ECONOMICS APPENDIX

FLORIDA KEYS COASTAL STORM RISK MANAGEMENT DRAFT INTEGRATED FEASIBILITY STUDY AND ENVIRONMENTAL IMPACT STATEMENT

MONROE COUNTY, FLORIDA

APPENDIX C

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U.S. Army Corps
of Engineers
Norfolk District

Table of Contents

1 ECONOMIC EVALUATION 4

1.1 Introduction 4

1.1.1 NED Benefit Categories Considered 4
1.1.2 *Regional Economic Development.* 5

1.2 Study Area Description 6

1.2.1 Geographic Location 6
1.2.2 *Land Use* 9
1.2.3 Socioeconomics 9

1.2.3.1 Population and Housing 9
1.2.3.2 Income 11
1.2.3.3 Employment 12

1.2.4 Recent Storm History 13
1.2.5 Compliance 16
1.2.6 Scope of Study 17

1.2.6.1 Structural Measures 18
1.2.6.2 Nonstructural Measures 18

2 STUDY METHODOLOGY 20

2.1 Risk and Uncertainty 21
2.2 Model Overview 21

2.2.1 Model Variables 22
2.2.2 Economic Inputs 23

2.2.2.1 Structure Inventory 24
2.2.2.2 Structure Values 24
2.2.2.3 Future Development Inventory 25
2.2.2.4 Content-to-Structure Value Ratios 25
2.2.2.5 Debris Removal 27
2.2.2.6 First Floor Elevations 28
2.2.2.7 Depth-Damage Relationships 28
2.2.2.8 Uncertainty Surrounding the Economic Inputs 29
2.2.2.8.1 Structure Values 29
2.2.2.8.2 Content-to-Structure Value Ratios 30
2.2.2.8.3 Depth-Damage Relationships 30

2.2.3 Engineering Inputs to the Model 31

2.2.3.1 Storms 31
2.2.3.2 Save Points 32
2.2.3.3 Stage-Probability Relationships – H5 Files 32

2.2.3.1 Uncertainty Surrounding the Engineering Inputs 33
3 Existing Condition 33
3.1 Model Areas 34
3.1.1 Model Area 34
3.1.2 Protective System Elements 35
3.1.3 Volume-Stage Functions 35
3.2 Assets 35
3.3 Evacuation Planning Zones 36
4 FUTURE WITHOUT PROJECT CONDITIONS 37
4.1.1 G2CRM Model Assumptions 37
4.1.2 Modeling Results 39
5 FUTURE WITH-PROJECT CONDITION 40
5.1 Formulation of Alternatives 40
5.1 Alternatives Screening 41
5.2 Final Array of Alternatives 41
5.3 Evaluation of Alternatives 42
6 TENTATIVELY SELECTED PLAN 44
6.1 Construction Schedule 45
6.2 Benefit and Cost Calculation 46
6.2.1 TSP Economic Summary 47
6.2.2 Route 1 Roadway System – Revetment 47
6.2.3 Critical Infrastructure Floodproofing 47
6.2.4 Nonstructural Measures 48
6.2.5 Results at the OMB 7% Discount Rate 48
6.3 Sea Level Rise Scenarios 49
7 REGIONAL ECONOMIC DEVELOPMENT 49
7.1.1 Methodology 49
7.1.2 Assumptions 51
7.1.3 Description of Metrics 51
7.1.4 Results 51
8 CONCLUSION 51
9 REFERENCES 52

Table of Figures

Figure 1-1: Model Areas 1 – 10 7
Figure 1-2: Model Areas 11 – 21 8
Figure 1-3: Model Areas 22 - 34 8

Table of Tables

Table 1-1: Population, 1990 - 2040 10
Table 1-2: Households, 1990 - 2018 10
Table 1-3: Housing Units, 2018 10
Table 1-4: Demographics, 2018 11
Table 1-5: Median Household Income, 2000 - 2018 12
Table 1-6: Labor Force and Employment, 2018 13
Table 1-7: Historical Storm Events and FEMA Disaster Declarations 14
Table 1-8: FEMA Flood Claims in Monroe County 16
Table 1-9: Public Assistance Projects 16
Table 1-10: Optimal Elevation Height for Project Model Areas 20
Table 2-1. Content-to-Structure Value Ratios and Triangular Distribution 26
Table 5-1. Initial Array of Alternatives 40
Table 5-2: Alternative Plan Comparison 43
Table 6-1: Nonstructural Measure Counts by Locality or Municipality 44
Table 6-2-4: Nonstructural Measures 48

1 ECONOMIC EVALUATION

1.1 Introduction

This appendix presents an economic evaluation of the Tentatively Selected National Economic Development Plan for the Florida Keys Coastal Storm Risk Management Feasibility Study for Monroe County, Florida. The study area includes the Florida Keys, located in Monroe County Florida. The Keys consist of more than 1,700 islands that stretch 123 miles from Key Largo in the north to Key West at the southern tip of the archipelago.

The non-Federal sponsor for this study is Monroe County, Florida.

This analysis was conducted in accordance with Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 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. Generation II Coastal Risk Model (G2CRM) was used to model economic damage to residential and commercial structures because it is designed to evaluate inundation of areas not immediately adjacent to beaches, but still in a coastal environment where the effect of wave action contributes to the damage. The G2CRM analysis is covered in greater detail in Chapter 2.

The economic appendix consists of a description of projects costs and the methodology used to determine National Economic Development (NED) damage under existing future conditions. The damage and costs were originally calculated using October 2018 (FY 2019) price levels and indexed to reflect October 2019 (FY 2020) price levels. Damage was converted to equivalent average annual values using the fiscal year 2020 federal discount rate of 2.75% and a period of analysis of 50 years. The year 2030 was identified as the base year for each of the alternatives as the basis for plan comparison.

1.1.1 NED Benefit Categories Considered

The NED benefits attributable to the Florida Keys project are largely the reduction of inundation damage to structures and their contents based on nonstructural alternatives. These alternatives include a combination of elevating the first floor of residential structures above the floodplain, floodproofing commercial structures, and/or acquiring properties to be returned to their natural state as they were before development.

In addition to inundation benefits, the study also evaluated measures to reduce risk to segments of US Route 1, which runs approximately 110 miles between Key Largo and Key West.

Physical Flood Damage Reduction Benefits. Physical flood damage reduction benefits include the decrease in potential damage to residential, commercial, industrial, or public structures and their contents. Damage to associated vehicles and reduction in emergency services were not evaluated due to the nonstructural solution which would not protect vehicles. Future population growth was not projected for the study. A future structure inventory based on development was not included in the damage calculations due to the limited remaining available land and the proposed zoning and development restrictions that are expected to be implemented by Monroe County through a Non-Residential Rate of Growth Ordinance enacted in 2001 (Monroe County, 2011).

Non-Physical Flood Damage Reduction. Non-physical flood damage benefits include emergency costs incurred by the community during and immediately following a major storm. This includes the costs of emergency measures, such as evacuation and reoccupation activities conducted by local governments and homeowners, repair of streets, highways, and railroad tracks, 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.

Other NED/NER Benefits. Other benefits of coastal storm management projects beyond those tied to flood damage reduction include recreation benefits which result from the additional recreation opportunity provided by the project. This was not evaluated for this study since there are no alternatives under consideration that would significantly affect the recreation opportunities currently found in the study area.

1.1.2 *Regional Economic Development.*

When the economic activity lost in the flooded region can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts on the employment, income, and output of the regional economy are considered part of the Regional Economic Development (RED) account. The input-output macroeconomic model RECONS will be used to address the impacts of the construction spending only associated with the Recommended Plan, since only this alternative provides detailed cost information necessary to prepare a complete and accurate analysis. The RED account is addressed in Section 7.

1.2 Study Area Description

1.2.1 Geographic Location

The study area includes all land and water resources within the vicinity of the Florida Keys, a 123 mile long chain of islands extending into the Gulf of Mexico from the southern tip of mainland Florida, provided they are located entirely within the jurisdictional boundary of Monroe County, Florida. The average elevation of the islands ranges from 0 to 20 feet (NAVD88). Based on the low lying topography and location relative to hurricane tracks, the Florida Keys are recognized as an area of elevated risk to impacts from sea level rise and coastal storms.

Due to the number of water bodies, the 81 miles of coastal shoreline, and varied land use, the study area of Monroe County is divided into 34 model areas (MAs) to facilitate initial economic analysis of the project alternatives using the Planning-certified model Generation 2 Coastal Risk Model (G2CRM). The 34 model areas and save points (discussed further in Section 2.2.3.2) are represented below in Figures 1, 2, and 3.

Figure 1-1: Model Areas 1 – 10

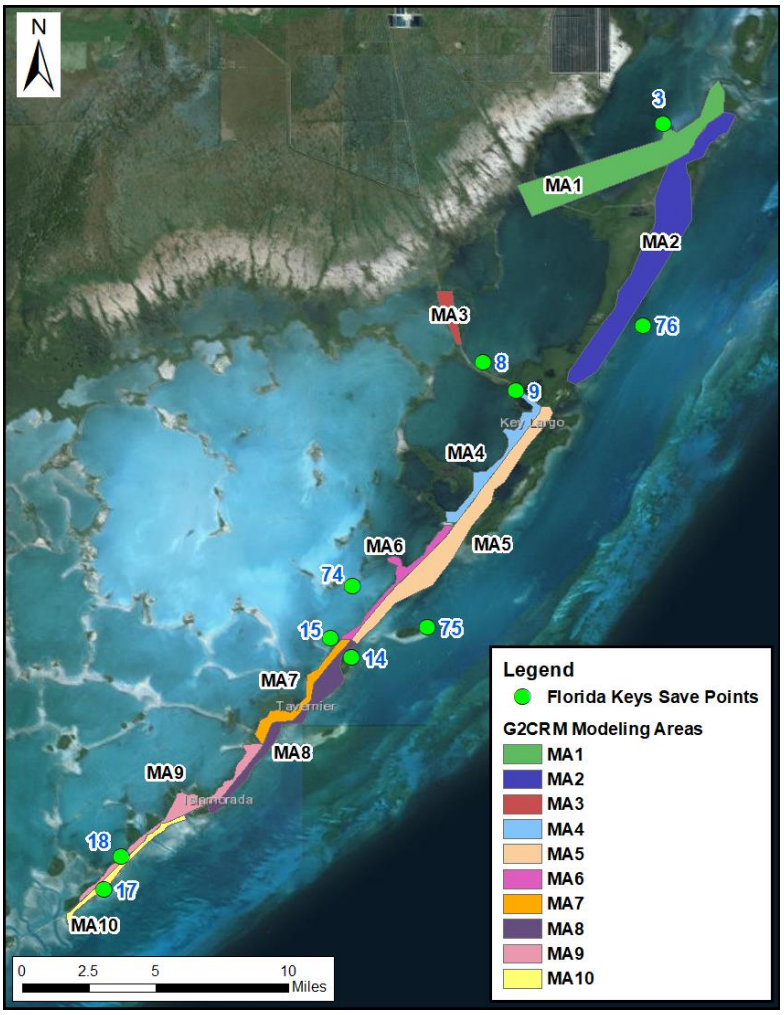


Figure 1-2: Model Areas 11 – 21

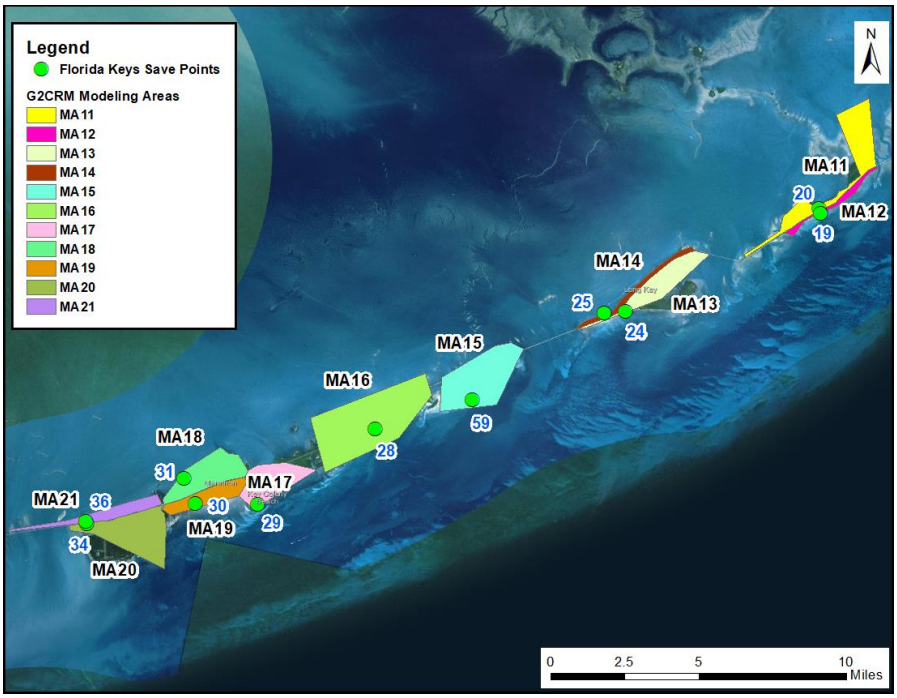
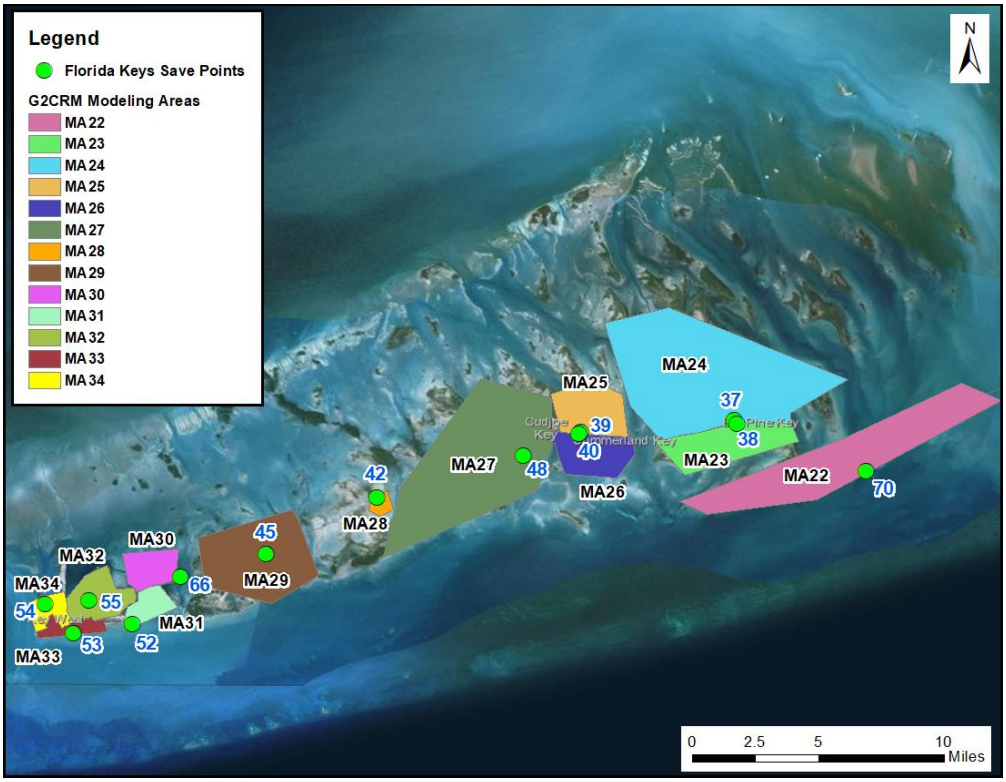


Figure 1-3: Model Areas 22 - 34



1.2.2 *Land Use*

The United States (US) Census totals the number of developed and undeveloped land within Monroe County at 3,738 square miles, of which 983 square miles is land and 2,754 square miles is water. It is the largest county in the State of Florida (Florida) by total area. While 87% of the county's land area is on the mainland, that region is either part of the Everglades National Park or Big Cypress National Preserve, and is virtually uninhabited. Over 99% of the county's population lives on the Florida Keys.

Land Use in the Keys is similar throughout the Upper and Middle Keys. It is predominantly low and middle intensity development dispersed along population centers on US Route 1. Key Largo, Tavernier, Islamorada, and Marathon are large population centers. The developed landscape intensifies with more middle intensity development near Marathon. In the Lower Keys, Boca Chica Key and Key West in particular, are large population centers, with an urban landscape of low, medium and high density development.

At 74.3 people per square mile (28.6/km2), Monroe County's population density is moderately lower than the US as a whole, and substantially lower than the rest of Florida. However, the Florida Keys islands portion of Monroe County has a population density of 591 per square mile (227.3/km2).

1.2.3 Socioeconomics

1.2.3.1 Population and Housing

Based on the US Census Bureau's American Community Survey, Monroe County had a total population of 76,212 in 2019 and contained 30,982 households in 2018. Monroe County experienced population decline of 8.17% between 2000 and 2010, but has grown slowly by 4.27% since. Monroe County is projected to experience low levels (less than 1%) of population growth through 2040. Actual, estimated, and projected population levels for the Monroe County and Florida are shown below in Table 1-1.

Table 1-1: Population, 1990 - 2040

	Monroe Country		State of Florida	
Year	**Population**	**Change From Previous Period**	**Population**	**Change From Previous Period**
1990	78,024		12,937,926	
2000	79,589	2.01%	15,982,378	23.53%
2010	73,090	-8.17%	18,801,310	17.64%
2019	76,212	4.27%	21,208,589	12.80%
2030	76,800	0.77%	24,426,200	15.17%
2040	77,400	0.78%	26,428,700	8.20%
Source: American Community Survey, US Census Bureau, current estimate (2019) and projections from UFL Bureau of Economic and Business Research, January 2020				

Available information on housing units is provided in Tables 1-2 and 1-3. The number of households has declined by 5.05% between 2010 and 2018 (latest available data). There is no available data specifying how non-owner occupied housing units are categorized into vacant units, rental units, or units for occasional use (seasonal).

Table 1-2: Households, 1990 - 2018

	Monroe Country		State of Florida	
Year	**Population**	**Change From Previous Period**	**Population**	**Change From Previous Period**
1990	33,583		5,134,869	
2000	35,086	4.48%	6,337,929	23.43%
2010	32,629	-7.00%	7,420,802	17.09%
2018	30,982	-5.05%	7,621,760	2.71%
Source: US Census Bureau, 2018 uses the 2014-2018 American Community Survey 5-year estimate				

Table 1-3: Housing Units, 2018

	Monroe Country	State of Florida
Housing Units	53,455	9,547,305
Owner Occupied Housing Unit Rate	59.6%	65.0%
Source: US Census Bureau, Owner Occupied Housing Unit Rate is a 2014-2018 American Community Survey 5-year estimate		

Additional demographic data is shown below in Table 1-4. The population in Monroe County is primarily white, with other races generally making up slightly more than 10% of the population. Compared to the state as a whole, Monroe County has slightly higher percentage of older citizens. When compared to the State of Florida, Monroe County has a slightly higher median age of 46.7 compared to 42; only 15.1% of people under 18 years old compared to 19.9%, and a slightly higher percentage of people in the 65 years or older demographic, at 23% compared to 20.5% for the entire state. It also has a higher percentage of white population at 89.3% compared to 77.3% for Florida. Hispanic or Latino populations are classified by the US Census Bureau as a person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin regardless of race. Therefore, this population is already included in applicable race categories.

Table 1-4: Demographics, 2018

	Monroe Country		**State of Florida**	
Demographic	**Number**	**Percentage**	**Number**	**Percentage**
Age				
Median Age (Years)	46.7	N/A	42	N/A
Under 18 years	11,329	15.10%	4,238,566	19.90%
19 to 64 Years	46,442	61.90%	12,694,398	59.60%
65 years and over	17,256	23.00%	4,366,362	20.50%
Race				
White	67,672	88.70%	15,529,098	75.40%
Black or African American	5,399	7.10%	3,316,376	16.10%
American Indian and Alaska Native	114	0.10%	58,118	0.30%
Asian	977	1.30%	559,168	2.70%
Native Hawaiian or Pacific Islander	107	0.10%	12,887	0.10%
Two or More Races	1,135	1.50%	542,340	2.60%
Hispanic or Latino (of Any Race)	18,206	23.90%	5,184,720	25.20%
Total	75,027	100%	21,299,325	100%
Source: Estimates retrieved from 2014-2018 American Community Survey 5-year estimates, US Census				

1.2.3.2 Income

Table 1-5 exhibits median household income levels for Monroe County and Florida between 2000 and 2018. Income has risen steadily for Monroe County, with higher average growth than Florida as a whole. Household income growth slowed for both Monroe County and Florida between 2005 and 2010, largely due to the Great Recession; it has since risen above pre-recession levels.

Table 1-5: Median Household Income, 2000 - 2018

	Monroe Country		State of Florida	
Year	**Income**	**Change Monroe from Previous Period**	**Income**	**Change Monroe from Previous Period**
2000	42,447		38,856	
2005	47,268	11.36%	42,990	10.64%
2010	50,388	6.60%	44,066	2.50%
2015	58,332	15.77%	48,825	10.80%
2018	67,094	15.02%	54,644	11.92%
Source: Federal Reserve Bank of St. Louis, not inflation adjusted, not seasonally adjusted				

1.2.3.3 **Employment**

Major employment sectors in Monroe County include Hospitality, Retail Trade, Healthcare, and Construction. After high unemployment rates during the Great Recession, Monroe County experienced County high unemployment rates during the Great Recession. Currently, however, the county has a relatively low unemployment rate of 2.6%, even lower than Florida's 3.6%. Summary data regarding unemployment rate, labor force size, and employment by industry for the study area are shown below in Table 1-6.

The tourism industry is a pillar of Monroe County's economy, supporting a total of 26,506 employees. Direct, indirect, and induced tourism-related employment constitute nearly 70% of total employment in 2018 for Monroe County. Residents and tourists are attracted to the beaches, resorts, and recreational activities in the Florida Keys such as sailing, snorkeling, fishing, state parks, and cruises. The 5.1 million visitors in 2018 generated $2.4 billion in tourism spending and 1.8 billion in total economic impact in Monroe County. (2018 Tourism in the Florida Keys & Key West, 2018)

Table 1-6: Labor Force and Employment, 2018

	Monroe Country		State of Florida	
Category	**Number of People**	**Percentage**	**Number of People**	**Percentage**
Labor Force				
Unemployment	1,058	2.60%	365,097	3.60%
Total Labor Force	40,693	100%	10,234,770	100%
Employment, by Industry				
Hospitality	8,602	21.70%	908,997	9.21%
Retail	4,958	12.51%	1,312,667	13.30%
Healthcare	3,424	8.64%	1,312,667	13.30%
Construction	2,865	7.23%	675,086	6.84%
government	2,547	6.43%	443,148	4.49%
Education	2,124	5.36%	775,756	7.86%
Professional (Scientific, Technical)	2,063	5.20%	660,281	6.69%
Real Estate	1,745	4.40%	280,299	2.84%
Other Services	1,743	4.40%	526,054	5.33%
Administrative	1,670	4.21%	595,141	6.03%
Entertainment	1,624	4.10%	302,999	3.07%
Transportation	1,596	4.03%	429,331	4.35%
Finance and Insurance	1,069	2.70%	480,653	4.87%
Manufacturing	959	2.42%	509,275	5.16%
Agriculture, Forestry, Fishing, hunting	710	1.79%	96,723	0.98%
Wholesalers	689	1.74%	276,351	2.80%
Utilities	602	1.52%	74,023	0.75%
Information	564	1.42%	192,459	1.95%
Oil, Gas, and Mining	60	0.15%	8,883	0.09%
Management	21	0.05%	7,896	0.08%
Total Employment	39,635	100%	9,869,673	100%
Sources: Bureau of Labor statistics, not seasonally adjusted, full-time employment				

1.2.4 Recent Storm History

During the past 100 years, Monroe County has been impacted by 14 major tropical events. Table 1-7 below lists storm events and their associated Federal Emergency Management Agency (FEMA) disaster and emergency numbers.

Table 1-7: Historical Storm Events and FEMA Disaster Declarations

	Storm Event	Date	FEMA Disaster Number
1	The Key West Hurricane	September 9-10, 1919	N/A
2	“Bahamas”	September 28-29, 1929	N/A
3	Florida Keys Labor Hurricane	September 3,1915	N/A
4	Unnamed Hurricane	September 20-22, 1948	N/A
5	Unnamed Hurricane	October 5, 1948	N/A
6	Hurricane Donna	September 8-10, 1960	DR-106
7	Hurricane Cleo	August 26-27, 1964	DR-175
8	Hurricane Betsy	September 8, 1965	DR-209
9	Hurricane Andrew	August 23-24, 1992	DR-955
10	Tropical Storm Gordon	November 14-16, 1994	DR-1043
11	Hurricane Georges	September 24,1998	EM-3131 & DR-1249
12	Hurricane Irene	October 14-15,1999	EM-3150 & DR-1306
13	Hurricane Wilma	October 23-24, 2005	DR-1609
14	Hurricane Irma	September 9-11, 2017	EM-3385 & DR-4337

Hurricane Donna - 1960

Hurricane Donna had a variable trajectory as it made its way across the Atlantic before hitting the Upper Keys on September 10, 1960 as a Category 4 hurricane. Areas in the Middle and Upper Keys experienced almost complete destruction. In Key West, over 500 homes were destroyed and over 1000 were damaged. The storm surge reached 8 to 12 feet above mean sea level in the Middle and Upper Keys.

Hurricane Irene - 1999

Hurricane Irene made landfall in the lower keys as a Category 1 Hurricane with gusts reported on Big Pine Key at 100 miles per hour (mph). The storm was called a “major rainmaker” by the National Hurricane Center.

Hurricane Wilma - 2005

Hurricane Wilma is the second strongest storm recorded in the Atlantic Ocean basin. Wilma was a Category 3 hurricane (111-130 mph) when it passed by Key West. This event created the largest water surface elevation ever recorded by the Vaca Key gauge.

Hurricane Irma - 2017

Hurricane Irma made landfall as a Category 4 hurricane at Cudjoe Key with maximum sustained winds at 130 mph. Wind gusts were reported at Big Pine Key at 160 mph. The event produced the second largest water level on record for Vaca Key gauge.

Table 1-8 provides a summary of Federal Emergency Management Agency (FEMA) flood claims paid to Monroe County individual policyholders as a result of these tropical events; including the number of paid losses, the total amount paid, and the average amount paid on each loss. The table excludes losses that were not covered by flood insurance such as wind damage.

Table 1-9 provides the amount of Public Assistance grant funding to Monroe County, for approved projects dealing with debris removal, public buildings, utilities, roads and bridges. The grants also covered protective measures provided during storm events such as emergency operations centers and security measures to provide for public safety, respond to emergency needs, block flooded roads and carry out night time patrols in areas without power (OpenFEMA Dataset).

Table 1-8: FEMA Flood Claims in Monroe County

Storm Event	Year	Number of Paid Claims	Total Amount Paid - 2020 CPI Adjusted ($)	Average Amount Paid - 2020 CPI Adjusted ($)
Hurricane Andrew	1992	184	190,700	1,036
Tropical Storm Gordon	1994	188	2,122,000	11,287
Hurricane Georges	1998	7,266	69,665,200	9,588
Hurricane Irene	1999	859	7,603,300	8,851
Hurricane Wilma	2005	9,193	452,674,000	49,241
Hurricane Irma	2017	8,172	308,767,100	37,784
Source: Federal Insurance & Mitigation Administration National Flood Insurance Program (FIMA NFIP)				

Table 1-9: Public Assistance Projects

FEMA Disaster Number	Year of Declaration	Incident Type	Totals Paid 2020 CPI-Adjusted ($)
1306	1999	Hurricane	5,384,000
1539	2004	Hurricane	335,000
1545	2004	Hurricane	45,000
1551	2004	Hurricane	465,000
1595	2005	Hurricane	8,454,000
1602	2005	Hurricane	8,090,000
1609	2005	Hurricane	85,464,000
1785	2008	Severe Storm(s)	4,430,000
3259	2005	Hurricane	3,404,000
3293	2008	Hurricane	787,000
4084	2012	Hurricane	950,000
4337	2017	Hurricane	115,030,000
Source: FEMA Public Assistance Funded Projects			

1.2.5 Compliance

Given continued growth in population and employment, it is expected that development or, most likely, redevelopment will continue to occur in the study area with or without a coastal storm risk management system, and, in general, will not conflict with PGL 25 and Executive Order 11988, which states that the primary objective of a flood risk reduction project is to protect existing development, rather than to make undeveloped

land available for more valuable uses. The overall growth rate is anticipated to be the same with or without the project in place as no new lands will be created but rather measures will reduce the risk of population being displaced. However, it is possible that the construction of structural measures could reduce the perceived necessity for higher flood risk management standards and therefore, redevelopment behind structural measures could occur at lower standards than if the structural measures were never constructed. It is, therefore, recommended that structures with lowest adjacent grades at or below the effective FEMA Base Flood Elevation (BFE) be treated as if it remains within a regulatory floodplain and be subject to the existing floodplain ordinance. Furthermore, it is, also, recommended that structures with lowest adjacent grades above the effective BFE but below the Zone X elevation be subject to the existing floodplain ordinance that requires the first floor elevation be 18 inches above the highest adjacent grade. These additional standards are necessary to further reduce the risk of flooding that can and does occur behind structural measures either from pooled storm water or failure or overtopping of the structural measure. Implementation of these standards behind the structural measures are consistent with the County's resilient strategy and the recommendation of multiple layers of protection to reduce residual risk.

1.2.6 Scope of Study

Problem Description

The overarching problem to be addressed by this study is that coastal storm events cause damage to the natural and built environment in the Florida Keys as a result of flooding, wave action, and erosion. There are several more specific drivers and issues within this problem:

- Critical infrastructure features, including fire stations, airports, hospitals, etc., are vulnerable to the effects of coastal storms.
- Critical transportation routes and US Route 1 specifically is vulnerable to the effects of coastal storms and there have been instances of storm surge and erosion affecting evacuation before/during storms and the timely return of residents after the evacuation is lifted post-storm.
- Structures (commercial and residential), are vulnerable to the effects of coastal storms.
- There are rich environmental resources that are unique to the study area that are vulnerable to the effects of coastal storms. Some of these resources, mangroves for example, provide a reduction in the impacts of coastal storms on the study area and their loss increases the risk of storm impacts on the study area.

Project Measures and Alternatives

The study investigated structural and nonstructural measures that comprise alternative plans. Project alternatives, including the Tentatively Selected Plan, are described in chapters 7 – 9 in the feasibility report.

1.2.6.1 Structural Measures

Alternatives that included most structural solutions, especially large-scale measures such as sea walls and surge barriers, were eliminated early in plan formulation due to site conditions. The Florida Keys are a unique study area: the islands' characteristics increase the area's vulnerability to coastal storms and ultimately limit the application of many risk reduction measures that are used in other coastal communities. Most coastal communities in the US, even those in southern Florida, have a defined coastline where coastal storms make landfall and then coastal risk gradually decreases moving inland away from the coast. As an archipelago situated between the Atlantic Ocean and Gulf of Mexico, coastal storms can make landfall from any direction and the Islands are so small that there is effectively no area to retreat. Most structural measures are designed to reduce storm surge and wave energy from one direction, so that there is an area behind that measure with significantly reduced risk. However, in the Keys, there is effectively no way to reduce risk to an area behind a wall or surge barrier without encircling an entire island. Considering this and also the porous limestone geology in the Keys, all large-scale structural measures were screened from consideration except for shoreline stabilization with a revetment. The rational for including the revetment as an alternative is discussed later in this appendix.

1.2.6.2 Nonstructural Measures

The following is a brief overview of the nonstructural measures considered in this study.

Buyout/Acquisition

This mitigation measure removes the structure, subject to damage, from the structure inventory. The land becomes open space, making room for the water. When strategically planned, multiple acquisitions can be grouped together to provide recreation and/or nature-based opportunities. Recreation opportunities can have positive benefits reflected in increased property values and health benefits through recreation opportunities. While it is the only measure that completely removes flood risk, the perceived financial and social implications of acquiring properties and potentially disrupting communities and removing structures from the tax base can make it a less

favored option. The team compared the cost of acquisition, elevation and floodproofing. Acquisition was *only* selected when it was the most economical option.

Floodproofing

This mitigation measure was employed on non-residential structures where the first floor is located below the FEMA 1% annual chance flood elevation + 2075 immediate sea level rise. For the economic analysis, the floodproofing height limit was set at 3 feet above the ground stage. According to the Flood Insurance Administration Technical Bulletin 3-93, floodproofing to flood heights greater than 3 feet may be cost prohibitive. Floodproofing is not an appropriate measure in a coastal A or VE Zones where wave action is expected. Additionally, it should be noted that FEMA certification requires an additional foot of floodproofing above BFE. Therefore, the assumption of 3 feet in the economic analysis may not result in a measure that would be certified by FEMA. While USACE does not, specifically, formulate to NFIP requirements, compliance with the NFIP is a requirement for local sponsors to partner with USACE.

Floodproof (dry)

This nonstructural technique involves sealing building walls with an impermeable layer or other materials to prevent entry of floodwaters. Additional methods include the use of barriers for window and door openings. For this economic analysis, the floodproofing height was set at 3 feet above the ground stage. Dry floodproofing is appropriate for areas without wave action or scour potential and shallow and low velocity flooding.

Elevation

This nonstructural technique involves lifting a structure to a higher elevation. For structures within Coastal AE or VE Zones, the lowest horizontal member must be located above the design water surface elevation. This can add an additional foot of elevation, considering the depth of the floor joists, when measuring to the top of the first floor. In addition, the FEMA Base Flood Elevations in these zones include additional elevation above the still water to account for wave action, specifically 1.5’ – 3’ in Coastal A Zone and 3’+ in VE Zone. For structures in these zones, the recommended course of action is to add 1.5’ to the Design Water Surface Elevation for buildings in the Coastal A Zone and 3’ to the Design Water Surface Elevation for buildings in the VE Zone to account for wave action.

For the Florida Keys study, damage estimates per storm surge level from the future without-project condition were analyzed in order to understand the optimal elevation height for the future with-project condition. The optimal elevation height was defined where damage increases at a rate of around 5%. This 5% threshold is used as the

potential damage reduced with elevation height increases beyond this optimal height are likely not worth the additional cost of elevation. As a precaution, the team will eventually include sea level rise scenario sensitivity analysis using a foot higher and lower the optimal elevation height to see which height reasonably maximizes net NED benefit. For the purposes of this report, however, the initial optimal height is used in the analysis. This optimal elevation height was determined for each of the 34 MAs, as each is associated with a different save point. Table 1-10 represents each level by MA.

Table 1-10: Optimal Elevation Height for Project Model Areas

MA 1 – 15	MA 10 – 12	MA 19 – 12	MA 28 – 12
MA 2 – 13	MA 11 – 10	MA 20 – 10	MA 29 – 13
MA 3 – 15	MA 12 – 13	MA 21 – 14	MA 30 – 15
MA 4 – 10	MA 13 – 13	MA 22 – 15	MA 31 – 11
MA 5 – 14	MA 14 – 10	MA 23 – 14	MA 32 – 13
MA 6 – 10	MA 15 – 13	MA 24 – 12	MA 33 – 11
MA 7 – 12	MA 16 – 14	MA 25 – 13	MA 34 – 12
MA 8 – 15	MA 17 – 13	MA 26 – 14	
MA 9 – 14	MA 18 – 14	MA 27 – 13	

2 STUDY METHODOLOGY

In order to develop plans to address water resource problems within a study area, three conditions must be fully analyzed: the “existing” condition, the “future without-project” condition, and the “future with-project” condition.

In this analysis, the existing condition represents current conditions that is without sea level change. The future without project condition is the condition that would likely exist in the future without the implementation of a Federal project and incorporates sea level change. This condition is evaluated for a 50 year period for coastal storm management projects, and the results are expressed in terms of average annual damage. For this study, the future without project condition is for the years 2030-2079. The future with-project condition is the condition that would likely exist in the future with the implementation of a Federal project, using the same 50 year period as in the future without-project condition.

The difference in expected annual flood damage to the Monroe County study area assets between the future without- and with- project conditions represents the flood risk management benefits to the project. Economic and other significant outputs may accrue to the project as well, including recreation benefits, ecosystem restoration benefits, regional economic benefits, and other social effects. Other social effects, which often defy quantification in monetary terms, range from improvement in the quality of life within the study area to community impacts. This analysis attempts to recognize and,

where possible, quantify the reduction of damage from coastal storm surge inundation due to the Federal project in the study area (i.e. NED benefits).

2.1 Risk and Uncertainty

Risk and uncertainty are inherent in water resources planning and design. These factors arise due to errors in measurement and from the innate variability of complex physical, social, and economic situations. The measured or estimated values of key planning and design variables are rarely known with certainty and can take on a range of possible values. Risk analysis in flood risk management projects is a technical task of balancing risk of design expedience with reducing the risk from flooding; trading off uncertainty of flood levels with design accommodations; and providing for reasonably predictable project performance. Risk-based analysis is therefore a methodology that enables issues of risk and uncertainty to be included in project formulation.

The US Army Corps of Engineers (USACE or Corps) has a mission to manage flood risks:

"The USACE Flood Risk Management Program (FRMP) works across the agency to focus the policies, programs and expertise of USACE toward reducing overall flood risk. This includes the appropriate use and resiliency of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, flood proofing, etc.) reduce the risk of loss of life, reduce long-term economic damages to the public and private sector, and improve the natural environment."

As a part of that mission, the Institute for Water Resources (IWR) in cooperation with other Corps groups has developed G2CRM to support planning-level studies of hurricane protection systems (HPS).

2.2 Model Overview

G2CRM is distinguished from other models currently used for that purpose 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 damage. The model version used for this analysis is G2CRM 4.558.3. G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). This allows for incorporation of time-dependent and stochastic event-dependent behaviors such as sea level change, tide, and structure raising and removal. 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 model components are discussed below.

- **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.
- **Assumptions** – In any model-based analysis, assumptions are an important and necessary component to outline in detail. The general G2CRM- and study-related assumption are listed later in this appendix.

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 are lost. A simplified representation of hydraulics and water flow is used. Modeled areas currently include unprotected areas and coastal uplands defended by a seawall or bulkhead. Protective system elements are limited to bulkheads/seawalls. The economic and engineering variables that compose these components are discussed in the following sections.

2.2.1 Model Variables

According the USACE Engineering Regulation (ER) 1105-2-101, 7. Variables in Risk Assessment. (b.):

A variety of variables and their associated uncertainties may be incorporated into the risk assessment of a flood risk management study. For example, economic variables in an urban situation may include, but are not necessarily limited to depth-damage curves, structure values, content values, structure first-floor elevations, structure types, flood warning times, and flood evacuation effectiveness. Uncertainties in economic variables include building valuations, inexact knowledge of structure type or of actual contents, method of determining first-floor elevations, or timing of initiation of flood warnings. Other key variables and associated uncertainties include the hydrologic and hydraulic conditions of the system. Uncertainties related to changing climate should be addressed using the current USACE policy and technical guidance.

As previously stated, G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). Monte Carlo Simulation (MCS) is a method for representing uncertainty by making repeated runs (iterations) of a deterministic simulation, varying the values of the uncertain input variables according to probability distributions. A triangular distribution is a three-parameter statistical distribution (minimum value, most likely value, maximum value) used throughout G2CRM to characterize uncertainty for inputs in the model. The following sections attempt to characterize the uncertainties for both the economic and engineering inputs that went into the G2CRM for the study area.

2.2.2 Economic Inputs

Uncertainty was quantified for errors in the underlying components of structure values for residential and non-residential structures, content to structure value ratios for residential and non-residential structures, depth-percent damage relationship for both residential and non-residential structures, and first floor elevations for all structures. G2CRM used the uncertainty surrounding these variables to estimate the uncertainty surrounding the storm-damage relationships developed for each in the study area.

The uncertainty surrounding each of the economic and engineering variables is also considered in the model. Either a normal probability distribution, with a mean value and a standard deviation, or a triangular probability distribution, with a most likely, maximum and minimum value, was entered into the models to quantify the uncertainty associated with the key economic variables. A normal probability distribution was entered into the model to quantify the uncertainty surrounding the ground elevations. The number of years that stages were recorded at a given gage was entered for each study area reach to quantify the hydrologic uncertainty or error surrounding the stage-probability relationships.

2.2.2.1 Structure Inventory

Parcel boundaries and tax assessor data were provided by Monroe County to assist with characterizing residential and non-residential structures for the economic analysis. Data included addresses, property class description, property use, dwelling year built, dwelling condition/grade, crawl code, number units, number of floors, etc. With the building footprints provided by the County, property class descriptions and Google Maps were used to classify buildings into damage categories and occupancy types. First floor elevation assumptions were based on foundation type and verified with available elevation certificates or Google street views. Florida statewide building footprints were used to validate building footprints and to fill in data gaps in the structure inventory dataset. Critical infrastructure status is also noted in the inventory in order to assist in analyzing and comparing the plan alternatives, detailed later in this appendix.

2.2.2.2 Structure Values

Depreciated replacement value per square foot was calculated for residential and non-residential structures using data from Gordian's 40th edition of "Square Foot Costs with RSMeans Data."

According to the RS Means depreciation schedule, structures were depreciated based on age, and then, depreciated an additional percentage to equal a regional adjustment of 80% for residential, as determined by RS Means for the Ft. Myers area. This process was used to calculate a most-likely cost per square foot for each construction class within each residential occupancy category. When appropriate and necessary, categories were grouped with respect to the RS Means tables available. These estimates are based on nearly 90% of the structure inventory dataset. The most-likely depreciated cost per square foot was then multiplied by the square footage of individual structures in each occupancy to obtain a total depreciated cost or value for each structure in an occupancy.

Since square footage was not available for all structures, to determine a square footage per building, the following methodology was used. 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. An average square footage was calculated for three construction classes (economy, average, and luxury) within each residential occupancy category reflecting the quality of the materials used in the construction of the buildings. An average replacement cost per square foot was calculated for four exterior walls types (wood frame, brick veneer, stucco, or masonry) within each construction class.

An average square footage was calculated for each non-residential category or occupancy, and an average replacement cost per square foot was calculated for six exterior wall types (decorative concrete with steel frame and bearing walls frame, face brick with concrete block back-up with steel frame and bearing walls frame, metal sandwich panel with steel frame, an precast concrete panel with bearing walls frame) within each occupancy. Based on Monroe County Assessor's data, it was determined that the average non-residential structure in the study area was approximately 30 years old. The RS Means depreciation schedule for non-residential structures provides three depreciation percentages for structures based on their exterior wall type: wood frame exterior walls; masonry on wood frame; and masonry on steel frame. The masonry on wood exterior wall depreciation percentage was used as the most-likely value and applied to all of the non-residential structures in the structure inventory. An additional regional adjustment of 84 percent, or a 6% decrease in value, for the Monroe area was applied to the depreciated cost per square foot. This process was used to calculate a most-likely cost per square foot for each structure within a non-residential category or occupancy. The most-likely depreciated cost per square foot was then multiplied by the actual square footage of the individual structures in each occupancy to obtain a total depreciated cost. The Replacement Values shown below in Table 2-1 have been indexed using the RS Means 2020 Historical Cost Indexes to calculate FY20 price levels.

2.2.2.3 **Future Development Inventory**

Due to the density of structures in the County, state imposed growth restrictions, and limited vacant land, a future development structure inventory was *not* included in the damage calculations. It is anticipated that the majority of future development will be the infill of structures on the limited vacant land, or, most likely, redevelopment. The percentage of infill or new development is anticipated to have a negligible impact on the growth of the structure inventory and future damage as existing floodplain ordinance require new or substantially improved structures in FEMA's Special Flood Hazard Area, or the 1% annual chance floodplain, to be constructed at BFE plus three feet of additional elevation. In addition, structures within FEMA's Zone X, or the 0.2% annual chance floodplain to be elevated 18 inches above the highest adjacent grade. Similarly, additional vehicles were not considered in the future inventory.

2.2.2.4 **Content-to-Structure Value Ratios**

Site-specific Content-to-Structure Value Ratios (CSVRs) information was not available for the study area. Residential and non-residential CSVRs used in this feasibility study were obtained from NACCS Resilient Adaptation to Increasing Risk, NACCS Physical

Depth-Damage Function Summary Report, and the revised 2013 Expert Elicitation draft report completed by the USACE Institute of IWR. 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. The appropriate categories were utilized for the study.

Table 2-1. Content-to-Structure Value Ratios and Triangular Distribution

Structure Category		Percent			Source
		CSVR Most Likely	Min	Max	
Residential	One-Story, No Basement (1SNB)	50.00	25.00	75.00	NACCS, Prototype 5A
	One Story With Basement (1SWB)	50.00	25.00	75.00	NACCS, Prototype 6A
	Two Story No Basement (2SNB)	50.00	25.00	75.00	NACCS, Prototype 5B
	Two Story With Basement (2SWB)	50.00	25.00	75.00	NACCS, Prototype 6B
	Mobile Home*	142.00	0.64 SD		
	Apartment				
	Apartment, One story, No Basement (A-1SNB)	9.90	7.50	13.50	NACCS, Prototype 1A-1
	Apartment, Three Story, No Basement (A-3SNB)	9.90	7.50	13.50	NACCS, Prototype 1A-3
non-residential	Commercial				
	Engineered, Non Perishable (ENG-NP)	18.10	14.00	24.00	NACCS, Prototype 2
	Grocery (GROC-LG)	70.00	61.50	78.50	2013 Prototype 2
	Grocery, Convenience (GROC-SM)	34.00	25.00	40.00	2013 Prototype 3
	Hospital (HOSPITAL)	43.90	35.00	50.00	2013 Prototype 6
	Hotel (HOTEL)	25.60	20.00	32.50	2013 Prototype 4
	Urban High Rise (HRISE-U)	18.10	14.00	24.00	NACCS, Prototype 4A
	Beach High Rise (HRISE-B)	9.90	7.50	13.50	NACCS, Prototype 4B
	Medical Office (MEDICAL)	60.49	53.20	66.20	2013 Prototype 5
	Office (OFFICE)	18.10	14.00	24.00	2013 Prototype 7
	Pre-Engineered Non-Perishable (PREENG-NP)	38.20	31.50	44.00	NACCS, Prototype 3
	Restaurant (REST)	22.90	16.50	28.50	2013 Prototype 9
	Restaurant, Fast Food (REST-F)	27.20	21.00	32.50	2013 Prototype 8

Structure Category		Percent			Source
		CSVR Most Likely	Min	Max	
non-residential	Retail Clothing (RETAIL-C)	45.00	36.50	52.50	2013 Prototype 12
	Retail Electronics (RETAIL-E)	65.00	60.00	75.00	2013 Prototype 10
	Retail Furniture (RETAIL-F)	36.50	31.00	42.60	2013 Prototype 11
	Service Station (SERVICE)	66.00	55.50	73.80	2013 Prototype 13
	Industrial				
	Industrial Light (LT)	38.20	31.50	44.00	2013 Prototype 14
	Warehouse, Non-refrigerated (WARE-N)	37.40	31.00	43.50	2013 Prototype 4
	Warehouse, Refrigerated (WARE-R)	35.60	30.00	41.50	2013 Prototype 4
	Public				
	Education (EDU)	6.50	5.00	9.00	2013 Prototype 21
	Protective Services (RESCUE)	69.50	60.00	75.00	2013 Prototype 18
	Recreation (RECR)	24.60	20.00	31.00	2013 Prototype 19
	Religious Facility (RELIGIOUS)	6.90	5.00	10.50	2013 Prototype 20

1) Mobile Home*, Standard Deviation used instead of a triangular distribution
2) non-residential Flood Depth-Damage Functions Derived from Expert Elicitation, Revised 2013
3) NACCS, NACCS Physical Depth Damage Function Summary Report

2.2.2.5 **Debris Removal**

In addition to structural damage, a flooded community typically incurs a variety of other flood related costs including debris removal. The cost of the debris removal can vary according to the residential or non-residential occupancy type of the structure. The content-related debris includes white goods (refrigerators, stoves, dishwashers, etc.), electronics, and hazardous waste (paints, oil, household chemicals, poisons, etc.).

Interviews were conducted with experts in the fields of debris collection, processing, and disposal following Hurricanes Katrina and Rita. The experts were asked to provide a minimum, most likely, and maximum estimate for the cleanup costs associated with the 2 feet, 5 feet, and 12 feet depths of flooding. A prototypical structure size in square feet was used for the residential occupancy categories and for the non-residential occupancy categories. The experts were asked to estimate the percentage of the total cleanup caused by floodwater and to exclude any cleanup that was required by high winds.

In order to account for the cost/damage surrounding debris cleanup, values for debris removal were incorporated into the structure inventory for each record according to its occupancy type. These values were then assigned a corresponding depth-damage function with uncertainty in the economic models. All values and depth-damage functions were selected according to the short-duration flooding data specified in a report titled “Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes.” The debris clean-up values provided in the report were expressed in 2010 price levels for the New Orleans area. These values were converted to fiscal year 2019 price levels using the indexes provided by Gordian’s 40th edition of “Square Foot Costs with RS Means Data.” The debris removal costs were included in the structure records for the individual residential and non-residential structures and used to calculate the expected annual without-project and with-project debris removal and cleanup costs.

2.2.2.6 **First Floor Elevations**

Ground elevations were obtained from Light Detection and Ranging (LiDAR) digital elevation model (DEM), developed in support of new FEMA coastal Flood Insurance Rate Map update, using NAVD88. Parcel data from the 2019 real estate assessment tables provided by the County included type of foundation for some structures, but was supplemented with foundation type data from the National Structure Inventory (NSI2). The Norfolk team determined the average height above ground for each foundation type and validated with FEMA Elevation Certificates provided by the County. Google Street View was used to estimate foundation heights for structures that did not have data in the provided database. Steps were assumed to have a height of 6 inches. The foundation height (sum of the number of stairs) was added to the ground elevation to determine the first floor elevation of each structure in NAVD88.

2.2.2.7 **Depth-Damage Relationships**

Various depth-damage functions (DDFs) were considered for use in the study. However, given that no geographically specific curves were available for the Florida coastal region, a broader geographic collection of curves was considered. Residential and Non-residential depth-percent damage relationships are sourced from (1) the North Atlantic Coast Comprehensive Study (NACCS) Physical Depth-Damage Function Summary Report and (2) the revised 2013 Expert Elicitation draft report completed by the USACE Institute of Water Resources (IWR). Various flood depth-damage functions were used with respect to structure characteristics. These depth-damage functions are assumed to be representative of the structures in the floodplain. The DDFs established within the NACCS Physical Depth Damage Function Summary Report were determined

to be appropriate for use in the study. The NACCS curves were used to model damage for all residential structures and the majority of non-residential structures, unless curves for more specific non-residential structure types were developed as part of the non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Report in 2013 (2013). These curves were used in lieu of the NACCS curves for non-residential inundation to more closely match specific non-residential occupancy types within the structure inventory.

A depth-damage function was also used for US 1 in the modeling analysis. This road depth-damage function was developed by the USACE New Orleans District in cooperation with Gulf South Research Corporation and MWH Americas, Inc. Analyzed flood-event-related economic losses associated with street infrastructure stem from two common loss types: Labor Diversion and Capital Use. Physical infrastructure and direct industry Costs are aggregated into a single street and major/secondary highway flood emergency cost per a distance of roadway to facilitate further flood analyses. Specific ceteris paribus assumptions for this category are that streets/roads and highways/freeways have already been built to completion, are in a stage of depreciation, and that all emergency flood costs can be associated per a certain amount of miles of roadway per lane (more information on the derivation and assumptions of this function used can be found in the following report: “Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes”, 2012).

2.2.2.8 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 models. The G2CRM model used the uncertainty surrounding these variables to estimate the uncertainty surrounding the stage-damage relationships developed for each study area reach.

2.2.2.8.1 Structure Values

A triangular probability distribution based on the depreciated replacement costs derived for the three construction classes (economy, average, and luxury) was used to represent the uncertainty surrounding the residential structure values in each occupancy category. The most-likely depreciated replacement value was based on the average construction class, the minimum value was based on the economy construction class, and the maximum value was based on the luxury construction class. These values were then converted to a percentage of the most-likely value with the most-likely

value equal to 100% of the average value for each occupancy category; the minimum value equal to 80% of the most likely, and the maximum value equal to 120% of the most likely. The triangular probability distributions were entered into the G2CRM model to represent the uncertainty surrounding the structure values in each residential occupancy category.

A triangular probability distribution based on the depreciation percentage associated with the three exterior wall types (wood frame, masonry on wood frame, and masonry on masonry or steel) was used to represent the uncertainty surrounding the non-residential structure values in each occupancy category. The most-likely depreciated value was based on the depreciation percentage assigned to a masonry exterior wall construction, the minimum value was based on the depreciation percentage assigned to a wood frame exterior wall construction, and the maximum value was based on the depreciation percentage assigned to a masonry on masonry/steel exterior wall construction. These values were then converted to a percentage of the most-likely value with the most-likely value being equal to 100% and the minimum and maximum values equal to percentages of the most-likely value. The triangular probability distributions were entered into the economic models to represent the uncertainty surrounding the structure values for each non-residential occupancy category.

2.2.2.8.2 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, was obtained from the Willoughby GRR, an evaluation completed in Norfolk, Virginia, while the maximum CSVR value, 70 percent, was based on a survey of homes in coastal Louisiana. The most-likely value, 50 percent, was obtained from an economic analysis completed in support of a Continuing Authorities Program, Section 205 study on Newmarket Creek, Hampton, VA. 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.

2.2.2.8.3 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 and the 2013 Draft non-residential Flood Depth-Damage Functions Derived from Expert Elicitation. A national panel of building, construction, insurance, and restoration experts was used to develop the data contained in these reports. Moreover, both contained a normal distribution function with an associated standard deviation of damage to account for uncertainty surrounding the damage percentage associated with each depth of flooding. This distribution was then converted into a triangular distribution for input into the model.

2.2.3 Engineering Inputs to the Model

2.2.3.1 Storms

For the study area, a reduced storm set was selected. The number of storm selected was driven by schedule and budget constraints, and by knowledge gathered from other previous and ongoing USACE feasibility studies about the minimum number of storms required to adequately capture the storm surge hazard. The goal of storm selection was to find the optimal combination of storms given a predetermined number of storms to be sampled, referred to as reduced storm set. In the process of selecting the number for the study area, it was determined that a reduced storm set of this size adequately captured the storm surge hazard for the range of probabilities covered by the full storm set.

The storm selection process was performed using the design of experiments (DoE) .The DoE compares still water level, hazard curves derived from the reduced storm set to “benchmark” hazard curves corresponding to the full storm set at a given number of save points within the study area. The difference between the reduced storm set hazard curves and full storm set benchmark curves is minimized in an iterative process considering multiple subsets of cyclones. In summary, the general steps in this DoE approach for selecting a subset of storms are:

1. Identify a set of save points critical to a project or study area, where optimization will be performed.
2. Develop hazard curves for the full storm set.
3. Select number of storms to be sampled.
4. Develop hazard curves for the reduced storm set.

5. Choose the range of probabilities for which hazard curves will be compared. The reduced storm set versus full storm set differences can be computed along the entire hazard curve, or by prioritizing a specific segment of the curves, for example, 50 to 500 years.

6. Compute differences between reduced storm set and full storm set hazard curves.

7. An iterative sensitivity analysis is performed to determine the optimal combination of storms constituting the reduced storm set.

Once the optimal combination of storms is determined, an optional analysis can be performed to evaluate the benefits of increasing storm subset size; finalize storm selection.

2.2.3.2 **Save Points**

The numerical modeling aspect of the study area is to provide estimates of waves and water levels for existing condition, future without project condition, and future with project condition. A save point is a point of interest in the study area. From a dataset of over 1000 points, 34 save points were selected. These save points contained the water elevations and wave heights for each of the storms in the reduced storm set to be used in the model and eventually used to represent the final model areas. These water elevations were applied to the model areas along with economic inputs to derive flood damage in the existing condition, future without project condition, and future with project condition for the Monroe County Study Area.

The initial economic analysis leading up to the TSP was based on a course granularity of storm data, using only 5 save points for the 9 modeled areas delineated across the Keys. As the study was refined, additional save points were incorporated to finalize the number of structures to be evaluated for the Agency Decision Milestone. Additional model areas were also added to improve the analysis. Therefore, the model areas are more so based on the save points rather than localities and/or municipalities. The study currently has 34 save points and 34 model areas. Specific details for the revised save points can be found in coastal hydrology appendix.

2.2.3.3 **Stage-Probability Relationships – H5 Files**

Stage-probability relationships were provided for the existing (2030) without-project condition and future without (2079) project conditions. Water surface profiles were provided for 9 annual chance expedience (ACE) events: 50% (2-year), 20% (5-year),

10% (10-year), 5% (20-year), 2% (50-year), 1% (100-year), 0.5% (200-year), 0.2% (500-year), and 0.1% (1000-year). The without-project water surface profiles were based on 34 save points. The mean sea level trend of 0.0126 ft/yr (Vaca Key, FL) was used as the sea level change rate. Additional information regarding water surface elevation calculations can be found in the Engineering Appendix.

2.2.3.1 Uncertainty Surrounding the Engineering Inputs

The uncertainty surrounding the key engineering parameters was quantified and entered into G2CRM. The model is based upon driving forces (i.e. storms) that affect a study area. The study area is comprised of individual sub-areas of different types, defined as model areas, which may interact hydraulically and may be defended by coastal defense elements, such as protective system elements, that serve to shield the areas and the assets they contain from storm damage. The model used the uncertainty surrounding the storm information to account for uncertainty surrounding the elevation of the storm surges for the study area. The Engineering Appendix contains more information regarding G2CRM engineering inputs.

3 Existing Condition

There are thousands of structures in the FEMA 1% annual chance exceedance (ACE), or 100 year, floodplain in the Monroe County Study Area. These property owners are technically required to purchase flood insurance, although flood insurance has eligibility requirements and numerous exclusions. The FEMA National Flood Insurance Program does not cover additional living expenses, such as temporary housing, while the building is being repaired or is unable to be occupied; loss of use or access to the insured property; financial losses caused by business interruption; property and belongings outside of an insured building, such as trees, plants, wells, septic systems, walks, decks, patios, fences, seawalls, hot tubs, and swimming pools; most self-propelled vehicles, such as cars[1], including their parts; and personal property kept in basements. Federal flood insurance coverage is also capped at $250,000 per building and $100,000 for contents.

Parcel data from the 2019 real estate assessment tables provided by the County included type of foundation for some structures, but was supplemented with foundation type data from the National Structure Inventory (NSI2). The inventoried structures were

[1] The PDT has reserved the option to include vehicles as damageable inventory in optimization after TSP, but before ADM.

categorized as residential or non-residential and were further categorized into occupancy type.

3.1 Model Areas

The term “model area” describes various geographic units that may exist within the study area. Flood elevations are uniform within a model area (MA). A storm event is processed to determine the peak stage in each defined MA and it is this peak stage that is used to estimate consequences to assets within the MA. Therefore, MA boundaries tend to correspond to the drainage divides separating local-scale watersheds. Considerable professional judgment was used in defining MA boundaries including taking into account natural or built topological features (e.g. a ridge, highway, or railway line) to define MA boundaries. Dividing the study area into model areas facilitates evaluation of flood damage by breaking the study are down into several areas having some common features, and analyzing them separately also speed up the economic modeling process. The study area consists of 34 MAs. These model areas are spatial areas defined by geospatial polylines.

3.1.1 Model Area

The study area is divided into 34 model areas as shown in the three figures at the beginning of the appendix. Within each MA, the model areas are further defined by types: unprotected and upland. An unprotected modeled area is a polygonal boundary within G2CRM that contains assets and derives associated stage from the total water level (i.e. storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, without any mediation by a protective system element (PSE). An upland modeled area is a polygonal boundary within G2CRM that contains assets and derives associated stage from the total water level (i.e. storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, as mediated by a protective system element such as a bulkhead/seawall that must be overtopped before water appears on the modeled area. It also has an associated volume-stage relationship to account for filling behind the bulkhead/seawall during the initial stages of overtopping.

Each of the model areas were modeled as an upland MA because in the future with project condition each of these model areas would have a PSE (reference the following subsection) and would be an upland MA (further discussed and explained in the future with project condition section of this Appendix). Therefore, having each MA be a component of an Upland MA in the existing and future without project condition was a modeling strategy utilized in order to model the future with project condition.

3.1.2 Protective System Elements

Flood hazard as manifested at the storm location is mediated by the associated bulkhead/seawall PSE. The PSE prevents transmission of the flood hazard into the MA until the flood hazard exceeds the top elevation of the bulkhead/seawall. When the flood hazard exceeds the bulkhead/seawall top elevation the flood hazard is instantaneously transmitted into the MA unmediated by the bulkhead/seawall.

PSEs are defined in G2CRM to capture the effect of built flood risk management (FRM) infrastructure (i.e. what in G2CRM is categorized as a bulkhead/seawall). For the study area the FRM infrastructure is neither present in the existing condition nor future without project condition, but rather a part of an alternative FRM plan. Since this was the case, this influenced the decision on the MA type to use. That is a MA is not protected by a bulkhead/seawall in the existing condition but one of the FRM alternatives to be considered involves protecting the MA with an engineered bulkhead/seawall.

Therefore, for both the existing and future without condition simulation, in G2CRM, the top elevation is specified at the approximate existing ground elevation within the MA. In this way, the bulkhead/seawall does not influence the existing condition consequences of the flood hazard. For the future with project condition the bulkhead/seawall top-elevation is raised and its influence on consequences is captured.

3.1.3 Volume-Stage Functions

Volume-stage functions (alternatively called stage-volume functions) are associated with an upland MA. For the study area, the volume-stage functions were derived from the digital terrain model (the same used to determine ground elevation of structures) provided by Engineering and GIS sections and describe the relationship between the volume contained in the model area and the associated stage (water depths) for the each MA. Water level within the MA are computed by first estimating the volume of water passing over the PSE and then using the stage-volume relationship to determine water level within the MA. Once the storage area in the MA is filled, the flood hazard is transmitted into the MA unmediated by the bulkhead/seawall.

3.2 Assets

Assets are spatially located entities that can be affected by storms. For this analysis, assets consist mainly of those structures and its contents located within the Monroe County study area as shown in the table below. The low elevations and tidal connections place a significant percentage of the city at risk of flooding from nor’easters, tropical storms, hurricanes, and other storms.

The residential and non-residential assets included in the economic analysis were classified into distinct damage categories (residential, apartment, commercial, industrial, and public) and structure occupancies. An overview of the total structures in the inventory are shown in Table 3-2. Structures that did not fall into the main categories are still represented in the total estimate. The value of the land was not included in the valuation analysis.

Table 3-2: Existing Structure Inventory by Category

Structure Type	Count	Average Depreciated Replacement Value	Average Depreciated Replacement Value (Including contents)
Residential			
One Story	15,346	159,613	239,420
Two+ Story	10,967	306,504	459,757
Total	26,313	466,117	699,177
Apartment			
Apartment, One story	3,009	618,336	927,504
Apartment, Two+ Story	720	625,603	920,795
Total	3,729	1,243,939	1,848,299
Commercial and Industrial			
Urban/Beach High Rise	170	5,676,975	6,238,996
Hospital	9	2,577,380	3,708,850
Nursing Home	13	731,317	1,096,976
Bank	42	839,098	1,216,693
Office	156	671,960	793,585
Industrial building	210	479,327	695,024
Retail	1,326	488,106	707,754
Garage	3	966,261	1,603,994
Other commercial	307	338,559	421,844
Total	2236	12,768,983	16483716
Public			
Government	1,375	706,574	834,464
Religious	155	995,028	1,063,684
Education	109	581,694	644,232
Total	1,639	2,283,296	2,542,380
Total Structure Inventory	**39,041**	**294,415**	**424,043**

3.3 Evacuation Planning Zones

According to the Fourth National Climate Assessment, communities in the Southeast are particularly vulnerable to flooding. Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, low-income communities, and some communities of color are often disproportionately affected by, and less resilient to, the health impacts of climate change. Lessons from numerous coastal storm events have made it clear that even if the elderly, functionally impaired persons, and/or low income residents wish to evacuate from areas at risk from a pending coastal storm, they are unable to evacuate due to their physical or socioeconomic condition. Flooding in urban areas can cause serious health and safety problems for the affected population. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing waters can easily overcome even good swimmers. When people attempt to drive through flood waters, their vehicles can be swept away in as little as two feet of water.

An evacuation planning zone (EPZ) is a spatial area, defined by a polygonal boundary that is used within loss of life calculations in G2CRM to determine the population remaining in structures during a storm (i.e. population that did not evacuate). Each Asset is assigned to an MA which is assigned to an EPZ and then modeled in G2RM for potential life loss given a storm event.

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. In order for life loss calculations to be made, the maximum stage in the modeled area has to be at least two feet over ground elevation for foundation heights greater than or equal to two feet, or the maximum stage must be greater than the foundation height plus the ground location for foundation heights under two feet.

Loss of life calculations are separated out by age categorization with under 65 being one category and 65 and older being the second category. 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, and chance would have the highest expected life loss. Life loss estimates will likely be included in future analysis.

4 FUTURE WITHOUT PROJECT CONDITIONS

4.1.1 G2CRM Model Assumptions

The G2CRM model version 0.4.558.3 was used to evaluate flood damage using risk-based analysis. Damage were reported at the index location for each of the 34 model

areas for which a structure inventory had been conducted. The model also used the number of years that stages were recorded at a given gage to determine the hydrologic uncertainty surrounding the stage-probability relationships.

The possible occurrences of each variable were derived through the use of 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. 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. Model assumptions and additional configuration settings are listed below.

For this analysis, assumptions made in the model include the following:

- The number of iterations selected for the analysis was 100. The sum of all sampled values was divided by the number of samples to yield the expected value for a specific simulation. At 100 iterations the estimates were found to be efficient with the least variance.
- The G2CRM model used the economic and engineering inputs to generate a stage-damage relationship for each structure category in each study area reach under existing (2030) and future (2079) conditions.
- A mean and standard deviation was automatically calculated for the damage at each stage.
- Floodplain residents will react to a floodplain management plan in a rational manner.
- Real property will continue to be repaired to pre-flood conditions subsequent to each flood event given a rebuilding period with a maximum rebuild of 5 times, and not removed from the asset inventory (i.e. cumulative damage threshold not used).
- Residential structures are raised after receiving significant damage within the period of analysis with respect to the appropriate optimal elevation height as detailed in the previous section.
- Residential and Non-residential depth-percent damage relationships for structure and content are sourced from (1) the North Atlantic Coast Comprehensive Study (NACCS) Physical Depth-Damage Function Summary Report and (2) the revised 2013 Expert Elicitation draft report completed by the USACE Institute of Water Resources (IWR). Various flood depth-damage functions were used with respect to structure characteristics. A road depth-damage function was also used for US

1 in the modeling analysis. These depth-damage functions are assumed to be representative of the structures in the floodplain.

- The present valued damage, first costs, and benefits will be annualized using the fiscal year 2020 Federal discount rate of 2.75% assuming a period of analysis of 50 years.
- All values are equivalent to fiscal year 2020 dollars.
- All project alternatives are evaluated for a 50 year period of analysis.
- The project construction is scheduled to begin in 2026.
- The final year of the 50-year period of analysis ends December 31, 2079.
- Unless otherwise stated, elevations are in feet (ft) North American Vertical Datum of 1988 (NAVD88).
- Sea level change follows the USACE Intermediate Curve and used a sea level change rate of 1.26% feet per year (Vaca Key, FL).
- Depreciation is calculated for structures (i.e. replacement values) during the life cycle analysis (before inputted into the model).

Additional model configuration settings:

- Project base year, the year in which benefits begin to accrue: 2030
- Sea Level Change basis year: 1992
- USACE High Curve
- Calculate Depreciation: No
- Raise Structures: Yes
- Calculate Assets: Yes
- Use Benefit Bases: No
- Cumulative Damage Removal: No
- Calculate Life Loss: No
- Auto-Generated Waves: On

4.1.2 Modeling Results

The forecast of the future without project condition reflects the conditions expected during the period of analysis and provides the basis from which alternative plans are evaluated, compared, and selected since a portion of the flood damage would be prevented (i.e. flood damage reduced) with a Federal project in place.

The years 2030-2079 were selected to represent the future without project condition. No additional development within the study area is anticipated since it was assumed that no new development would be subject to future flood risk during the period of analysis. However, a combination of both wealth and complementary effects are likely to

contribute to growth in the value of the assets at risk in the study area. The same structures in the Monroe County Study Area will continue to be affected by the risk of flooding from coastal storms and suffer increasing losses each year.

Under the future without project condition, which represents expected damage in the absence of a flood risk management project, damage is expected to increase. Exacerbating the flooding is the phenomenon of relative sea level rise, which is the combination of water level rise and land subsidence. The future without-project condition damage estimates are provided in comparison to the future with-project condition damage estimates in the next section.

5 FUTURE WITH-PROJECT CONDITION

The future with-project condition is the most likely condition expected to exist in the future if a specific project is undertaken. A total of eight alternatives were considered for the study, based on the results of these results. The analysis did not formulate a project alternative for recreation because it is considered incidental to the project. The analysis includes a discussion of residual flood damage and flood damage reduction for each alternative.

5.1 Formulation of Alternatives

The initial array of alternatives were formulated in spite of known data gaps, then refined throughout the planning process as information was collected and developed. The initial array of alternatives consist of a variety of structural, nonstructural, and natural or nature-based measures. Structural coastal flood risk management measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. Nonstructural coastal flood risk management measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Natural or nature-based coastal flood risk management measures work with or restore natural processes with the aim of wave attenuation and storm surge reduction.

The initial array of alternatives consisted of eight alternatives and the following table provides descriptions for each alternative.

Table 5-1. Initial Array of Alternatives

Alternative	Description	Measures
1	Route 1 Corridor	Shoreline stabilization (revetment)
2	Critical Infrastructure	Floodproofing
3	Population/Development	Floodproofing, elevation, and acquisition
4	Combo Alts 1 + 2	Shoreline stabilization (revetment) and floodproofing
5	Combo Alts 1 + 3	Shoreline stabilization (revetment), floodproofing, elevation, and acquisition
6	Combo Alts 2 + 3	Floodproofing, elevation, and acquisition
7	Combo Alts 1 + 2 + 3	Shoreline stabilization (revetment), floodproofing, elevation, and acquisition
8	No Action	N/A

5.1 Alternatives Screening

The PDT performed additional planning iterations with a focus on screening measures and alternatives that would not meet the planning objectives in an effective and efficient manner. Without substantial data to base the screening on, professional judgment was used to assess how well measures met a set of criteria.

The screening criteria used in this study include effectiveness, efficiency, and acceptability. Effectiveness is the ability of the measure to meet or partially meet a study objective. Efficiency is the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment. Acceptability is the workability and viability of the alternative plan with respect to acceptance by state and local entities and the public and compatibility with existing laws, regulations, and public policies.

Completeness, constructability, and study constraints were also used as screening criteria, but did not result in elimination of any measures. Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. Constructability at this stage of planning is the subjective assessment of whether a feature could be constructed or implemented using standard industry techniques and is compliant with Corps policy for implementation. Study Constraints is the likelihood that the measure does not violate a constraint. Each conceptual alternative was found to be complete, constructible, and compliant with study constraints.

5.2 Final Array of Alternatives

Based on the screening assessment, none of the alternatives were able to be excluded from further analysis.

5.3 Evaluation of Alternatives

Relevant data for the various measures described above were entered into G2CRM to estimate flood damage associated with each measure over the period of analysis. The modeling results for the nonstructural measures for the future without-project (FWOP) and future with project (FWP) conditions are detailed in the table below. The reduction in damage between the FWOP and FWP defines the economic benefit for the various alternative plans. Furthermore, a summary of the total first costs involved with the structural and nonstructural measures are also provided below. These total cost estimates were determined in coordination between the planning and cost engineering teams. Relatively high construction cost contingencies were used to estimate total first costs due to economic uncertainty. More detailed information on construction costs and cost contingencies can be found in the engineering appendix and cost engineering sub-appendix. The damage estimates are provided in present value (PV) levels and annualized in order to allow for a direct comparison with annualized costs. Subtracting average annual costs from average annual benefits results in the net remaining benefits shown in the table below.

Table 5-2: Alternative Plan Comparison

Cost Item	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Total First Cost	15,688,000	17,204,000	5,504,459,000	32,892,000	5,520,147,000	5,521,663,000	5,537,351,000
Interest During Construction	71,000	58,000	18,715,000	130,000	18,787,000	18,774,000	18,844,000
Annualized Investment Cost	617,000	675,000	216,110,000	1,292,000	216,727,000	216,786,000	217,402,000
Annualized O&M Cost	301,000	0	0	301,000	301,000	0	301,000
Total Average Annualized Cost	918,000	675,000	216,110,000	1,593,000	217,028,000	216,785,000	217,703,000
PV Damage FWOP	9,067,000	537,245,000	19,712,524,000	546,312,000	19,721,591,000	20,249,769,000	20,258,836,000
PV Damage FWP	1,842,000	356,605,000	10,071,164,000	358,447,000	10,073,007,000	10,427,769,000	10,429,611,000
Present Value Benefit	7,225,000	180,641,000	9,641,359,000	187,865,000	9,648,584,000	9,822,000,000	9,829,225,000
Total Average Annual Benefits	268,000	6,691,000	357,125,000	6,959,000	357,393,000	363,816,000	364,084,000
Benefit-Cost Ratio	**0.29**	**9.91**	**1.65**	**4.37**	**1.65**	**1.68**	**1.67**
Net Remaining Benefits	**(650,000)**	**6,016,000**	**141,015,000**	**5,366,000**	**140,365,000**	**147,031,000**	**146,381,000**

(1) Interest rate: 2.75%
(2) Estimates rounded

6 TENTATIVELY SELECTED PLAN

Based on initial analysis and interim project review, the PDT proceeded with plan alternative seven, which includes the roadway revetment system, nonstructural measures, and critical infrastructure floodproofing. Other large-scale structural alternatives, aside from the revetment, do not warrant Federal interest in the Florida Keys. While the chosen structural measure is technically economically unjustified, incorporating a traffic analysis component in future analysis will likely add benefits to this measure. Additionally, US 1 is an essential roadway throughout the study area. Furthermore, all three nonstructural solutions were evaluated: elevating first floors of residential structures, acquisitions of residential structures, and floodproofing of non-residential structures. Finally, the last component of the tentatively selected plan (TSP) is floodproofing of critical infrastructure. The nonstructural measures component is a main pillar of the TSP, both in cost and benefit. Table 6-1 below provides detail by locality or municipality of the nonstructural measures. In total, the TSP is economically justified with a BCR of 1.67 and net remaining benefits totaling $146,381,000. The following sections present the initial construction and cost evaluation for the structural and nonstructural measures comprising the TSP.

Table 6-1: Nonstructural Measure Counts by Locality or Municipality

Locality/Municipality	Acquisition	Elevate	Floodproofing	Grand Total
BIG COPPITT KEY	2	81	46	**129**
BIG PINE KEY	6	510	149	**665**
BIG TORCH KEY	0	4	0	**4**
BOCA CHICA	0	10	49	**59**
COCO PLUM KEY	1	36	17	**54**
CONCH KEY	0	16	5	**21**
COUPON KEY	0	1	0	**1**
CUDJOE KEY	3	242	19	**264**
DUCK KEY	1	96	34	**131**
EAST ROCKLAND KEY	0	6	2	**8**
GEIGER KEY	0	10	2	**12**
GRASSY KEY	1	63	18	**82**
KEY COLONY BEACH	56	253	48	**357**
KEY HAVEN	0	200	1	**201**
KEY LARGO	25	752	265	**1,042**
KEY WEST	95	2,324	1,883	**4,302**
LAYTON	2	31	18	**51**
LITTLE TORCH KEY	2	82	27	**111**
LONG KEY	0	5	14	**19**
LOWER MATECUMBE KEY	0	143	31	**174**

MARATHON	84	1,003	611	**1,698**
MIDDLE TORCH KEY	0	2	2	**4**
NO NAME KEY	0	1	0	**1**
NORTH STOCK ISLAND	0	0	2	**2**
OCEAN REEF	1	186	99	**286**
OHIO KEY	0	7	0	**7**
PLANTATION KEY	0	307	90	**397**
RAMROD KEY		71	14	**85**
ROCKLAND KEY		12	18	**30**
SADDLEBUNCH KEY	1	41	13	**55**
SHARK KEY		1		**1**
STOCK ISLAND	2	271	161	**434**
SUGARLOAF KEY		133	19	**152**
SUMMERLAND KEY	3	109	14	**126**
SUNSET KEY			1	**1**
TAVERNIER		23	13	**36**
TEA TABLE KEY			1	**1**
UPPER MATECUMBE KEY	1	82	134	**217**
WINDLEY KEY		10	32	**42**
Grand Total	**286**	**7,124**	**3,852**	**11,262**

6.1 Construction Schedule

The tentatively selected plan has a five-year construction schedule with the total construction cost divided into annual increments. There is also a nonstructural component that involves acquiring, elevating, and wet/dry floodproofing of structures in 34 model areas. Unlike the various project increments that comprise the structural component of the plan, each individual structure comprising the nonstructural component is essentially a self-contained, fully functioning, stand-alone project increment. The construction period for each structure contained in the nonstructural component of the plan would be no more than one-year. No matter where in the five-year period of construction that a nonstructural measure is applied, the period of construction starts and ends for that single structure once that period begins and ends. If one or more structures are included in the first through fourth year of the construction period, that structure would continue to accrue IDC over the entire remaining construction period, even though construction was entirely completed for that structure, which would greatly overstate IDC for those structures. In order to control for the unnecessary accrual of IDC, each structure in the nonstructural component of the plan was placed in the final year of construction of the five-year construction schedule. Another component of the construction schedule is the structural measure. The revetment is estimated to take 5 months for each section.

6.2 Benefit and Cost Calculation

The tables below depict the benefits and costs for the structural and nonstructural components of the TSP, including average annual construction costs, the annual operation and maintenance costs, and the total average annual costs, total average annual benefits, BCR, and total annual net benefits. The interest during construction costs is also included in the calculation of total average annual costs. Interest during construction (IDC) was calculated for each measure. The assumption is that elevation and floodproofing of structures will take four months, acquisition will take one month, and each revetment section will take 5 months. The expected annual benefits attributable to the project alternative were converted to an equivalent time frame by using the fiscal year 20 Federal discount rate of 2.75% for the TSP. The base year for this conversion is the year 2030. 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 average annual costs from the equivalent annual benefits.

The net benefits were used to help determine the economic justification of the project alternative. A plan that reasonably maximizes net national economic development (NED) benefits, consistent with the Federal objective, is identified as the NED plan Furthermore, the alternative plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment shall be selected as the NED (ER 1105-2-100). Granted, the addition of the revetment leads the TSP to have a slightly lower BCR and net remaining benefit compared to plan alternative six. However, the revetment provides environmental benefits and the plan is likely to have additional benefits with future traffic analysis. The Tentatively Selected Plan follows this guidance and therefore is determined to be the National Economic Development plan. The sections and tables below summarize the benefit and cost calculations for the TSP and by measure. More detailed information on construction cost line items (lands and damage; planning, engineering, and design, construction management, etc.) and cost contingencies can be found in the engineering appendix and cost engineering sub-appendix.

6.2.1 TSP Economic Summary

Table 6-2-1: TSP Summary of Benefits and Costs

TSP Economic Summary	Total
TSP Total First Cost	$5,537,351,000
IDC	$18,844,000
Total Investment Cost	$217,402,000
Capital Recovery Factor at 2.75%	3.7%
Average Annual O&M	$301,000
Total Average Annual Cost	$217,703,000
Total PV Benefits	$9,829,225,000
Average Annual Benefits	$364,084,000
Benefit to Cost Ratio	**1.67**
Total Annual Net Benefits	**$146,381,000**
(1) Interest rate: 2.75% (2) Estimates rounded	

6.2.2 Route 1 Roadway System – Revetment

Table 6-2-2: Route 1 Roadway System – Revetment

Economic Evaluation	Total
Revetment First Cost	$15,688,000
IDC	$71,000
Total Investment Cost	$617,000
Capital Recovery Factor at 2.75%	3.7%
Average Annual O&M	$301,000
Total Average Annual Cost	$918,000
Total PV Benefits for the Revetment	$7,225,000
Average Annual Benefits	$268,000
Benefit to Cost Ratio	**0.29**
Total Annual Net Benefits	**-$650,000**
(1) Interest rate: 2.75% (2) Estimates rounded (3) Assumed O&M annual costs are $5,000. Reconstruction costs are estimated to be 10% of the initial first cost and will occur every five years in the period of analysis.	

6.2.3 Critical Infrastructure Floodproofing

Table 6-2-3: Critical Infrastructure Floodproofing

Economic Evaluation	Total
Number of CI Eligible for Floodproofing	47

Floodproofing First Cost	$17,204,000
IDC	$58,000
Total Investment Cost	$675,000
Capital Recovery Factor at 2.75%	3.7%
Total Average Annual Cost	$675,000
Total PV Benefits for CI Floodproofing	$180,641,000
Average Annual Benefits	$6,691,000
Benefit to Cost Ratio	**9.91**
Total Annual Net Benefits	**$6,016,000**
(1) Interest rate: 2.75% (2) Estimates rounded	

6.2.4 Nonstructural Measures

Table 6-2-4: Nonstructural Measures

Economic Evaluation	**Total**
Number of Structures Eligible for Acquisition	286
Number of Structures to Elevated	7,124
Number of Structures to Floodproof	3,805
Total First Cost	$5,504,459,000
IDC	$18,715,000
Total Investment Cost	$216,110,000
Capital Recovery Factor at 2.75%	3.7%
Total Average Annual Cost	$216,110,000
Total PV Benefits for Acquisition	$9,641,359,000
Average Annual Benefits	$357,125,000
Benefit to Cost Ratio	**1.65**
Total Annual Net Benefits	**$141,015,000**
(1) Interest rate: 2.75% (2) Estimates rounded	

6.2.5 **Results at the OMB 7% Discount Rate**

Project costs, OMRR&R, equivalent annual project damage, benefits, and net benefits are similarly displayed in the table below using the Office of Management and Budget (OMB) discount rate of 7 percent for each measure in the Tentatively Selected Plan.

Table 6-2-5: Results at the OMB 7% Discount Rate

TSP Economic Summary	**Total**
TSP Total First Cost	$5,537,351,000
IDC	$47,186,000
Total Investment Cost	$464,899,000
Capital Recovery Factor at 7.00%	7.26%
Average Annual O&M	$277,000
Total Average Annual Cost	$465,176,000
Total PV Benefits	$9,829,225,000
Average Annual Benefits	$364,084,000
Benefit to Cost Ratio	**0.78**
Total Annual Net Benefits	**-$101,092,000**
(1) Interest rate: 7.00% (2) Estimates rounded	

6.3 Sea Level Rise Scenarios

The without-project conditions and benefits for the Tentatively Selected Plan were developed employing the USACE high sea level rise scenario. The benefits will be further evaluated using the USACE low and medium sea level rise scenarios during the optimization analysis. The benefits will then be compared to the project costs for the recommended plan. It should be noted that while the net benefits increase, significant residual risk remains if sea level rise trends high with the recommended plan. The flat topography makes the project difficult to adapt without significantly adding to the footprint of the project.

7 REGIONAL ECONOMIC DEVELOPMENT

The Regional Economic Development impact analysis is underdevelopment.

7.1.1 Methodology

When the economic activity lost in the study area can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts of the employment, income, and output of the regional economy are considered part of the RED account. The input-output macroeconomic model RECONS was used to address the impacts of the construction spending associated with the Tentatively Selected Plan (TSP).

For this Regional analysis, the regional economic development (RED) effects of implementing the TSP or Alternative seven will be estimated. The RECONS Standard Geographic Area for the Miami-Dade County was selected using an expenditure year of 2026.

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. RECONS is designed to evaluate a discrete spending stimulus, which means that all expenditures occurring over multiple years that are required to complete a project are considered to occur in a single year. Therefore, RECONS is not time-sensitive with respect to the calculation of effects and reporting of outputs. 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 2020 dollars.

7.1.2 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. Finally, since the model is static, it is assumed that the economic conditions of 2019, the year of the socio-economic data in the RECONS model database, will prevail during the years of the construction process.

7.1.3 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.

7.1.4 Results

Further Regional Economic Development (RED) analysis of the Recommended Plan will be completed as part of the final report.

8 CONCLUSION

Monroe County is highly susceptible to storm damage. This is particularly true for the large and high-value residential structures. When factoring in the potential for sea levels to rise in excess of baseline projections, significant economic damage from coastal forces can be expected to increase dramatically.

In an effort to reduce as much damage as possible, the modeling team considered a multitude of alternatives to most efficiently address the problems in the study area. Years of technical expertise, best professional judgment and rigorous modeling efforts were all leveraged to determine a plan that maximizes net-benefits and contributes to national economic development. In conclusion, it was determined that alternative seven reasonably maximizes benefits and meets the objectives of the study and an NED plan. The BCR is 1.67 and net remaining benefits totals $146,381,000. The plan is efficient, acceptable, and complete.

9 REFERENCES

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