When considerable uncertainties are identified, cost risk analysis can establish the areas of high-cost uncertainty and the probability that the estimated project cost will or will not be exceeded. This gives the management team an effective additional tool to assist in the decision-making process associated with project planning and design." An Abbreviated Risk Analysis (ARA) will be completed on the Final Array of Alternatives described in the Engineering Appendix. And, a full Cost and Schedule Risk Analysis (CSRA) was performed on the Recommended Plan.

12.2 Construction Schedule

For this analysis, the Recommended Plan is assumed to have a five-year construction schedule for the entire project, starting in 2025 with a base year of 2030. The nonstructural component of the project involves elevating and floodproofing of 497 structures. Each individual structure comprising the nonstructural component is essentially a self-contained, fully functioning, stand-alone project increment. Accordingly, the nonstructural component of the project is assumed to have a 3-month construction schedule for purposes of calculating interest during construction, as would be expected for each individual structure.

12.3 Economic Summary of the Recommended Plan

The expected annual benefits attributable to the project alternative were converted to an equivalent time frame using the FY 2022 Federal discount rate of 2.25% for the Recommended Plan. The base year for this conversion is the year 2030 for the Recommended Plan. The equivalent annual benefits were then compared to the average annual costs to develop a benefit-to-cost ratio for the alternative. The net benefits for the alternative were calculated by subtracting the equivalent annual costs from the equivalent annual benefits. The net benefits were used to determine the economic justification of the project alternative. The economic summary for the Recommended Plan is displayed in **Table 12-2**.

Table 12-2: Economic Summary of the Recommended Plan

Federal discount rate FY22 = 2.25%, OCT 2021 Price Levels, 50-Year Period of Analysis, Figures in $ Except BCR	
Project First Costs	
Construction	168,466,000
Preconstruction Engineering & Design (PED)	27,750000
Construction Management (CM)	9,344,000
Real Estate	6,675,000
Environmental Mitigation	0
Cultural Resource Mitigation	2,718,000
Contingency	51,589,000
Project First Costs Total	**266,541,000**
Average Annual Costs	
Annualized First Costs	9,555,000
Interest During Construction (IDC)	25,000
Total Average Annual Cost (AAC)	**9,580,000**
Average Annual Benefits (AAB)	14,399,000
Net Benefits	4,819,000
Benefit-Cost Ratio (BCR)	**1.5**

12.4 Residual Risk

Residual risk remains for 11,657 structures and $967M estimated present value damages in the 100-year floodplain; however, inundation damage is reduced by 27 percent for the 100-year floodplain and 73 percent for the structures included in the Recommended Plan. The residual risk associated with implementation of the Recommended Plan is estimated and shown in the following table. The number of structures listed as “protected by alternatives” is the number of structures with measures implemented that are intended to reduce the coastal storm risk and provide protection to varying degrees depending on the measure rather than full protection from coastal storm risk. As such, there are varying amounts of risk that remain for structures included in the FWP alternatives that are not included in the residual number of structures at risk.

It should be noted that the residual damages indicated here are reflective of the damages remaining based on modeling results that include damages in the years prior to project implementation. Since residual risk is defined as the flood risk that remains in the floodplain after a proposed coastal storm management project is implemented, the actual residual risk would therefore be less than what is stated here shown in the following table.

Table 12.3: Residual Risk of the Recommended Plan by Locality

	100YR Floodplain FWOP		Plan NS-A.1		Residual		
Locality	**Number of Structures at Risk**	**Total Present Value Damage ($)**	**Number of Structures Elevated or Floodproofed in RP**	**FWP Present Value Damage Reduced by RP ($)**	**Remaining Number of Structures at Risk**	**Total Remaining Present Value Damage ($)**	**Percent Damage Reduction**
Barrington	3,555	58,812,019	14	12,178,807	3,541	46,633,212	21%
Bristol	345	59,707,474	5	1,898,677	340	57,808,797	3%
Cranston	522	12,925,974	11	3,760,372	511	9,165,603	29%
East Greenwich	16	41,929,449	10	19,628,559	6	22,300,889	47%
East Providence	90	16,055,724	1	374,953	89	15,680,771	2%
Jamestown	56	15,673,039		0	56	15,673,039	0%
Little Compton	58	7,690,694	4	3,076,463	54	4,614,231	40%
Middletown	30	101,183,112		0	30	101,183,112	0%
Narragansett	1,333	19,999,670	5	2,758,140	1,328	17,241,530	14%
New Shoreham	60	43,548,940	5	5,084,853	55	38,464,086	12%
Newport	680	484,122,041	123	175,883,358	557	308,238,683	36%
North Kingstown	549	134,638,450	132	57,330,744	417	77,307,706	43%
Pawtucket	2	137,911		0	2	137,911	0%
Portsmouth	892	48,083,961	1	818,165	891	47,265,797	2%
Providence	84	51,097,737		0	84	51,097,737	0%
South Kingstown	293	12,463,139	1	553,188	292	11,909,951	4%
Tiverton	196	29,063,671	3	1,629,665	193	27,434,006	6%
Warren	2,025	102,869,639	104	46,962,404	1,921	55,907,235	46%
Warwick	1,345	76,763,499	55	18,221,164	1,290	58,542,335	24%
Total	**12,131**	**1,316,766,143**	**499**	350,159,511	**11,657**	**966,606,632**	**27%**

12.5 Participation Rate Analysis

The recommended plan includes elevation of residential homes and floodproofing of non-residential structures throughout Rhode Island. The primary economic analysis assumes 100% participation of the structures included in the Recommended Plan. The total project cost that is ultimately authorized into law will be the estimated cost to implement 100% of the structures recommended for nonstructural measures. However, while project economics have confirmed that 100% of these structures comprise a plan that provides NED benefits, these measures will be implemented on a voluntary basis and structure owners may choose to participate in the project. For this reason, a sensitivity analyses of different participation rates is used to clearly communicate to decision makers the uncertainty in benefits and costs for voluntary nonstructural measures.

The study team considered other USACE nonstructural projects and coordinated with the non-Federal sponsor to gather information that may affect the expected participation rate for nonstructural measures in the Recommended Plan. The study team used the five factors in the USACE Nonstructural Committee’s Best Practice Guide 02 (BPG 2020-02) to consider the likely participation in voluntary nonstructural measures in Rhode Island. These factors are include:

1. Temporal Proximity of Severe Flood Damage - The BPG states that owners who experienced significant flood damage more than 10 years ago are less likely to participate than owners damaged more recently. Furthermore, the likelihood that properties have changed ownership is increased, and new owners that have not personally experienced flood damages are less likely to participate. On the other hand, should recent flood damages be catastrophic, the more difficult it is for ownership of the properties to be proved, hindering participation. Over the past ten years the destruction caused by Hurricanes Henry and Sandy has created considerable apprehension particularly in Rhode Island coastal communities. Hurricane Sandy generated extremely large waves and a dangerous storm surge which extended from New Jersey to Rhode Island. In addition to hurricanes and other tropical and coastal storms, there is an ongoing threat of rising sea levels from global warming. Most homeowners would likely participate in the "nonstructural measures" offered as part of the project implementation.

2. Decent, Safe, and Sanitary - In order to participate in a USACE project, property owners must correct existing violations of state and local heath, sanitary and safety codes, which have been identified by a local code enforcement official and which are the minimum necessary to assure decent, safe and sanitary (DSS) living conditions. The BPG states that in older metropolitan communities with stringent code adoption, the extra costs imposed on the owner to correct violations can be significant enough to hinder participation. In Rhode Island, $277,000 is the median home value, which is considerably lower than the national median of $428,000. The participation rate for nonstructural measures would have to be consistent with current health, sanitary, and safety codes which could affect the overall participation rate. The lower quality of homes in RI might be expected to have a negative effect on this factor compared to the overall concern of homeowners. In addition, when evaluating owner-occupied housing, 82% of these

units have a median value of $299,999. Interestingly, the owner-occupancy decreases for properties $300,000 and above. This suggests that owners with higher property values in RI may not use their residence as a primary home, but rather a secondary dwelling or a seasonal rental. This higher property group of homeowners may have concerns that elevation might negatively affect the aesthetics of their residence, which could add to the negative participation rate.

3. Hazardous, Toxic, Radioactive Waste - Owners must provide proof that their property contains no Hazardous, Toxic, or Radioactive Waste (HTRW) to participate in a USACE project. The BPG states that if a property does contain HTRW, the owner may still participate if they are willing to pay for remediation. The HTRW information recorded in the Authorizing Document is a good reference source. A community construction department may be consulted for an average age of the housing stock. This may be supplemented with the structure inventory conducted for the assessment of the nonstructural alternatives. A higher rate of structures constructed prior to approximately 1980 is correlated with higher rates of remediation and with lower rates of participation (this is a result of 42 U.S.C. Ch. 63A: Residential Lead-Based Paint Hazard Reduction, which requires disclosure of known information on lead-based paint and lead-based hazards before the sale or lease of most housing built before 1978). In RI, about 90 % of all housing units were built before 1980 which is higher than the national percentage of 53.6%. This factor is not expected to have a measurable impact on the participation rate for nonstructural measures.

4. Temporary Relocation - Owners must be willing and able to afford temporary relocation if structures are to be elevated. The BPG states that for owners dependent upon community services/transportation, this may be cost-prohibitive. Even if owners are willing, adequate temporary housing with some proximity could be in short demand if many structures will be elevated around the same timeframe, which could necessitate non-participation. Even if temporary housing exists in the timeframe needed, owners may not be able to afford it, especially if they carry a mortgage on their own structure, as they would be required to pay both mortgage and temporary housing costs concurrently. Any of these factors can significantly hinder participation. Employment statistics recorded in the Authorizing Document can be considered to indicate owner ability to afford temporarily relocation. Higher unemployment rates, higher rates of families below the poverty line, and lower median income rates are considered to correlate with lower ability to afford temporary relocation costs and hence with lower participation rates. This factor affecting participation rates only relates to structures being elevated. The median household income in Rhode Island of $70,305, reported in 2020, is slightly higher than the median national income of $67,521. The official US poverty line for a family of four in Rhode Island is $24,860. In Rhode Island, 11.6 % of the population live below this level which is slightly higher than the 11.4% national average. Renter occupancy in RI is 38.32% and 17.9% of these households were behind on their rental payments in 2021. Reports indicate that many states with a higher percentage of renters who reported being behind on payments are those with lower household incomes or higher poverty rates. This may have a negative effect on the participation rate, unless tenants receive financial assistance for temporary relocation as part of the project cost.

During the summer tourism season, however, rents are presumed to be higher than the rest of the year and generally lodging in RI is expensive and in short supply. Vacation destinations are in demand which might incentivize participation as the owners would not want to lose the tourist rental income. In addition, many property owners in RI do not occupy their homes year-round and only live there seasonally. These residents could temporarily relocate to their alternate residence while their home in the RI was being elevated resulting in a positive participation rate. The average household income, seasonal residents, and higher than average number rental properties in the RI would be expected to increase participation. This may, however, not completely outweigh the possible negative impact that lodging availability may have on temporary relocation as this factor is expected to slightly decrease the participation rate for nonstructural measures.

5. Physical Requirements - Owners must have the physical ability to perform any required maintenance or operational actions required to complete the protection (e.g., place door shields in anticipation of flooding in the case of dry floodproofing). For communities with a significant elderly population (or those with a significant number of very young children), participation could be hindered. The BPG states that higher rates of residents age 65 and above and higher rates of children under the age of five are correlated with lower ability to perform human intervention tasks and therefore lower participation rates. This factor only relates to those structures not being elevated. In RI, 18.1 % of the population is 65 or older and of this group 38% have some type of disability. These percentages are higher when compared to 16.5% of 65 or older and 34.5% disabled for the entire U.S. However, in terms of scale, the overall portion of the population in RI is less, therefore, this factor is expected to slightly increase the participation rate for nonstructural measures.

For this evaluation and the minimum expected rate of 25 percent, the estimated most likely participation rate for nonstructural measures in the recommended plan is 50 percent. An optimistic upper bound or “best case scenario” participation rate was also established in addition to the worst case and most likely rates. In assuming that in the best-case scenario temporary relocation and physical requirements factors did not have a slightly negative effect on the overall scoring, 75 percent was determined to be the upper bound for participation in nonstructural measures.

A sensitivity analysis was completed based on these numbers to examine the economic impact of different participation rates and quantitatively communicate to all stakeholders the uncertainty in benefits and costs for voluntary nonstructural measures. A random selection method was used to select individual structures in each of the participation rate sensitivity analyses. The results of this analysis, displayed in the following table, show the Recommended Plan would be justified regardless of the actual participation rate.

Table 12-4: Economic results of the Recommended Plan for Varying Participation Rates

	100%	75%	50%	25%
Average Annual Benefits	11,356,000	8,119,000	6,561,000	2,843,000
Average Annual Costs	7,668,000	5,821,000	3,861,000	1,933,000
Benefit-to-Cost Ratio	1.5	1.4	1.7	1.5
Average Annual Net Benefit	3,688,000	2,298,000	2,701,000	910,000

12.6 Sea Level Change Scenarios

The without-project conditions and benefits for the Recommended Plan were developed employing the USACE intermediate sea level rise. The recommended plan was further evaluated using the USACE sea level rise scenarios, low and high. These benefits were then compared to the project costs for the Recommended Plan. The results of the sea level rise scenarios are shown in the following table. The analysis shows that the recommended plan is economically justified for the high sea level rise scenarios but does result in slight negative net benefit for the low sea level rise scenario.

Table 12-5: Economic results of the Recommended Plan for Varying Rates of Sea Level Change

	High	Intermediate	Low
Average Annual Benefits	20,713,000	11,356,000	8,286,000
Average Annual Costs	8,944,000	8,944,000	8,944,000
Benefit-to-Cost Ratio	2.3	1.3	0.9
Average Annual Net Benefit	11,769,000	2,842,000	-659,000

12.7 Benefit Exceedance Probability

The economic models used the uncertainty surrounding the economic and engineering inputs to generate results that can be used to assess the performance of the G2CRM model results to aggregate all probabilistic information and calculate the average annual benefit (AAB) for each of the project alternatives. AAB at the 75, 50, and 25 exceedance probabilities are shown in the table below. These percentiles reflect the percentage chance that the benefits will be greater than or equal to the indicated values.

Table 12-6: Expected and Probabilistic Value of Annual Benefits (Values in October 2021 price levels, 50-year period of analysis)

Alternative	AAB ($m)		Probability AAB Exceeds Indicated Value ($m)		
	Mean	Standard Deviation	75%	50%	25%
No action	-	-	-	-	-
Nonstructural (Recommended Plan)[1]	11.7	11.0	19.1	11.7	4.3
Wellington Perimeter	0.63	125.8	85.5	0.63	-84.2
Warren River Surge Barrier (upper)	13.2	172.0	129.2	13.2	-102.7
Warren River Surge Barrier (lower)	14.9	171.4	130.5	14.9	-100.6
Middle Bridge Protection	0.95	36.0	25.2	0.954	-23.3

[1] Values for the Recommended Plan presented in this analysis may vary from the final Recommended Plan since this analysis was completed prior to several refinements on costs and benefits of the Recommended Plan.

Assuming a normal-fit, the benefit exceedance probability relationship for each of the project alternatives can be constructed using the mean the standard deviation. The generated probabilistic curve can be compared to the average annual cost (AAC) for each of the project alternatives to determine the probability that net benefits will be greater than zero. The intercept between the AAB and AAC curves shows the point where benefits are greater than costs for the alternative. The probability on the x-axis at the intercept is the probability that net benefits will be equal or greater than zero is the exceedance probability. The value on the y-axis at the intercept is the dollar value in average annual equivalent where the benefits of the project becomes greater than costs.

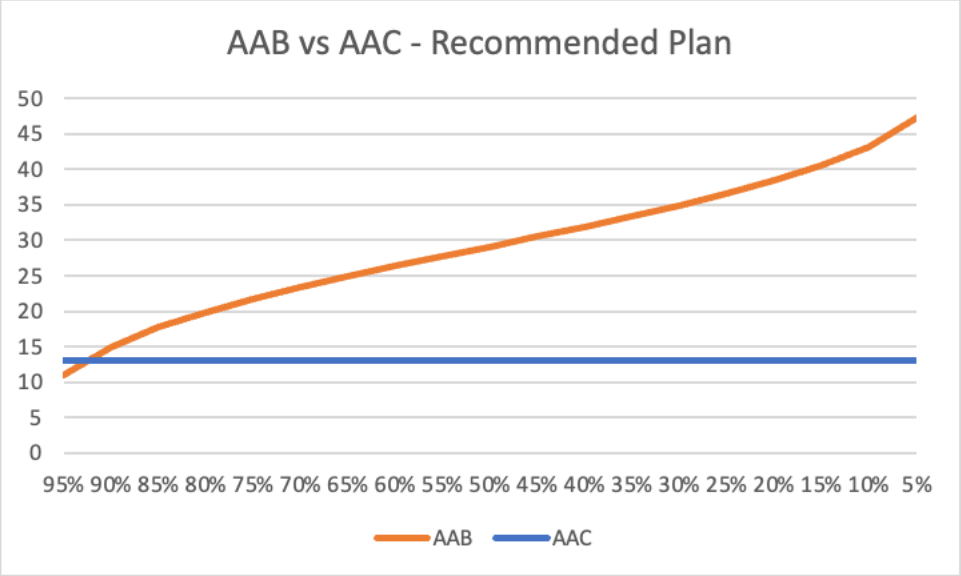


Figure 12-1: Probability of AAB exceeding AAC

In similar manner to the AAB, the expected annual net benefits for each alternative are described in the table below. The mean column shows the expected net benefits for each alternative. The standard deviation and the three exceedance probability columns show the distribution of the net benefits. Additionally, the threshold exceedance probability to which net benefits becomes greater zero are shown for each alternative. The thresholds are calculated by comparing the aggregated probabilistic information of benefits versus the point estimate of costs provided by the Cost Engineer**.** Unique to each alternative, these probabilities are equivalent to the x-axis value at the intercept shown in the graph above.

Table 12-7: Expected and Probabilistic Value of Net Benefits (Values in October 2021 price levels, 50-year period of analysis)

Alternative	AAE Net Benefit ($m)		Probability Net Benefit is > 0	Probability Net Benefit Exceeds Indicated Value ($m)		
	Mean	Standard Deviation		75%	50%	25%
No action	-	-	-	-	-	-
Nonstructural (Recommended Plan)[1]	2.7	11.7	60%	-4.6	2.7	10.2
Wellington Perimeter	-0.67	125.8	50%	-85.5	-0.67	84.2
Warren River Surge Barrier (upper)	-14.0	172.0	46%	-130.0	-14.0	102.0
Warren River Surge Barrier (lower)	-9.1	171.4	46%	-124.7	-9.1	106.4
Middle Bridge Protection	-4.1	36.0	46%	-28.4	-4.1	20.1

[1] Values for the Recommended Plan presented in this analysis may vary from the final Recommended Plan since this analysis was completed prior to several refinements on costs and benefits of the Recommended Plan

The following table contains the same information for the nonstructural alternative's benefit-cost ratio. The threshold for net benefits being greater than zero and the threshold for benefit-cost ratio being greater than unity is probabilistically equivalent.

Table 12-8: Expected and Probabilistic Value of BCR (Values in October 2021 price levels, 50-year period of analysis)

Alternative	Mean	Standard Deviation	Prob BCR is > 1	75%	50%	25%
Nonstructural (Recommended Plan)	1.5	0.88	72%	0.9	1.5	2.1

Finally, the probabilistic information of the benefit-cost ratio for the Recommended Plan is displayed graphically in the figure below. With an expected BCR of 1.5, the Recommended Plan has a 72% chance of being economically justified.

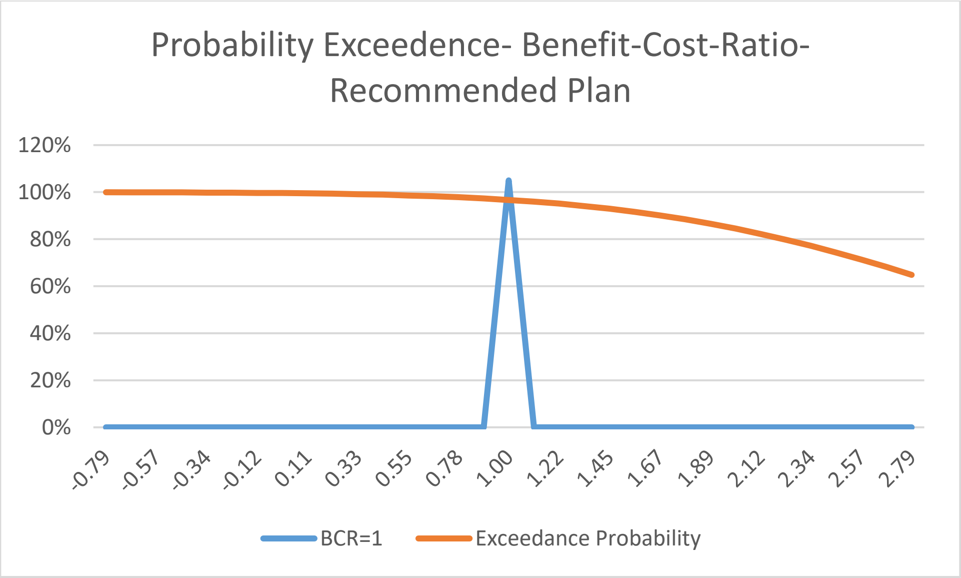


Figure 12-2: Benefit-to-Cost Ratio Exceedance Probability

12.8 Project Probabilistic Performance

Project Probabilistic Performance was calculated for the recommended plan, details of which can be found in the engineering appendix.

12.9 Risk and Uncertainty in Modeling Data

The recommended plan was developed based on data collection and modeling efforts that inherently include varying degrees of uncertainty. While extensive effort is made to limit incorrect information on structure specific data and associated assumptions, uncertainty in Feasibility study data still remains. This uncertainty affects both the benefit modeling as well as the cost estimation used for the economic analysis. This uncertainty is mitigated to a certain degree when analyzing larger groups of structures together. However, for analysis of nonstructural measures, the risk of inaccurate decision-making increases as the number of structures included in the economic modeling results being used for the decision-making decreases.

The formulation used for this study follows the formulation and evaluation methodology as specified in PB 2019-03, by applying a range of characteristics to combine structures into coherent groups for consideration. This range of characteristics is intended to logically group structures for evaluation using various criteria so as to not leave out individual structures that may have equivalent inundation damage but valued at a lower level. As the study progressed, some of these groupings ended up with a small number of structures due to implementation constraints and other screening requirements. The modeling results for these groups in particular have a higher degree of uncertainty due to potential uncertainty in structure specific data as discussed previously. In addition, there are multiple individual structures that were added to the recommended plan that pose the same risk in using individualized analysis results for decision making.

Since the purpose of this study and resulting Recommended Plan is to reduce coastal storm risk damage in the study area as efficiently as possible, it was determined to include these smaller groups and individual structures despite the associated uncertainty. There is risk that some of these individual structures may not warrant the measure recommended in this study. To mitigate this risk, each of the structures included in this Recommended Plan will be reviewed further during the PED Phase to ensure the accuracy of assumed structure characteristics. There is also risk in excluding individual structures or smaller community groups that were determined to not be economically justified. However, decisions for this study had to be made based on the best available information at the time of the study. The risk of excluding structures from a recommended nonstructural plan is much higher than that of a structural plan due to higher level individual structure data uncertainty.

13.0 COST AND BENEFIT UPDATES FOR FISCAL YEAR 2023

After all analysis was completed on the RIC study yet before the final report was approved, a new fiscal year began. As a result, the cost and benefit were updated to reflect October 2022 price levels and a discount rate of 2.5%. Total project first costs of the Recommended Plan at October 2022 price levels are approximately $289.8 million. The total fully funded cost of the project, with escalation through the mid-point of construction, is approximately $333 million.

Table 13-1: Economic summary of the recommended plan updated to October 2022 price levels and 2.5% discount rate

Federal discount rate FY23 = 2.5%, OCT 2022 Price Levels, 50-Year Period of Analysis, Figures in $ Except BCR	
Project First Costs	
Construction	184,867,000
Preconstruction Engineering & Design (PED)	29,002,000
Construction Management (CM)	9,728000
Real Estate	7,374,000
Environmental Mitigation	0
Cultural Resource Mitigation	2,718,000
Contingency	56,086,000
Project First Costs Total	**289,775,000**
Average Annual Costs	
Annualized First Costs	11,009,000
Interest During Construction (IDC)	32,000
Total Average Annual Cost (AAC)	**11,041,000**
Average Annual Benefits (AAB)	17,693,000
Net Benefits	6,652,000
Benefit-Cost Ratio (BCR)	**1.6**

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