ENGINEERING APPENDIX

FLORIDA KEYS COASTAL STORM RISK MANAGEMENT

DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

MONROE COUNTY, FLORIDA

APPENDIX B

JUNE 2020

U.S. Army Corps
of Engineers
Norfolk District

Florida Keys Coastal Storm Risk Management

Draft Integrated Feasibility Report and Environmental Impact Statement

GEOTECHNICAL SUB-APPENDIX

JUNE 2020

U.S. Army Corps
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1. INTRODUCTION

This report presents the results of the geotechnical engineering evaluation of the area covered by the Monroe County Coastal Storm Risk Management (CSRM) study. The purpose of this report is to document the geotechnical existing condition of the study area and to provide geotechnical information in support of the final array of alternatives in the Feasibility Study.

This study was authorized by Section 4033 of the Water Resources Development Act of 2007.

"The Secretary shall conduct a study to determine the feasibility of carrying out a project for hurricane and storm damage reduction and flood damage reduction in the vicinity of Monroe County, Florida."

Monroe County, Florida is the non-Federal sponsor for the project.

This report utilizes existing data gathered from a number of sources, including resources shared by the Florida Department of Transportation (FDOT) and Monroe County.

1.1 AREA DESCRIPTION

The Monroe County Coastal Storm Risk Management (CSRM) Study is a study conducted by the U.S. Army Corps of Engineers, Norfolk District and the Local Sponsor, Monroe County, to reduce the Florida Keys' risk of coastal storm damages and impacts to the year 2079. The Florida Keys are located in Monroe County. The Florida Keys include over 1,700 islands that stretch approximately 120 miles from Key Largo to Key West (**Figure 1.1**).

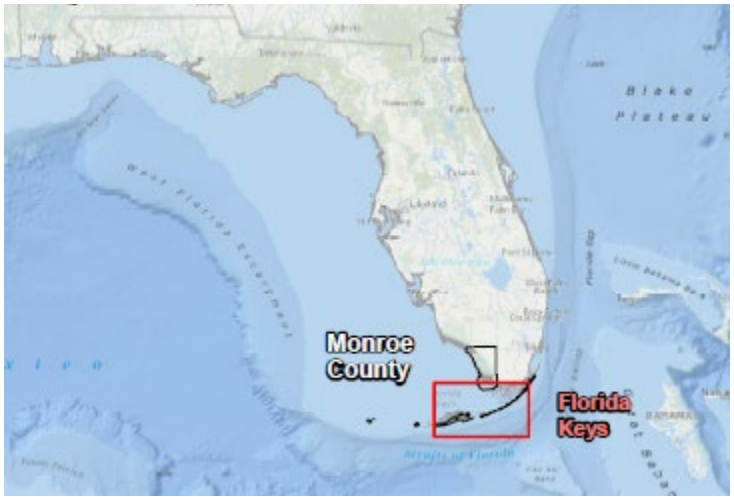


Figure 1.1 Project Area Map

Monroe County is located on the southern tip of Florida peninsula and encompasses the Upper, Middle and Lower Keys. The county is compromised of approximately 3,737 square miles, with water making up approximately 73 percent of that area. A reefline that parallels the island on the Atlantic side is the only living coral reef formation in North America.

2. PROJECT DATUM

2.1 HORIZONTAL CONTROL

The horizontal datum for this study is tied to the State Plane Coordinate System using North American Datum of 1983. Distances are in feet by horizontal measurement. Coordinates are Florida South Zone.

2.2 VERTICAL DATUM

As required by ER 1110-2-8160 all elevations provided herein are referenced to the North American Vertical Datum of 1988 (NAVD 88).

3. PAST AND HISTORICAL STORM EVENTS

The Florida Keys sees a number of coastal storms throughout the year and is constantly flooded by numerous regional storms over the years. These include hurricanes, tropical storms, and northeasters. In addition, intense localized storms frequently cause localized nuisance street flooding.

For more information on past and historical storms see the Main Report, Engineering Appendix, or the Hydraulics and Hydrology Sub-Appendix.

4. GEOLOGY, GROUNDWATER, AND SEISMICITY

4.1 REGIONAL GEOLOGY

South Florida lies within the Southern Zone of the coastal lowlands of the Coastal Plain physiographic province of the eastern United States. Most of this province originated from a combination of depositional and erosional processes associated with fluctuations in sea level during the late Pleistocene. The Florida peninsula sits atop the Florida Platform that consists of a porous plateau of karst limestone. The basement rocks of the Florida Platform include Precambrian-Cambrian igneous rocks, Ordovician-Devonian Sedimentary rocks, and Triassic-Jurassic volcanic rocks. A thick sequence of mid-Jurassic to Holocence sediments lies unconformably upon the eroded surface of the basement rocks. In response to renewed uplift and erosion in the Appalachian highlands to the north and sea-level fluctuations, siliciclastic sediments began to encroach upon the carbonate-depositing environments of the Florida Platform. Deposition of siliciclastic-bearing carbonates and siliciclastic sediments predominated from mid-Oligocene to the Holocene over much of the platform. Numerous disconformities that

formed in response to nondeposition and erosion resulting from sea-level fluctuations occur within the stratigraphic section.

Karst landscape features are typical in the region. Limestone Formations in the region are porous, allowing the acidic water to percolate through their strata, dissolving limestone and carrying it away in solution. Over time, this persistent erosional process has created extensive underground voids and drainage systems in much of the carbonate rocks throughout the state. Typical karst landscape features include sinkholes, caves, disappearing streams and bowl shaped topography. Other typical geologic hazard in the area can include moisture sensitive expansive clay soils and erosion from flooding and wind.

4.2 LOCAL GEOLOGY

The generalized geologic map units in the project region are listed below with descriptions typically summarized from geologic quadrangle maps. The Geologic Map of Monroe County is found in Plate 1. Review of existing geotechnical investigations proximate to the proposed site indicated typically shallow overburden depths consisting of light brown to gray fine sand with occasional various amounts of silt and clay. Beneath the surficial materials, limestone was encountered typically at depths less than five feet below the existing ground surface elevation. The encountered limestone was typically described light brown to gray and tan in color, containing various amounts of silt and sand.

4.2.1 KEY LARGO LIMESTONE (QK)

Quaternary aged coralling limestone composed of abundant specimens of small to large reef-forming corals, with the areas between the corals filled by reefal debris and numerous whole and fragmented fossils. The formation is exposed at the surface in the Florida Keys from Soldier Key on the northeast to Newfound Harbor Keys near Big Pine Key on the southwest. The Key Largo Limestone is a white to light gray, moderately to well indurated, fossiliferous, coralline limestone composed of coral heads encased in a calcarenitic matrix. Fossils present include corals, mollusks and bryozoans. The limestone is highly porous and permeable and is part of the Biscayne Aquifer of the surficial aquifer system.

4.2.2 MIAMI LIMESTONE (QM)

Quaternary aged formation that is a grainstone to packstone, composed of ooids, pellets, skeletal grains and carbonate mud with a variable, but generally minor, quartz sand component. Induration varies from poor to good and the limestone is often recrystallized. The Miami Limestone occurs on the mainland and in the southern Florida Keys from Big Pine Key to the Marquesas Keys. The formation consists of two facies, an oolitic facies and a bryozoan facies. The oolitic facies consists of white to orangish gray, poorly to moderately indurated, sandy, oolitic limestone (grainstone) with scattered concentrations of fossils. The bryozoan facies consists of white to orangish gray, poorly to well indurated, sandy, fossiliferous limestone

(grainstone and packstone). Beds of quartz sand are also present as unindurated sediments and indurated limey sandstones. Fossils present include mollusks, bryozoans, and corals. Molds and casts of fossils are common. The highly porous and permeable Miami Limestone forms much of the Biscayne Aquifer of the surficial aquifer system.

4.2.3 HOLOCENE SEDIMENTS (QH)

Occur near the present coastline at elevations generally less than 5 feet. The sediments include quartz sands, carbonate sands and muds, and organics.

4.2.4 TAMIAMI FORMATION (TT)

Contains a wide range of mixed carbonate-siliciclastic lithologies and associated faunas. It occurs at or near the land surface in the southern peninsula with numerous named and unnamed members recognized within the Tamiami Formation. Its unevenness indicates that the upper part has been subjected to erosion. The Tamiami Formation has highly permeable to impermeable lithologies that form a complex aquifer. Locally, it is part of the surficial aquifer system. In other areas, it forms a part of the intermediate confining unit/aquifer system.

4.3 TOPOGRAPHY AND DRAINAGE

The project is located in the following Geologic Quadrangles Blackwater Sound, Rock Harbor, Tavernier, Plantation Key, Upper Matecumbe Key, Lower Matecumbe Key, Long Key, Grassy Key, Crawl Key, Marathon, Sevennile Bridge, Big Pine Key, Summerland Key, Sugarloaf Key, Saddlebunch Key, Boca Chica and Key West. Topographically, this project is located in the Florida Keys. The section of Monroe County that the project is located in is generally flat plateau of a typical coastal plain region. The region experiences moderate to high infiltration rates but given the region is near at sea level, some sunny day flooding does occur due to the high water table.

4.4 GROUND WATER

4.4.1 REGIONAL GROUND WATER

The Floridan aquifer system generally consists of an Upper Floridan aquifer and a Lower Floridan aquifer, separated by less-permeable beds of highly variable properties termed the middle confining unit. The Upper Floridan aquifer is a highly permeable unit comprised of multiple different low permeability carbonate units that are referred to as the upper confining units. The Upper Floradan consists of two main zones that include the fluvial sand-and-gravel aquifer in the westernmost Florida panhandle and the Biscayne aquifer of southeast peninsular Florida. The Lower Floridan aquifer is comparatively less known geologically and hydraulically than the Upper Floridan. Much of the Lower Floridan contains saline water. For this reason and because the Upper Floridan is so productive, there is little incentive to drill into the deeper Lower Floridan in most areas. The Upper and Lower Floridan aquifers are separated by a sequence of low-permeability carbonate rock of mostly middle Eocene age. This sequence,

termed the middle confining unit, varies greatly in lithology, ranging from dense gypsiferous limestone in south-central Georgia to soft chalky limestone in the coastal strip from South Carolina to the Florida Keys.

4.4.2 LOCAL GROUND WATER

Although much of the drinking water supply for Key West comes from the Aqueduct Authority Well Field on the mainland, local groundwater does provide some local water sources. The small freshwater lens (typically less than 250 mg/L of chloride) varies, but freshwater has shown to be accessible up to 200 feet below ground surface. Groundwater levels are typically observed at around 5 foot below grade.

4.5 SEISMICITY

The seismic hazard in Monroe County is low. Florida is not located near any tectonic plate boundaries resulting in rare occurrences of earthquakes. However, historical earthquakes have been recorded and are presented in the table below. The largest earthquake in Florida since the development of seismographs occurred on 10 September 2006. The intraplate earthquake had a magnitude of 5.9 and the epicenter was located about 250 miles southwest of Anna Maria, Florida. The Florida Building Code (2017) and the International Building Code (2018) require seismic design considerations for structural designs.

Table 4.1 Largest Historic Earthquakes near Monroe County

Date	Location	Magnitude
March 31, 1992	Gulf of Mexico	3.8
April 18, 1997	Gulf of Mexico	3.9
May 4, 1997	Alabama	3.1
April 13, 2003	Gulf of Mexico	3.2
September 10, 2006	Gulf of Mexico	5.9

5. EXISTING FLOOD RISK MANAGEMENT STRUCTURES

5.1 GENERAL

Typical existing flood risk management structures within the Florida Keys consist of a small knee wall south of the Airport (Florida Keys Overseas Heritage Trail) and mostly shoreline revetments for most of the project area, including US Route 1. Revetments along the shoreline consist of vegetated/non-vegetated slopes, coral barriers, and riprap slopes. Most risk management in the project area is mediated by non-structural solutions such as house raising, buyouts, mangrove planting and beach renourishment. The revetments along US Route 1 are typically designed and maintained by the FDOT and the Federal Highway Administration (FHA).

5.2 EXISTING REVETMENT DESIGN

Based on information obtained from the FDOT, the existing revetment design/repairs typically consists of slight slope re-grading with additional fill from an approximate 2 foot offset to 22 feet from the edge of the roadway crest. Part of the fill is covered by approximately 8 to 10 feet of sod cover from the edge of the roadway crest towards the waterline. Further toward the waterline typically 14 to 30 feet of 2.5' diameter rubble riprap is underlain by a 6" stone bedding and a non-woven geotextile. The rubble riprap is keyed in to the slope vertically when the slope transitions from sod to riprap and from new riprap to existing riprap. See below for typical revetment repair details and cross sections:

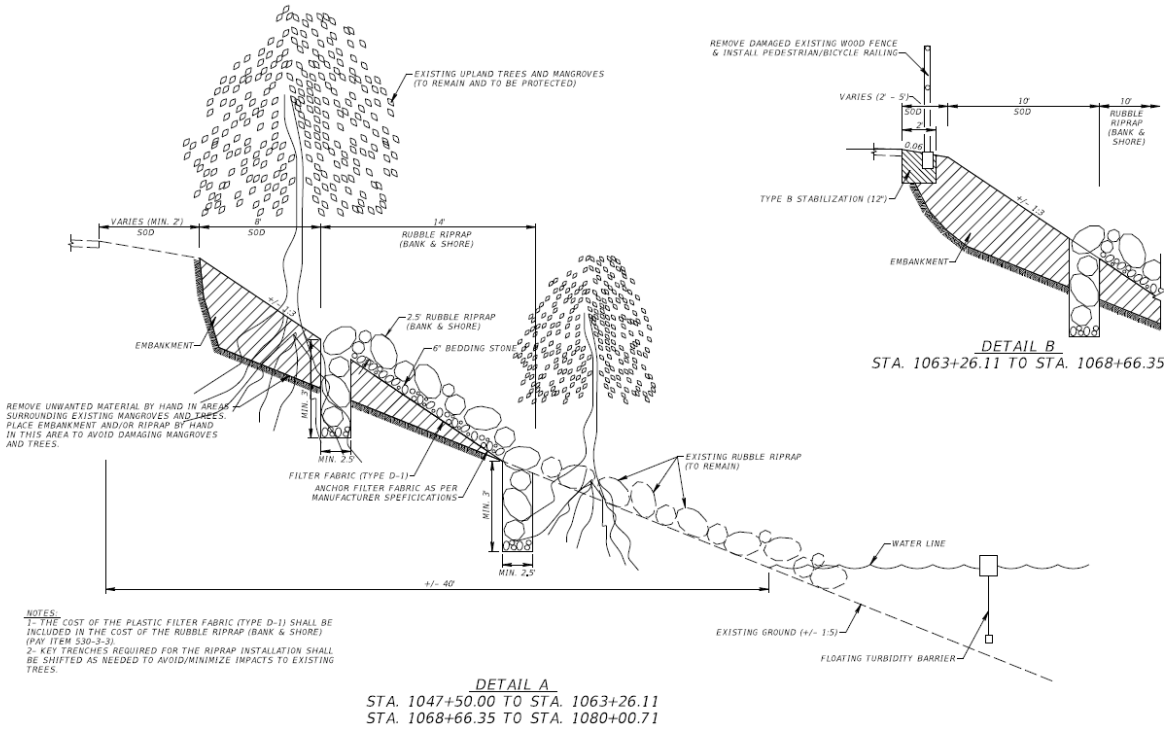


Figure 5.1 Existing Revetment Repair Design Detail

It should be noted that some areas of the study overlap with new or existing maintenance projects funded by the FDOT and the FHA. In cases of overlapping areas, USACE will yield to both agencies revetment programs.

5.3 HISTORICAL PERFORMANCE

Historically the Florida Keys have been shrinking in size due to the natural coastline erosion occurring over time, especially from coastal storms. To delay this erosion, most of the coastline is protected to some degree by revetment or otherwise. Typically, revetments are under constant maintenance and repair. The FDOT and FHA typically handle maintenance and repair due to most of the erosion occurring along route US 1. Monroe County is funded to provide support for areas elsewhere in the county.

6. GEOTECHNICAL ASPECTS OF STRUCTURAL STUDY MEASURES

6.1 GENERAL

This chapter discusses the geotechnical design considerations for the structural measures recommended in the Monroe County CSRM Feasibility Study. Due to the large size of the study area and the time and funding constraints imposed by the Corps Smart Planning process, the

design level in this study is considered to be 10 percent. This chapter also discusses the further data collection and analyses that would be performed during the Planning, Engineering, and Design (PED) phase of the project.

Many measures were considered and evaluated as part of this CSRM study. All measures considered, and their evaluations, are documented in the main report. Roadway revetments was carried forward for development as an alternative in which the geotechnical aspects are discussed in this section.

6.2 PROPOSED PRELIMINARY ROADWAY REVETMENT DESIGN

For the location of specific measures, the PDT relied heavily on previous studies and projects funded by Monroe County and the FDOT.

Roadway embankment protection includes the armoring or other protection of the shoreline in areas where erosion is threatening access and development throughout the Keys. In this study, roadway revetment was recommended for 6 locations along Route 1 to protect the roadway from coastal storm damage. The engineering PDT established the 6 locations for revetment based on a site visit, review of aerial imagery to identify areas where erosion has occurred and input from other agencies. The team also identified areas where there was some sort of existing revetment structure that could be improved. Roadway revetment is carried forward as a single measure within the array of alternatives.

For the PED phase and construction of the project, particle size for the surficial soils at the expected stone bearing grade will need to be determined to choose the appropriate geotextile fabric. Detailed construction recommendations will also need to be determined. Selection guidance for geotextile fabric is listed in section 6.2.1. A brief preliminary construction sequence is listed in section 6.4.

6.2.1 GEOTEXTILE FABRIC SELECTION

When selecting the appropriate geotextile fabric several key factors should be considered such as strength, permeability and durability. In the case of rip rap revetments, separation or retention between soil and coarse aggregate is often a deciding factor. Loading over time from the weight of the rip rap and wave energy will cause soil particles to migrate into the voids of the large aggregate causing clogging, increased maintenance and ultimately shorten the lifespan of the work. When selecting the geotextile consider project specific impacts to the materials lifespan such as salinity, PH and the dissolution of the limestone geography.

Geotextile fabric sizing is typically based on the size of the opening in the fabric. A general equation for retention criteria between the base soil and fabric (filter) is as follows:

Equation 1 Geotextile Fabric Retention Sizing

$$D_{15}\ filter < 4\ x\ D_{85}\ base\ soil$$

Where:

D_{15} = Soil particle size, 15% of soil particle smaller than the stated size.

D_{85} = Soil particle size, 85% of soil particle smaller than the stated size.

6.3 TYPICAL CONSTRUCTION SEQUENCE

6.3.1 TYPICAL REVETMENT CONSTRUCTION SEQUENCE

For areas that have no existing revetment the following general construction sequence should be observed (Bureau of Reclamation, Design Standards No. 13):

- Locate existing utilities.
- Set up road closure/safe working conditions.
- Grub existing area to remove and roots, vegetation and deleterious materials. If mangroves are in the existing area, hand dig around the mangrove to prevent damage to root system.
- Excavate area to desired depth, including vertical keyways at the top and bottom of the slope length to anchor the revetment. Key trench should be approximately 1.5 times the depth of the riprap design thickness.
- Place non-woven geotextile fabric without wrinkles or folds with the roll direction parallel to the slope. Typical lap length for adjacent sheets ranges from at least 2 - 3 feet, unless sewing is recommended.
- Begin placing stone bedding at the specified thickness starting from the bottom of slope moving upward.
- Begin placing the riprap at the specified thickness starting from the bottom of slope moving upward. Place 220 lbs. or less from a height less than 3.25 feet.
- Do not grade the riprap once it has been placed.

6.4 EXPECTED SUBSURFACE CONDITIONS

Existing conditions were reviewed mainly for near surficial soil classification. Surficial soils are expected to be poorly graded fine sands, clayey sands and soft weathered limestone. See the "Local Geology" section for more information. A subsurface investigation is typically not necessary for revetment design. Particle size of the bearing grade surficial soils will need to be determined to choose the appropriate geotextile fabric beneath the rip rap revetment.

7. CONSTRUCTABILITY

The primary constructability issues for the Monroe County CSRM project are expected to be construction adjacent to existing structures as well as water, traffic, tourism and life safety impacts. These issues are discussed individually in this chapter.

7.1 CONSTRUCTION ADJACENT TO EXISTING STRUCTURES

Many construction activities produce potentially damaging vibration levels, including pile driving and removal, concrete and asphalt demolition, compacting soil with a vibratory compactor, and excavation. Vibration amplitudes are typically measured and reported as peak particle velocity, usually in inches per second. The State of Florida limits a peak particle velocity of 0.5 inch per second levels within 2 miles of the urban development boundary (UDB) to prevent damage to adjacent structures.

Construction vibration monitoring experience on other urban projects has shown that construction vibrations, except for pile driving, will dissipate to negligible levels within 75-80 feet. A vibration monitoring plan will need to be considered during the construction phase.

Construction adjacent to existing structures or roadways also means that the temporary construction right-of-way must be minimized. Construction in tight quarters tends to take longer, which increases costs, and may be more dangerous for the workers.

7.2WATER IMPACTS

Given the proximity of the shallow water table and tidal cycles, work may be impacted if not planned properly. Placing and securing of the geotextile will most likely need to be performed during low tide. Material placement from the bottom of the slope towards the top will ensure the water is not impacted by falling debris creating hard bottom impacts. Given the project is near marine sanctuaries, mangroves and coral reef beds – possible hard bottom impacts must be monitored and mitigated. A dewatering plan may need to be included in the Erosion Control Plan submittal prior to construction.

7.3TRAFFIC, TOURISM AND LIFE SAFETY IMPACTS

Given that route US 1 is only roadway from the mainland, construction near and along the roadway will negatively impact traffic and may require temporary street or lane closures and traffic monitors. The construction contractor will need an extensive traffic control plan and will have to perform extensive coordination with the City to provide public notice of traffic impacts. Most of the proposed roadway revetments may be able to be constructed from land. Construction timing should also be coordinated with the local Sponsor to limit the negative effects on the local revenue generated by tourism in the Keys.

A traffic study should be considered to assess life safety impacts during evacuations along route US 1 and to the critical infrastructure in the Keys. A program such as HEC LifeSim can assist in performing a life safety study. Another possibility is conducting a Hurricane Evacuation Study (HES).

8. REFERENCES

Monroe County Government Website, https://www.monroecounty-fl.gov/613/Monroe-County-Information-History

US Department of Interior Bureau of Reclamation Design Standards No. 13 Embankment Dams, Chapter 19: Geotextiles

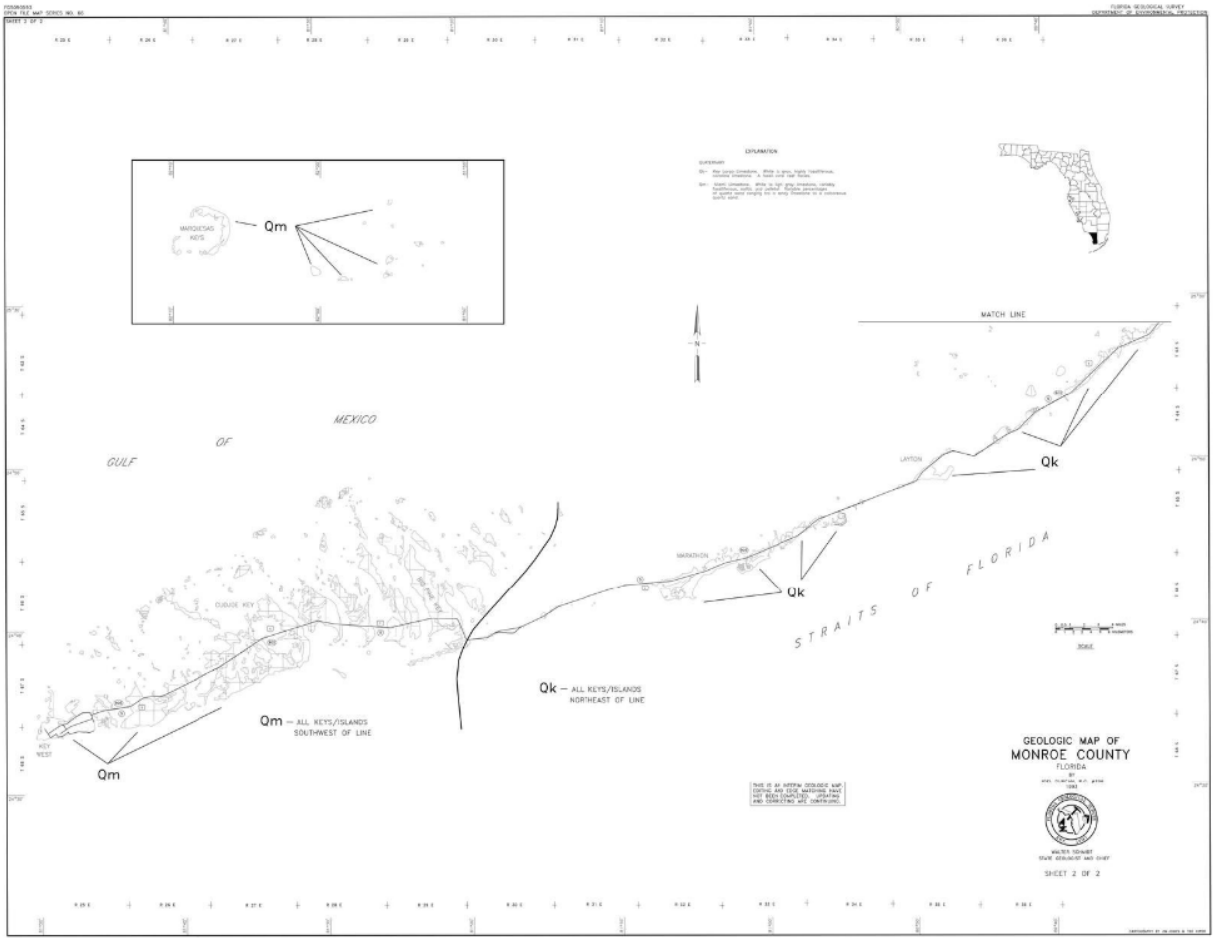
USACE EM 1110-2-1913, Design and Construction of Levees, 30 April 2000.

USACE EM 1110-2-2502, Retaining and Flood Walls, 29 September 1989.

USGS Groundwater Watch website, http://groundwaterwatch.usgs.gov/countymap.asp?sa=VA&cc=710

ATTACHMENT

Geologic Map of Monroe County



EXPLANATION

QUATERNARY

Qk— Key Largo Limestone. White to gray, highly fossiliferous, coralline limestone. A fossil coral reef facies.

Qm— Miami Limestone. White to light gray limestone, variably fossiliferous, oolitic and pelletal. Variable percentages of quartz sand ranging fro a sandy limestone to a calcareous quartz sand.

Florida Keys Coastal Storm Risk Management

Draft Integrated Feasibility Report and Environmental Impact Statement

HYDRAULICS, HYDROLOGY, & COASTAL

SUB-APPENDIX

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CHAPTER 1 INTRODUCTION

This report presents the results of the Hydraulics, Hydrology and Coastal (HH&C) engineering evaluation and analysis for the Florida Keys Coastal Storm Risk Management (CSRM) Study 10% engineering design. See **Figure 1.1** for an image of Monroe County which the Florida Keys are located in.

Figure 1.1 Map of Monroe County

The Florida Keys has experienced flooding from two types of storms: tropical storms and hurricanes. The storms that impact the Florida (and the South Florida area) are occurring more frequently. **Table 1.1** displays: (1) the date of historical storm events where the water surface elevations reached over 1.0 feet North Atlantic Vertical Datum (NAVD 88), (2) the type of storm, and (3) the peak water surface elevations. The peak water surface elevations were measured by the NOAA – Key West and NOAA – Vaca Key tide gauge. The tide gauges were reference to feet NAVD 88. During storms 1-3, the NOAA – Vaca Key tide gauge was not in service. Therefore, there is no information from this gauge for those events.

Table 1.1 Historical Storm Events

	Storm Event Name	Date	Peak Water Surface Elevations NAVD 88 (in feet) at the Key West Gauge	Peak Water Surface Elevations NAVD 88 (in feet) at the Vaca Key Gauge
1	Unnamed Hurricane	September 20-22, 1948	1.27	N/A
2	Hurricane Betsy	September 8, 1965	1.87	N/A
3	Hurricane Andrew	August 23-24, 1992	1.27	N/A
4	Hurricane Irene	October 14-15,1999	1.29	1.01
5	Hurricane Wilma	October 23-24, 2005	3.18	5.43
6	Hurricane Irma	September 9-11,2017	2.73	2.19

This report will discuss in detail all the existing information that was reviewed and how that information was used in the HH&C engineering evaluation and analysis to come up with the contribution of the elements to get to the tentatively selected plan and optimally the preferred plan for the study. The report will also provide recommendations for the next phase (Pre-Construction, Engineering and Design (PED) Phase) of the Florida Keys CSRM study.

CHAPTER 2 FEMA SOUTH FLORIDA STORM SURGE STUDY

For the Florida Keys CSRM, the Norfolk District used Federal Emergency Management Agency (FEMA) Region IV South Florida Storm Surge Study (SFL Study) stillwater elevations and wave heights for the project analysis and design. The FEMA SFL Study includes the coastal counties of Miami-Dade, Broward, Palm Beach, and Monroe. The purpose of the study is to determine the flood risk from 50% (2 year), 20% (5 year), 10% (10 year), 4% (25 year), 2% (50 year), 1% (100 year), and 0.2% (500 year) annual-chance floods for these coastal areas for production of revised Flood Insurance Rate Maps (FIRMs). See **Figure 2.1** for an image that depicts the SFL study area.

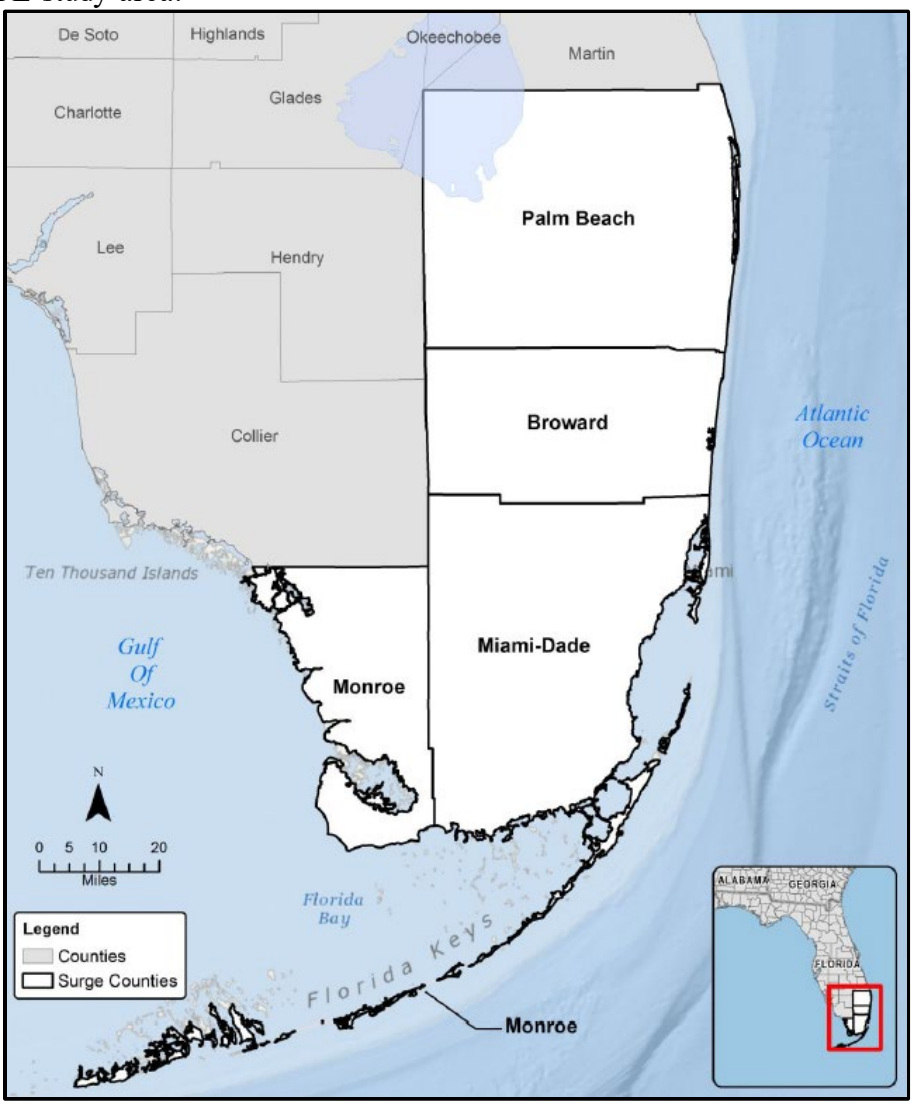

Figure 2.1 FEMA South Florida Storm Surge Study area (FEMA, 2014)

The SFL incorporated existing and future forcing and potential future climate change to perform statistical analyses and numerical hydrodynamic modeling for the region. The statistical analyses resulted in stillwater level elevations as average recurrence intervals (ARI) for a 100% flood (1 year flood), 50% flood (2 year flood), 20% flood (5 year flood), 10% flood (10 year flood), 5% flood (20 year flood), 2% flood (50 year flood), 1% flood (100 year flood), 0.50% flood (200 year flood), 0.20% flood (500 year flood), and 0.10% flood (1,000 year flood) for different confidence limits. The numerical modeling study was performed using the two-dimensional hydrodynamic model ADCIRC and the two-dimensional spectral wave model SWAN. The ADCIRC model is a coastal circulation and storm surge model that uses the finite element method to solve the reformulated, depth-averaged shallow water equations. The model is run on a triangulated mesh with elevations derived from a seamless bathymetric/topographic DEM that includes both offshore and overland areas. The triangulated format of the mesh allows variation in the element size, so the study area can have a high concentration of nodes while fewer nodes (with higher element areas) can be placed farther away to make the mesh size more efficient without compromising accuracy (FEMA 2014). The SWAN model runs on the same triangulated mesh that is used with the ADCIRC model. During the model simulations, the water levels from ADCIRC are fed into the SWAN model at 15-minute interval (of model time). The SWAN model computes the wind-driven development of the storm waves, the propagation of the waves over the model domain, and the wave radiation stress gradients where the waves break close to the shore. In turn, the ADCIRC component is informed of the computed radiation stress gradients at the completion of each SWAN component time step. This information is used by the ADCIRC component to adjust the nearshore water levels for the wave-driven setdown and setup in the zone of breaking waves near the shoreline. This process continues for the duration of the wind and pressure forcing from the meteorological input files. The model was validated with historic tide gage, high water mark, and wave buoy data.

The South Florida Storm Surge is documented in five Intermediate Data submittal (IDS) reports:

- IDS 1 is a detailed overview of the FEMA storm surge study, including background on the study area, field reconnaissance, modeling mesh development, storm climatology, and the selection of the storm surge validation storms used to validate the model (FEMA, 2014).
- IDS 2 describes the results of the tide and storm surge validation, mesh adjustments, development of the optimized set of synthetic hurricanes that fully represent the range of hurricane storm surge forcing that can occur in the project area based on an analysis of past events (the Joint Probability Modeling-Optimum Sampling [JPM-OS] storm set) (FEMA 2014).
- IDS 3 describe the development of computed maximum storm surge elevations for the series of synthetic hurricanes defines by the JPM-OS set.
- IDS 4 will describe the nearshore hydraulics, including applicable overland wave height, erosion, runup, and overtopping analysis
- IDS 5 will include the draft work maps and information on the development of the study's product.

As this study is still ongoing and some files may not be shared until a formal review and appeals process has taken place, release was granted for the following files:

- Meshes
- Fort.13
- IDS Reports
- Validation Storm run files
- Production run Max Elevation files
- Production run sample fort.15/26 file

The unsorted modeling data was sent to ERDC for processing and statistical analysis.

2.1 DATUMS

The native datum of the FEMA SFL study results was based on local mean sea level (MSL) tidal epoch 1983-2001. This was the datum that was used to define the regional hydrodynamic model (ADCIRC), from which storm surge results were obtained. Subsequently, all the data was converted from vertical datum Mean Sea Level (MSL) in meters to North American Vertical Datum 1988 (NAVD88) in feet, through conversion values provided by the tide gauge located on the Vaca Key. **Figure 2.2** displays the tidal datum conversions for the project area in feet relative to MSL. Unless otherwise noted, all stillwater elevations stated in this report are referenced to the North American Vertical Datum 1988 (NAVD 88).

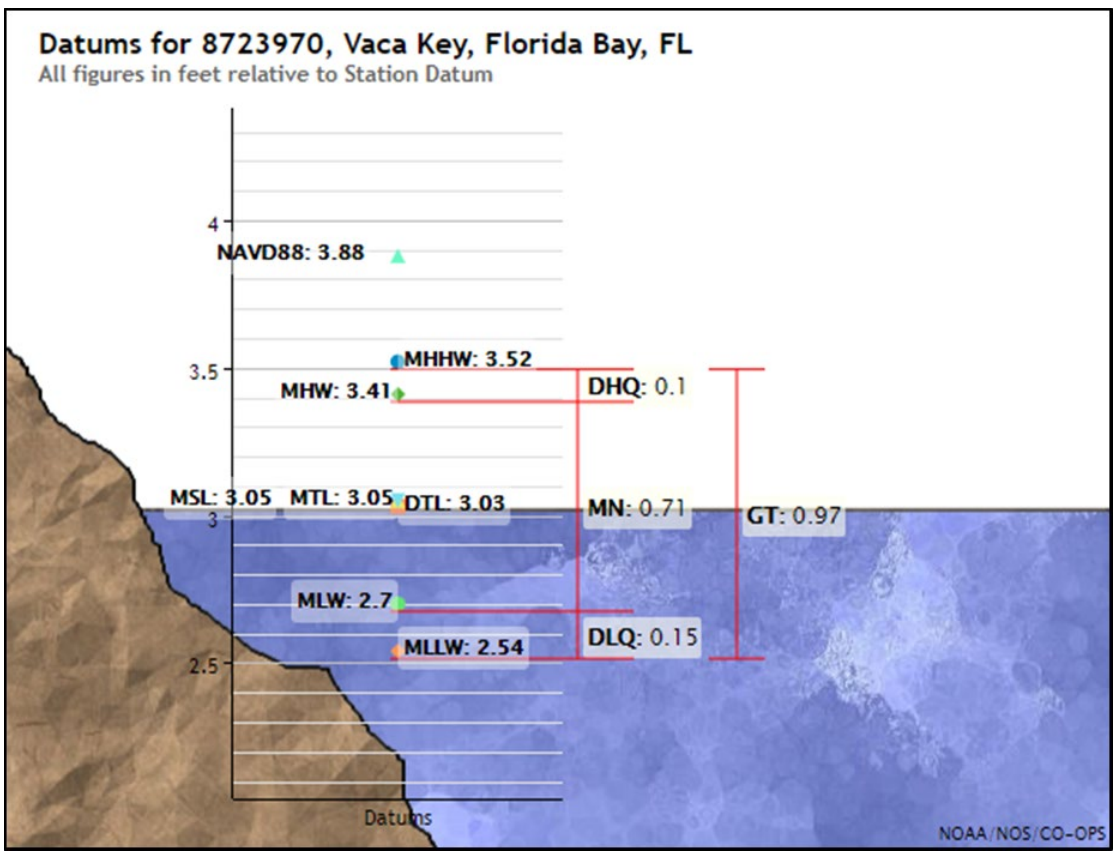

Figure 2.2 Datums for Vaca Key relative to MSL

2.2 DIGITAL ELEVATION MODEL (DEM) DEVELOPMENT

The topographic and bathymetric data were acquired from a variety of sources and assembled into the SFL Study's digital elevation model (DEM). **Table 2.1** and **Table 2.2** show datasets that were used to make the DEM for Monroe County.

Table 2.1 Digital Topographic Datasets Used to create the DEM

Year	Description	Data Type	Source/Owner
2008	Florida Keys Project, FL LiDAR	Airborne LiDAR	FDEM
Various	USGS National Elevation Data (10 meter DEMs)	Digital Elevation Model	USGS

Table 2.2 Bathmetry Datasets Used to create the DEM

Year	Datasets
2013	Monroe County Florida Keys Canal Survey
2011	National Ocean Service hydrographic surveys
2006	Joint Airborne LIDAR Bathymetry Technical Center of Expertise (JALBTCX)
1990	United States Geological Survey- St. Petersburg Coastal and Marine Sciences Center-Florida Bay
2006	NASA's Experimental Airborne Research LIDAR offshore of Key Largo

2.3 FEMA STORM SELECTION AND STATISTICAL METHOD DEVELOPMENT

Within the FEMA SFL project area, major events that contribute to the 10 year, 50 year, 100 year, 200 year, 500 year, and 1000 year average recurrence intervals are rare and the spacing of tide gauges is large compared to the characteristic scale of differenced in maximum hurricane storm surge levels, the available tide is not sufficient to determine these flood levels throughout the project area. Instead, numerical modeling of the storms and their resulting surge heights are relied upon to represent the maximum coastal flood elevations at points across the FEMA SFL project area. For more frequent events, 2 year and 5 year events, the tide gauge data is sufficient to develop the stillwater elevations as the gauge record lengths are much longer than the return periods themselves.

To develop the SFL storms, data from historical storms was used to develop a statistical description of the hurricane storm climate of the area. This information was for parameters such as central pressure deficit, radius to maximum winds, forward speed of the storm, azimuth of the storm track, etc., allowing for the probabilistic characterization of the occurrence and characteristics of potential hurricanes that may cause significant flooding along the SFL coast. Extra-Tropical storms were not included in the FEMA SFL Study because previous FEMA

studies in Florida provided evidence that they do not contribute to 10 year, 50 year, 100 year, 200 year, 500 year, and 1000 year storm surge heights.

The SFL Study followed the Joint-Probability Method (JPM) as described by Resio (2007) and Toro et al (2010a) and incorporated experience from past FEMA flood studies along the coast make appropriate data and model modifications to capture the conditions in South Florida. The JPM method considers all possible combinations of storm characteristics as landfall, with their associated probabilities, calculates the surge effects for each combination, and then combines these results to obtain the annual probability of exceeding any storm surge elevation of interest. This calculation is represented as a multi-dimensional integral (the JPM integral). The SFL Study used an approach referred to as the JPM-OS, where the OS refers to "optimum sampling", based on a procedure that approximates the multi-dimensional JPM integral by means of a weighted sum over a manageable number of discrete probability masses (Toro et al. 2010b). Each of these masses may be interpreted as the characteristics of a representative synthetic storm at landfall. These characteristics, together with some simple deterministic rules, are used to specify the entire storm history, which is then used as the as input to the numerical wind, wave, and surge models. The JPM-OS approach developed a representative set of 392 synthetic storms and their associated annual recurrence rates. These storms and their rates provide a condensed representation of the population of possible future synthetic storms used to calculate surge inundation probabilities.

2.4 MONROE COUNTY STORM DATABASE

A numerical hydrodynamic model (ADCIRC), forced by the synthetic storms, is used to translate the probabilistic model of storm conditions to the corresponding probabilistic definition of annual exceedance probabilities for coastal floods. FEMA provided the raw, unsorted modeling data for processing. While the documentation for the FEMA SFL study stated 395 storms were run for the production runs, the modeling data provided to ERDC included the responses for 392 storms. Additionally, some of these files were corrupted. Ultimately, ERDC processed the data for 388 storms. The statistical analysis performed by ERDC produced maximum Still Water Level (SWL) AEP curves and maximum wave AEP curves (heights and periods). SWL by USACE definition has 3 main components: mean sea level, astronomical tide, and storm surge. Also, as part of the hydrodynamic modeling, wave set-up is also included (SWL + wave set-up is sometimes called Dynamic SWL, or DSWL).

ERDC produced statistics and times series results for 78 "save points" around Monroe County (**Figure 2.3**). ERDC's methodology to calculate the AEPs is the same joint probability analysis performed for FEMA, but how the final results are presented differ. For example, for FEMA only one hazard curve is produced for each point, whereas for the USACE, a family of five (5) curves is generated to characterizes and convey the uncertainty; this is a mean curve and 4 non-exceedance confidence limits, 10%, 16%, 84%, and 90% for the Monroe County storm statistics. In addition to the statistics, water level and wave time series were also produced at each save point. Save points near proposed structural measures were reviewed and analyzed for all engineering evaluation purposes.

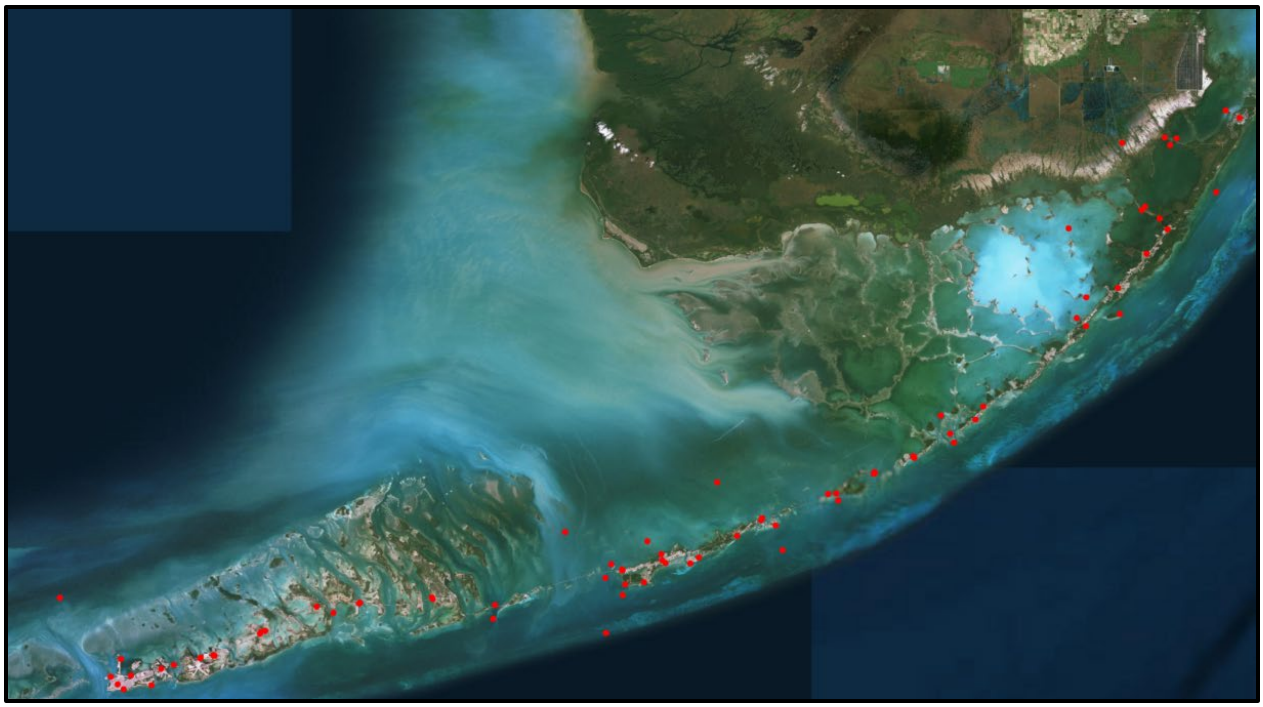

Figure 2.3 FEMA SFL Study Model Save Points for Monroe County

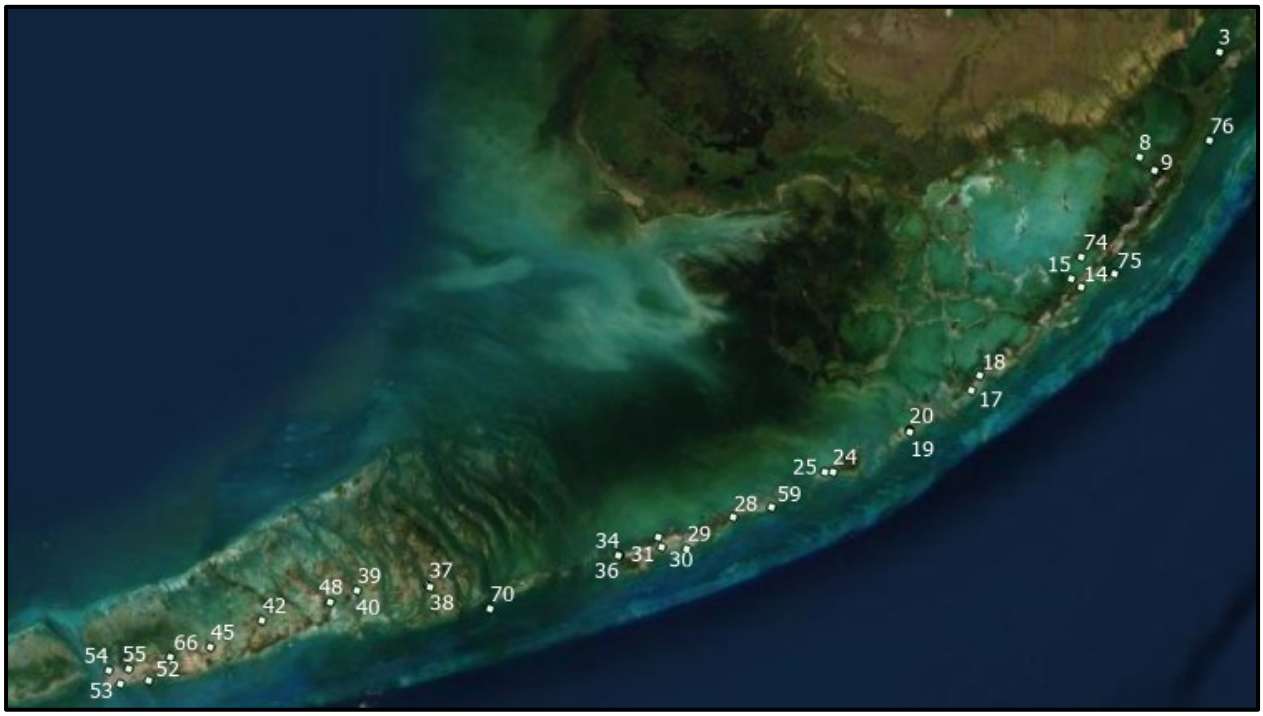

Figure 2.4 Save points used for Nonstructural and Structural Model Areas

The model areas were created by looking at the available save points (**Figure 2.3**) and their storm hydrographs, structure inventory (provided by the economist) and DEM (Digital Elevation Model). Only save points that were located in the nearshore were selected. Save points on land did not show inundation except for substantial storms. This would decrease the number of storms

applied to that point. With this criteria, 34 save points were selected to make 34 model areas. The selected save points can be seen in **Figure 2.4.**

The Florida Keys model areas were drawn by looking at the DEM and save points' water levels. The Florida Keys were typically split down the middle along US-1 which is the highest point on the Key except for Key West. Save points were selected on the Atlantic Ocean and Gulf of Mexico side of each Key. Water levels and wave heights are typically smaller on the Gulf of Mexico side of the Florida Keys compared to the Atlantic side. See **Figure 2.5** .

Figure 2.5 Model Areas split by US -1

2.5 CONFIDENCE LIMITS AND RISK DISCUSSION

As previously stated, ERDC results produced water levels, wave heights, wave period, etc., for different storm frequencies and confidence limits. **Figure 2.5** to **Figure 2.7** displays Stage-Frequency Curves from the ERDC results at save points throughout Monroe County for the mean

(50%), 10%, 16%, 84%, and 90% confidence limits for water levels. **Figure 2.4** displays the locations of the three (3) save points used in G2CRM for the shoreline stabilization measures.

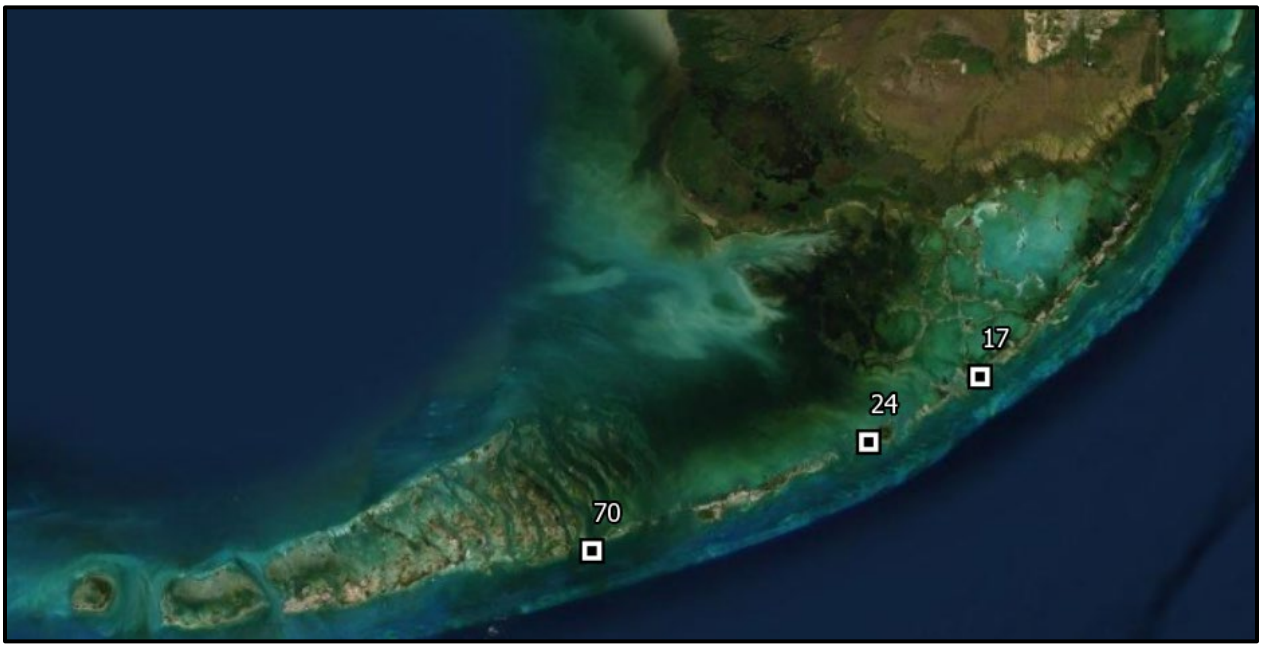

Figure 2.6 Locations of Save Points

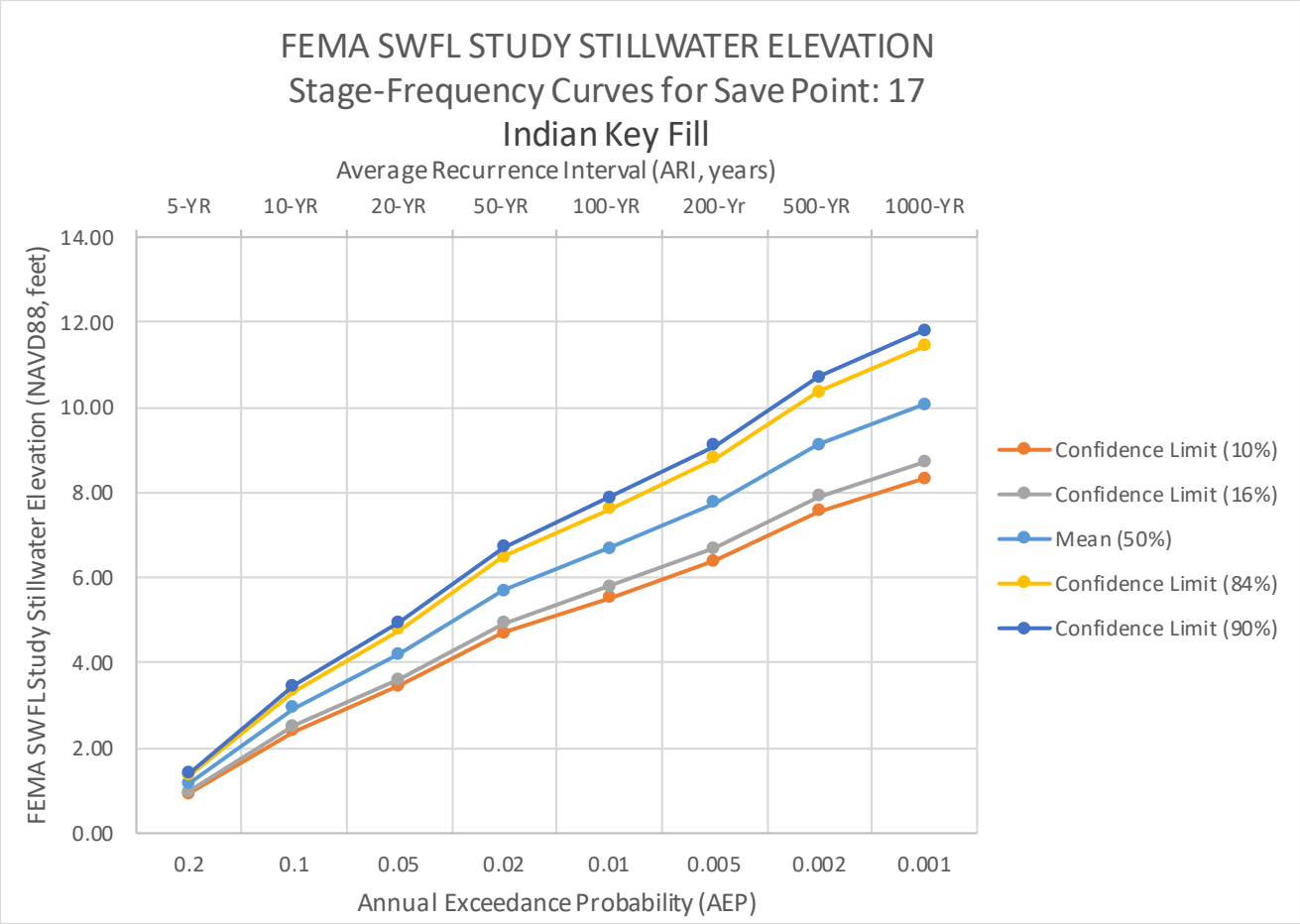

Figure 2.7 Stage-Frequency Curve for Save Point 17

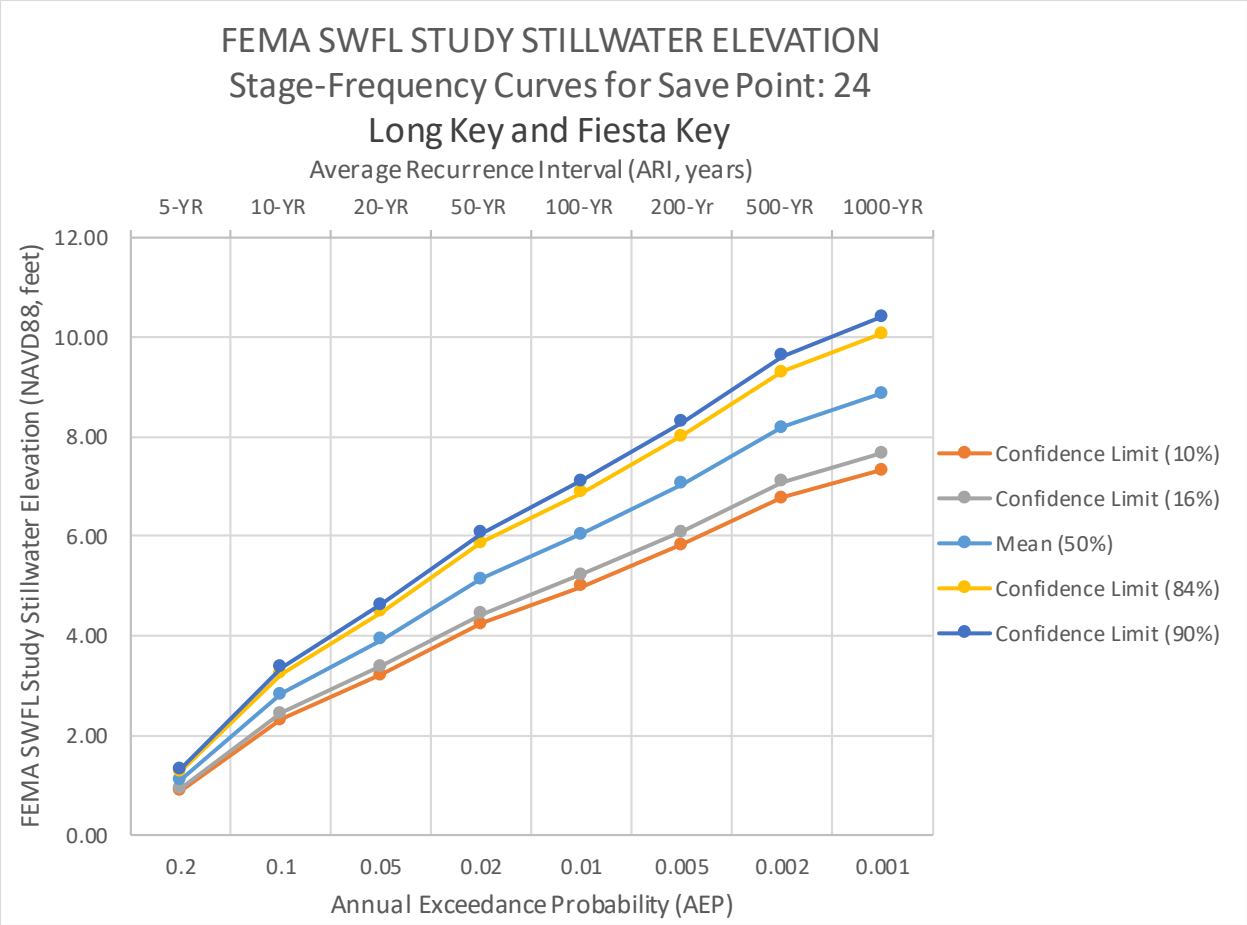

Figure 2.8 Stage-Frequency Curve for Save Point 24

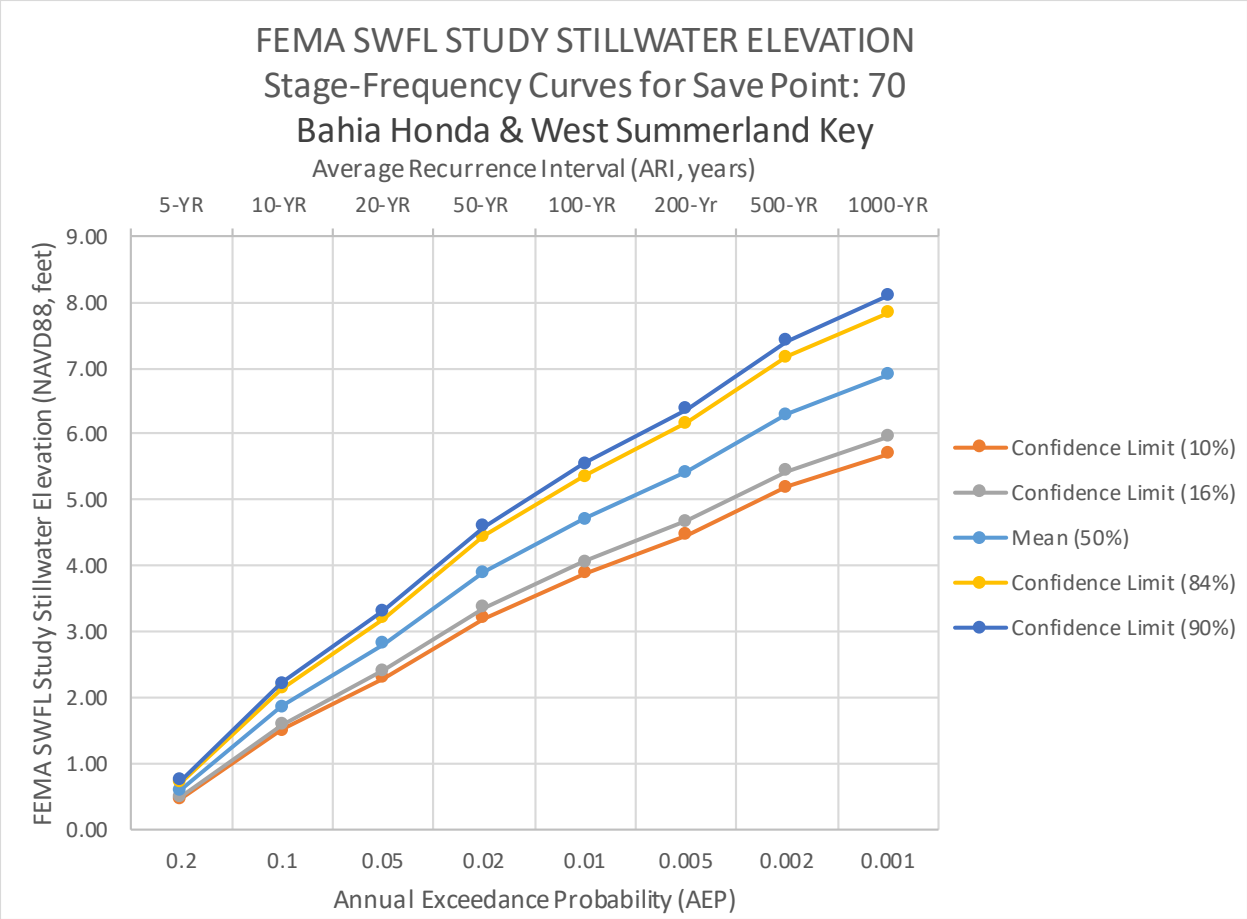

Figure 2.9 Stage-Frequency Curve for Save Point 70

2.6 HISTORICAL TIDE GAUGE ANALYSIS VS. COMPUTER MODELING

There have been discussions in the past about computing frequency water levels from a historical tide gauge analysis versus computer modeling (in this case the FEMA SFL Study model). The historical record at the NOAA Vaca Key (established in 1970) gauge mainly reflects maximum water levels from nor'easters, tropical storms, or hurricanes. However, no major storms on record have directly passed over Vaca Key or made landfall in Monroe County coming from the Gulf of Mexico. Hurricane Irma was the last major hurricane (Category 4) to make landfall on Cudjoe Key. Vaca Key is approximately 30 miles away from Cudjoe Key. Hurricane Irma did not produce the highest water level on record. Hurricane Wilma had the highest water level on record (5.43 feet NAVD88) and it did not make landfall in Monroe County (See Main Engineering Appendix Figure 3.12). Hurricanes coming the Gulf of Mexico tend to make higher water levels in the Florida Keys. These historical maximum water levels are approximately equal to a 2% ACE flood (50 year) to 1% ACE flood tidal events (100 year). A statistical gauge analysis of the historical record may suggest that what has occurred in the past will occur in the future, this may underestimate the risk. Modeling effects, such as what was

done for the FEMA SFL Study, provide an opportunity to evaluate impacts of stronger hypothetical storms that may not have occurred on record, but could occur.

CHAPTER 3 IMPACTS OF CLIMATE CHANGE

3.1 GUIDANCE

Climate change is defined as a change in global or regional climate patterns. Climate change has already been observed globally and in the United States. These included increases and changes in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice. Climate change has the potential to affect all of the missions of the United States Army Corps of Engineers (USACE). USACE mission in regards to climate change is: "To develop, implement, and assess adjustments or changes in operations and decision environments to enhance resilience or reduce vulnerability of USACE projects, systems, and programs to observed or expected changes in climate". The USACE's Climate Change Program develops and implements practical, nationally consistent, and cost-effective approaches and policies, to reduce potential vulnerabilities to the Nation's water infrastructure resulting from climate change and variability. The Department of the Army Engineering Regulation 1100-2-8162 (31 Dec 2013) requires that future Relative Sea Level Rise (RSLR) projections must be incorporated into the planning, engineering design, construction and operation of all civil works projects. The structural components of the proposed alternatives in consideration of the "low", "intermediate", and "high" potential rates of future RSLR were evaluated. This range of potential rates of RSLR is based on the findings of the National Research Council (NRC, 1987) and the Intergovernmental Panel for Climate Change (IPCC, 2007).

The same goes for hydrologic changes due to climate change. There is guidance for the Hydraulics and Hydrology analysis to incorporate Climate Change. This USACE guidance ECB (Engineering and Construction Bulletin) 2018-14, issued 10 September 2018 and expires 10 September 2020, and is titled "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects". This ECB "provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy. This policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of our water resources infrastructure." Hydrologic processes are very sensitive to changes in temperature, which can affect the form of precipitation (rain), precipitation intensity and volume, the timing and volume of runoff, and conditions that cause or enhance drought. Observed climate change and variability have affected USACE water resources management-related missions and operations. USACE has developed and implemented policy and guidance to continue to provide reliable services in changing conditions. This chapter discusses the climate change impacts of and predictions for SLR and hydrology and how they influenced the design.

3.2 COMPONENTS OF RELATIVE SEA LEVEL RISE

RSLR considers the effects of (1) the eustatic, or global, average of the annual increase in water surface elevation due to the global warming trend, and (2) the "regional" rate of vertical land movement (VLM) that can result from localized geological processes, including the shifting

of tectonic plates, the rebounding of the Earth's crust in locations previously covered by glaciers, the compaction of sedimentary strata and the withdrawal of subsurface fluids.

3.3 RATES OF RELATIVE SEA LEVEL RISE

When calculating the intermediate and high rates of RSLR, the local rate of VLM must first be determined. The USACE published guidance on how to adapt to changing sea levels, Engineer Pamphlet 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses and Adaptation. How RSLR is calculated is stated in the following paragraphs.

3.3.1 Historic Rate of Relative Sea Level Rise

The historic rate of future RSLR (or USACE Low Curve) is determined directly from gauge data gathered in the vicinity of the project area. The nearest NOAA tide gauge from which tide data can be evaluated include: The Vaca Key gage in Vaca Key, Florida (NOAA Station 8723970). Tide conditions at Vaca Key indicate a mean sea level trend of 3.66+/- 0.44 mm/year (**Figure 3.1**).

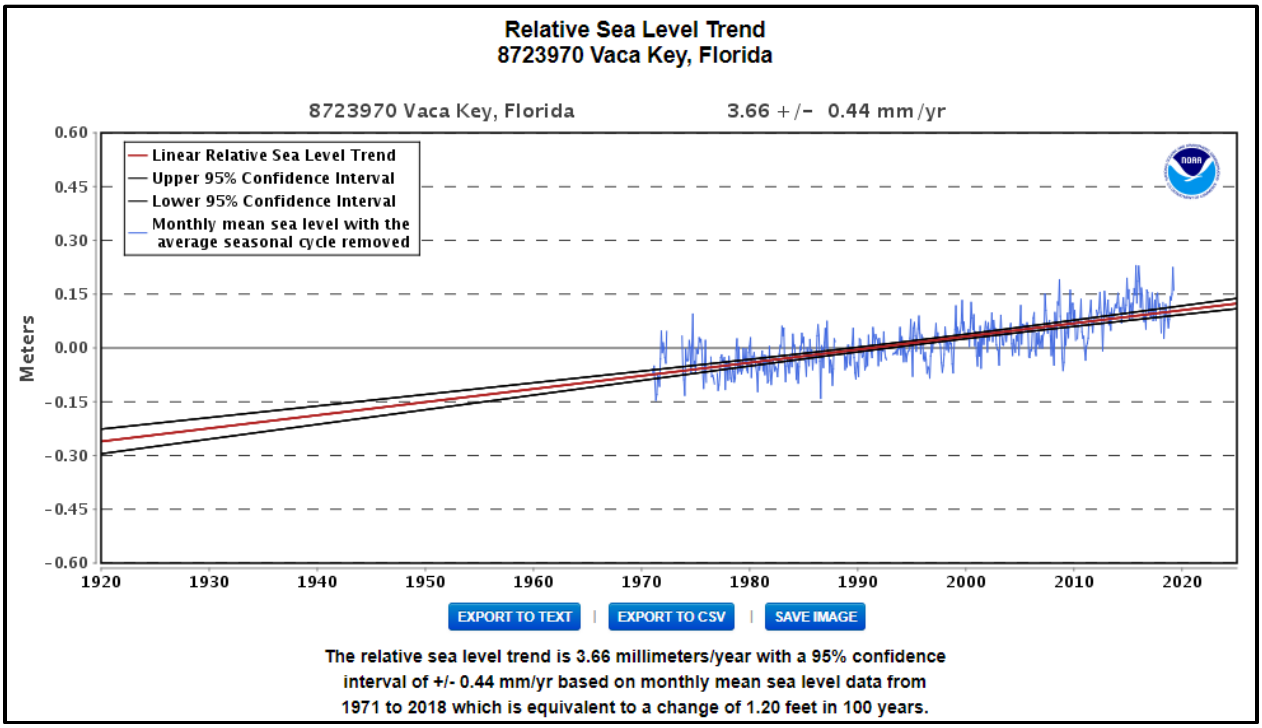

Figure 3.1 Relative Sea Level Trend at Vaca Key, Florida (NOAA Station # 8723970)

3.3.2 Intermediate Rate of Relative Sea Level Rise

The intermediate rate or "USACE Intermediate Curve" of local mean RSLR is estimated by considering the modified National Research Council (NRC) projections and adding the appropriate value to the local rate of vertical land movement. The intermediate rate of relative (local) sea level rise is based on the modified NRC Curve I (**Figure 3.2**) since its value is comparable to that of the IPCC projection.

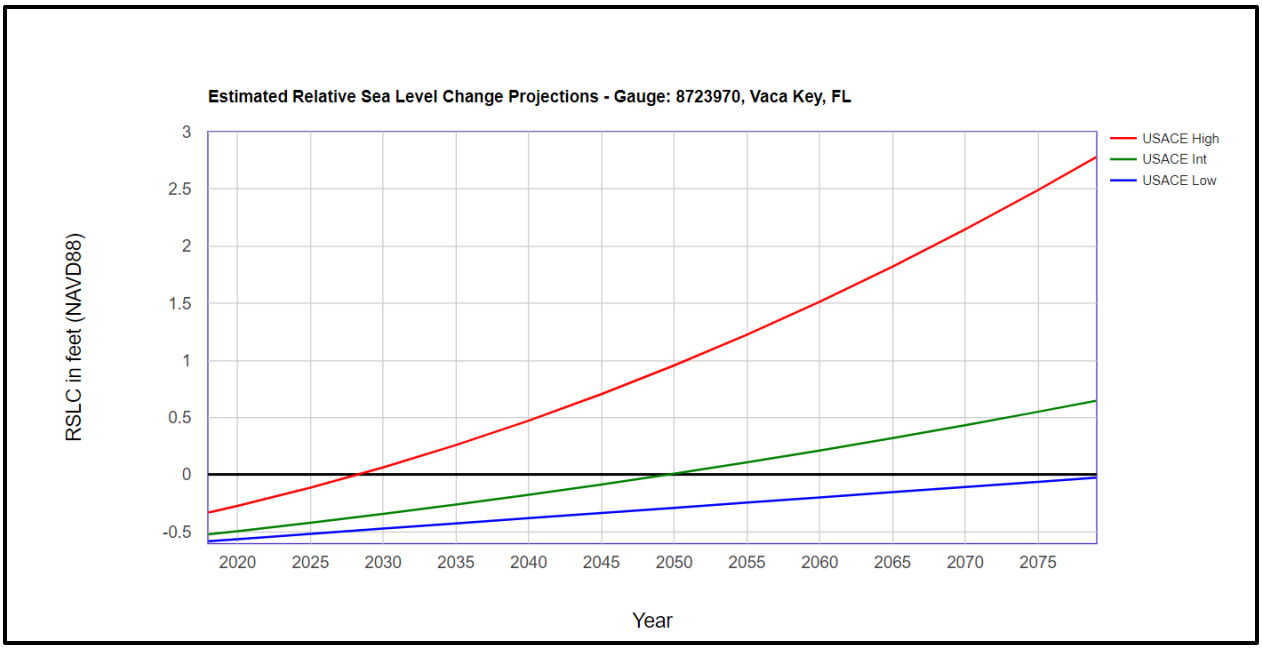

Figure 3.2 Modified NRC curves for predicting future rates of RSLR

NRC Curve I is based on the general equation $E(t) = 0.0017t + bt^2$, where the constant 0.0017 = the IPCC 2007 annual rate of eustatic SLR in meters; t = time in years (relative to the year 1986 when the curves were developed) and; $b = 2.71E^{-5}$.

3.3.3 High Rate of Relative Sea Level Rise

The high rate or "USACE High Curve" of mean RSLR is estimated by determining the modified NRC Curve III value and adding it to the local rate of vertical land movement. This high rate scenario exceeds the 2001 and 2007 IPCC projections and considers the potential rapid loss of ice from Antarctica and Greenland. NRC Curve III is also based on the general equation $E(t) = 0.0017t + bt^2$; however, the constant b changes to $b = 1.13E^{-4}$.

For both the intermediate and high rates of RSLR, the NRC curves accelerate upward over time beginning in the year 1992 when the curves were developed; therefore, it is necessary to estimate RSLR for a particular time horizon relative to 1992.

3.3.4 Determining Local VLM

The local rate of VLM, which is considered to be constant through time, is determined by subtracting the NRC/IPCC eustatic SLR value (1.7 mm/yr.) from the local mean sea level trend. Recall that the two components figuring into the local mean sea level include the RSLR value and the local rate of VLM. The mean rate of RSLR at the Vaca Key station is +3.66 mm/year (approximately 7.2 inches in 50 years).

The local rate of VLM at Vaca Key is calculated from the relationship:

$VLM_{VacaKey}$= [local rate of RSLR] – [eustatic rate of SLR], or

$VLM_{VacaKey}$= 3.66 mm/yr. – 1.7 mm/yr. = 1.96 mm/yr. (0.077 in./yr.)

The calculated VLM value is within 1 mm of the 2013 NOAA publication (NOAA, 2013). At the Vaca Key, the local rate of VLM accounts for a total of 3.85 inches (0.077 in. /yr. x 50 yrs.) at a 50-year time horizon. This local rate of VLM is added back into the sea level rise computations after the eustatic portion has been determined from NRC curves I and III.

3.4 CALCULATING RELATIVE SEA LEVEL RISE

3.4.1 Historic Rate

The historic rate of relative sea level rise is determined by extrapolating the mean RSLR trend and multiplying it by the desired time horizon. The RSLR trend at Vaca Key is 3.66 mm/yr. Based on the historic rate of RSLR it can be expected that sea level will rise 7.20 inches over a 50-year time horizon.

3.4.2 Intermediate Rate

The intermediate rate of sea level rise is computed using the equation

$$E(t_2) - E(t_1) = 0.0017(t_2 - t_1) + b(t_2^2 - t_1^2) + \text{local VLM}$$

Where t_1 and t_2 represent the start and end dates of the projected time horizon in years, relative to 1992; therefore, t_1=38yr and t_2=88 yr. (2030 and 2080 respectively). The variable b=.0000271 is a constant for the intermediate rate.

RSLR = (0.0017m/yr. (88-38)yr + 0.0000271 m/yr. ((88^2-38^2)yr.)) x (3.281 ft. /m) + (0.077in/yr. x 50 yrs.)/12 in/ft. ≈ 1.16 ft.

This is stating from the start of the project economic period of analysis (2030) to the end of the project economic period of analysis (2080), the sea level is expected to rise approximately 1.16 feet, which relates to what has been calculated in **Table 3.1** and **Table 3.4**.

3.4.3 High Rate

The high rate of RSLR is computed using the equation

$$E(t_2) - E(t_1) = 0.0017(t_2 - t_1) + b(t_2^2 - t_1^2) + \text{local VLM}$$

Where t_1 and t_2 represent the start and end dates of the projected time horizon in years, relative to 1992; therefore, t_1=38yr and t_2=88 yr (2030 and 2080 respectively) and b is a constant equal to 0.000113 m/yr. The sea level is expected to rise 2.94 feet using the high curve.

3.5 PROJECT WATER SURFACE LEVEL INCREASE

The Florida Keys CSRM project design water level stages were derived from the FEMA SFL Study. **Table 3.1** shows the projected increase in water surface elevation for the historic, intermediate, and high rates of future sea level rise at the Vaca Key Gage from year 1992 to 2100 using criteria in USACE ER 1100-2-8162 (see **Figure 3.3** for illustration of future sea level rise and subsidence).

Table 3.1 Estimated Relative Sea Level Change at Vaca Key Gauge

Estimated Relative Sea Level Change from 1992 To 2100 8723970, Vaca Key, FL User Defined Rate: 0.01201 feet/year All values are expressed in feet			
Year	**USACE Low**	**USACE Int.**	**USACE High**
1992	0.00	0.00	0.00
1995	0.04	0.04	0.04
2000	0.10	0.10	0.12
2005	0.16	0.17	0.22
2010	0.22	0.25	0.34
2015	0.28	0.32	0.47
2020	0.34	0.41	0.63
2025	0.40	0.49	0.80
2030	0.46	0.59	0.99
2035	0.52	0.68	1.20
2040	0.58	0.78	1.43
2045	0.64	0.89	1.68
2050	0.70	1.00	1.94
2055	0.76	1.11	2.23
2060	0.82	1.23	2.53
2065	0.88	1.35	2.85
2070	0.94	1.48	3.19
2075	1.00	1.61	3.55
2080	1.06	1.75	3.93
2085	1.12	1.89	4.32
2090	1.18	2.03	4.74
2095	1.24	2.18	5.17
2100	1.30	2.33	5.62

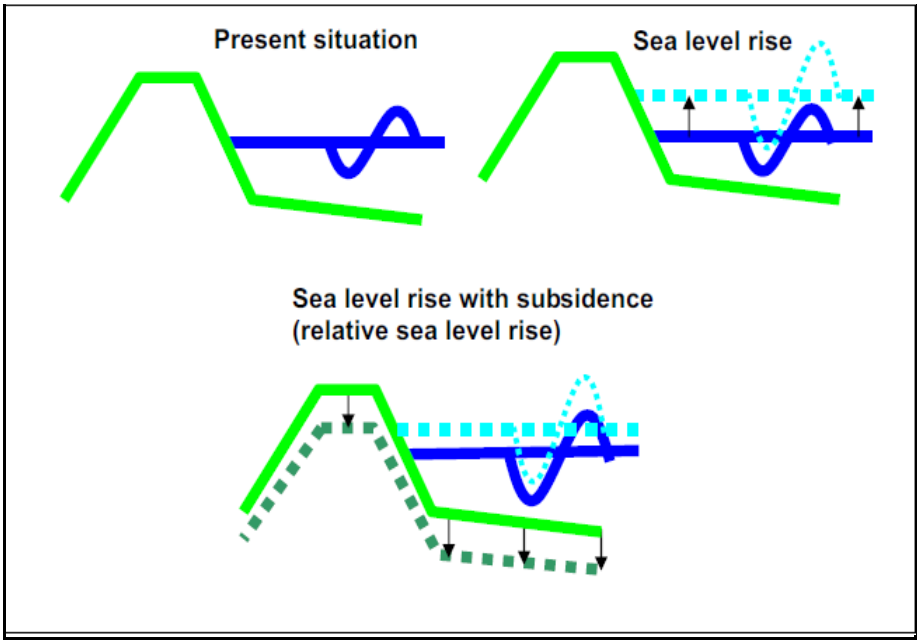

Figure 3.3 Illustrations and simple explanation of future sea level rise and subsidence

The scenarios presented in the USACE guidance estimate that the sea level, from the year 1992 thru 2100 for the Florida Keys at the NOAA's Vaca Key gauge, will increase 1.30 feet from the low approach, 2.33 feet of the intermediate approach and 5.62 feet for the high scenario.

The Sea Level Tracker tool was used to visualize the observed changes in sea level and to compare trends to the projected sea level changes per USACE Engineer Regulation 1100-2-8162 and Engineer Pamphlet (EP) 1100-2-1. The tool shows the historical and observed changes in mean sea level (MSL) as measured and reported for National Oceanic Atmospheric Administration (NOAA) tide gauges, mapped against the USACE sea level change (SLC) projections. Taken together, the tool enables the comparison of actual SLC with USACE SLC projections (as described in ER 1100-2-8162), along with observed monthly water levels and the computation of SLC trends based on historical data (Sant-Miller et al, 2018). **Figure 3.4** displays the results of this tool, comparing actual SLC for the 19-year (metonic cycle) midpoint moving average (dark blue line) and 5-year midpoint moving average (orange line) against the USACE SLC curve projections. The observed 19-year moving average is tracking along the intermediate SLC scenario while the 5-year moving average has been tracking nearer to the high scenario.

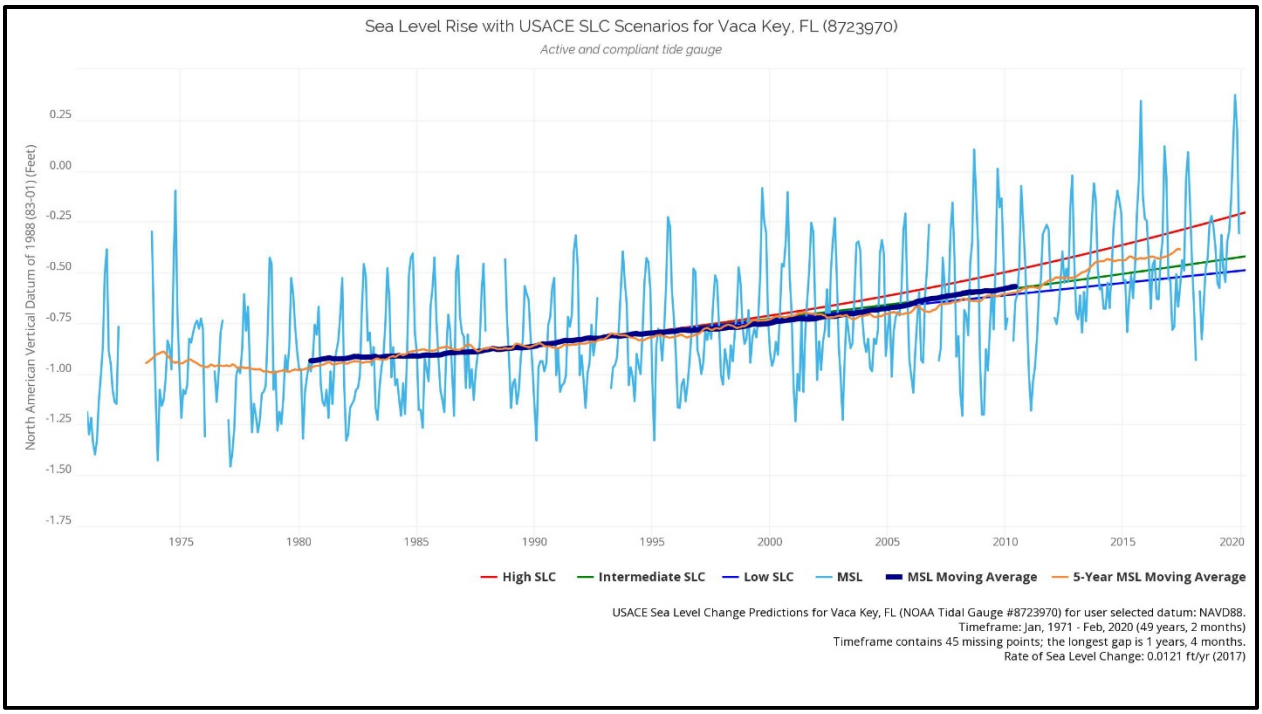

Figure 3.4 Sea Level Tracker for Vaca Key

Table 3.2 and **Table 3.3.** show the FEMA SFL Study water levels for 2018 and 2079 (which includes the high curve of 3.29 feet NAVD88 due to RSLR using the USACE high curve) for different save points. **Figure 3.5** and **Figure 3.6** provides a color contour map representation of the project water level increases. **Table 3.2** and **Table 3.3** show frequencies from 20 year to 1,000 year event. This assumes relative sea level rise to 2079 based on the USACE high curve.

Table 3.2 Water Levels at 2018

Save Point	**Shoreline Stabilization Measure**	Annual Exceedance Probability, AEP (1/year) of Water Level (feet, NAVD88) at 2018					
		20	**50**	**100**	**200**	**500**	**1,000**
17	Long Key & Fiesta Key	4.94	6.71	7.87	9.10	10.72	11.82
24	Bahia Honda & West Summerland Key	4.63	6.07	7.12	8.29	9.63	10.42
70	Indian Key Fill	3.32	4.60	5.55	6.38	7.41	8.10
	Average	**4.30**	**5.79**	**6.85**	**7.92**	**9.25**	**10.11**

Table 3.3 Water Levels at 2079 with Sea Level Rise

Save Point	Shoreline Stabilization Measure	Annual Exceedance Probability, AEP (1/year) of Water Level (feet, NAVD88) at 2079 with SLR					
		20	**50**	**100**	**200**	**500**	**1,000**
17	Long Key & Fiesta Key	8.23	10.00	11.16	12.39	14.01	15.11
24	Bahia Honda & West Summerland Key	7.92	9.36	10.41	11.58	12.92	13.71
70	Indian Key Fill	6.61	7.89	8.84	9.67	10.70	11.39
	Average	**7.59**	**9.08**	**10.14**	**11.21**	**12.54**	**13.40**

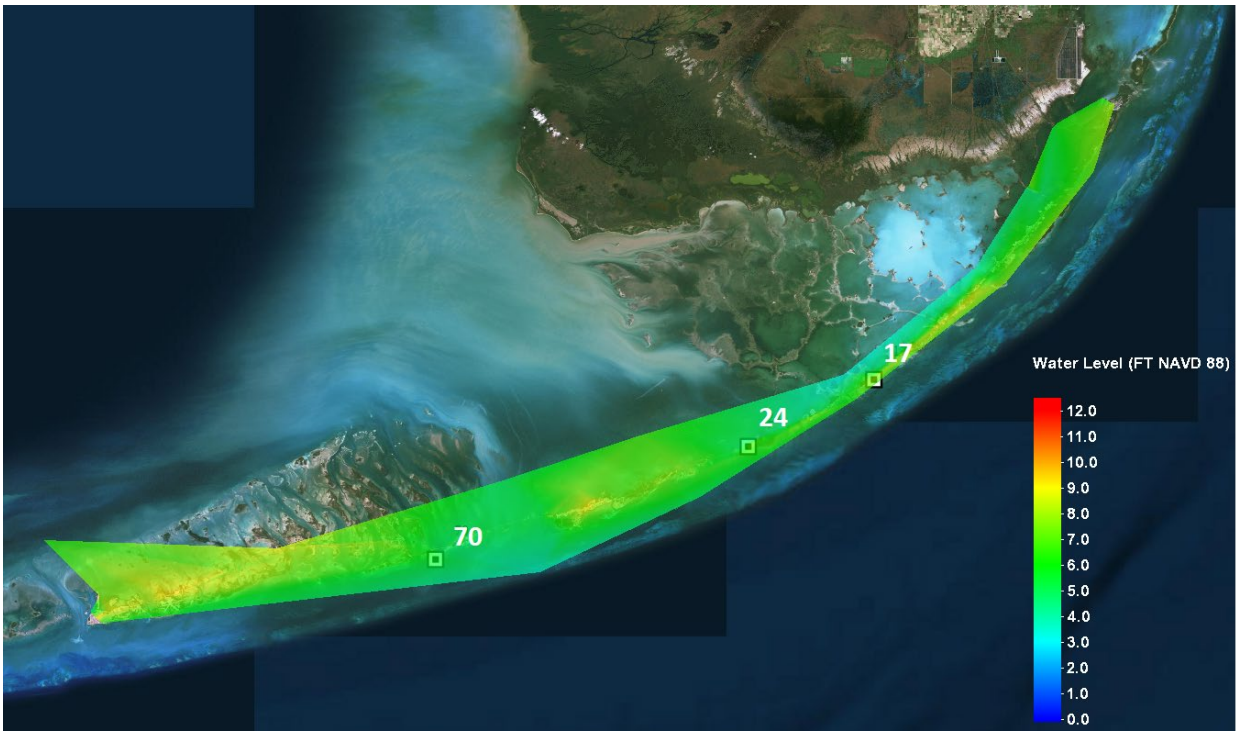

Figure 3.5 100 year Water Levels at 2018

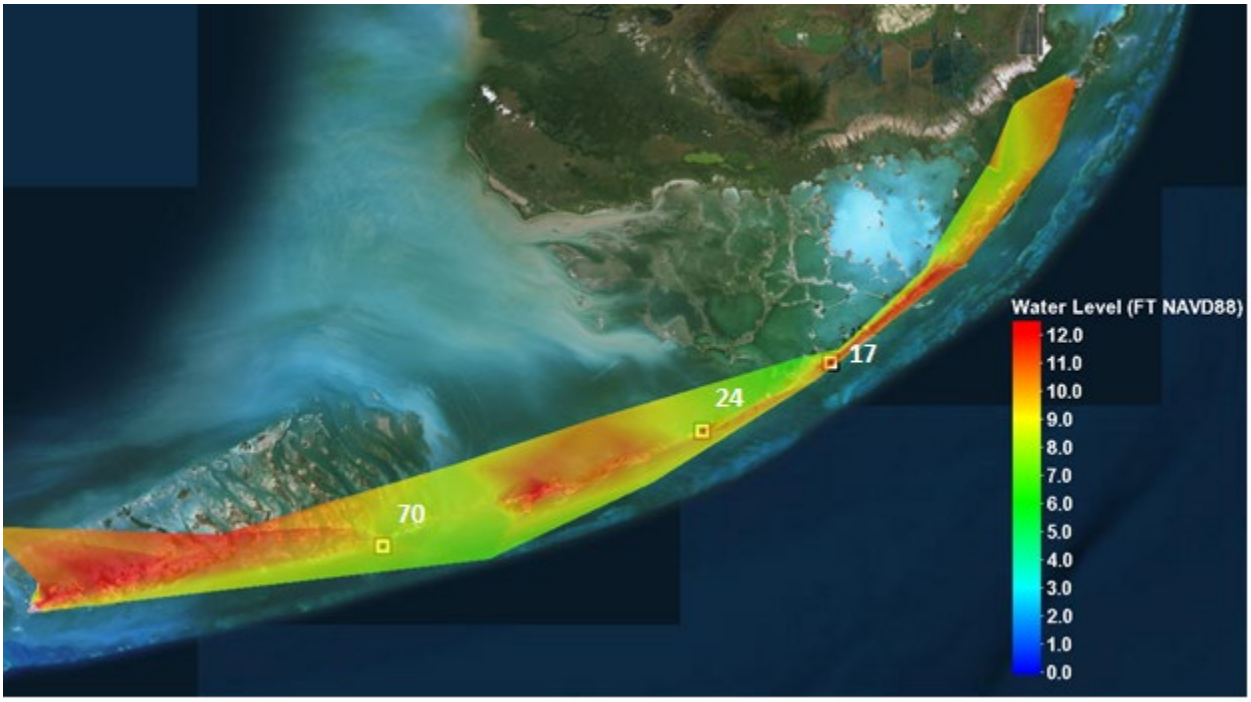

Figure 3.6 100 year Water Levels at 2079 with High SLR

3.6 IMPACTS OF SEA LEVEL RISE DURING FUTURE YEARS

Engineer Pamphlet (EP) 1100-2-1, Global Changes – Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation, recommends analyzing the effects of SLR on the project at three future time period post construction (the year 2030). The time periods include 20 years after construction is completed (the calendar year 2049), 50 years after construction (the calendar year 2079), and 100 years after construction (the calendar year 2129). This section will look at RSLR on the project at the year of 2079, which is the end of the project economic period of analysis and briefly discuss the RSLR rates over the project economic period of analysis. **Table 3.4** shows the predicted increase in SLR for the computed USACE curves 20 years (2049), 50 years (2079), and 100 years (2129) into the future after the proposed construction year of 2030.

Table 3.4 SLR predictions for 20 years, 50 years and 100 years in the future (in feet)

Year	USACE Low	USACE Int.	USACE High
2049	0.22	0.38	0.90
2079	0.59	1.13	2.83
2129	1.20	2.73	7.61

The values in **Table 3.4**, for the year 2049 and 2079, were derived from **Table 3.1** in this sub-appendix. **Table 3.1** and the USACE curves shown in **Figure 3.2** only predicts RSLR to the year 2100. Therefore, to predict the increase in the sea level rise for the year 2129 (100 years into the future), the equations and rates shown in Sections 3.2.1, 3.2.2, and 3.2.3 were used to calculate the predicted increase in the sea level for the Low, Intermediate, and High rates to the year 2129. For the low curve, RSLR trend at Vaca Key of 0.01201 ft. /yr. was applied. Using this rate, RSLR for the lower curve will increase an additional 1.20 feet from the year 2030 to 2129. For the intermediate curve analysis show that the sea level will increase 2.73 feet between the years 2030 to 2129. For the high curve, SLR, will increase 7.61 feet between the years 2030 to 2129. **Table 3.5** to **Table 3.9**, display the water levels with the predicted increase in SLR from 2018 to 2129 for the Low, Intermediate and High USACE SLR curves.

Table 3.5 Water Levels with RSLR at 2129 at Save Point 17

SLR Curve	Annual Exceedance Probability, AEP (1/year) of Water Level (feet, NAVD88) at 2129 with SLR					
	20	**50**	**100**	**200**	**500**	**1,000**
Low	6.29	8.06	9.22	10.45	12.07	13.17
Int.	7.89	9.66	10.82	12.05	13.67	14.77
High	12.98	14.75	15.91	17.14	18.76	19.86

Table 3.6 Water Levels with RSLR at 2129 at Save Point 24

SLR Curve	Annual Exceedance Probability, AEP (1/year) of Water Level (feet, NAVD88) at 2129 with SLR					
	20	**50**	**100**	**200**	**500**	**1,000**
Low	5.98	7.42	8.47	9.64	10.98	11.77
Int.	7.58	9.02	10.07	11.24	12.58	13.37
High	12.67	14.11	15.16	16.33	17.67	18.46

Table 3.7 Water Levels with RSLR at 2129 at Save Point 70

SLR Curve	Annual Exceedance Probability, AEP (1/year) of Water Level (feet, NAVD88) at 2129 with SLR					
	20	**50**	**100**	**200**	**500**	**1,000**
Low	4.67	5.95	6.90	7.73	8.76	9.45
Int.	6.27	7.55	8.50	9.33	10.36	11.05
High	11.36	12.64	13.59	14.42	15.45	16.14

See the Main Engineering Appendix for a more detailed discussion on adaptability of the structural measures for the Florida Keys CSRM study.

3.7 CLIMATE CHANGE IMPACTS TO HYDROLOGY

The USACE May 2015 Civil Works Technical Report, CWTS-2015-03 for the South Atlantic-Gulf Region of the U.S., focuses on temperature, extreme precipitation events, and stream flow trends and future findings. The report encompasses the HUC 03 (see **Figure 3.7**). The report states that trends in temperature and precipitation show a moderate increase, but a decrease in hydrology/stream flow. This is summarized in **Figure 3.8** which is a matrix of observed and projected climate trends from CWTS-2015-03.

If precipitation increases as projected in **Figure 3.8**, potential project vulnerabilities may include increased interior rainfall runoff leading to increased rainfall flooding. For the future trends the report states that the temperature had increased, the precipitation had increases in extreme storm events, but the extent was uncertain and the hydrology showed peak flow increases with a moderate consensus.

Locally, the official climatological gauge for Key West is located at the Key West International Airport. **Figure 3.9** and **Figure 3.10** represent the linear trends in annual total precipitation and annual average temperatures, respectively, over the period 1872-2018. The annual precipitation and temperature is increasing in Key West just as the CWTS-2015-03 predicts.

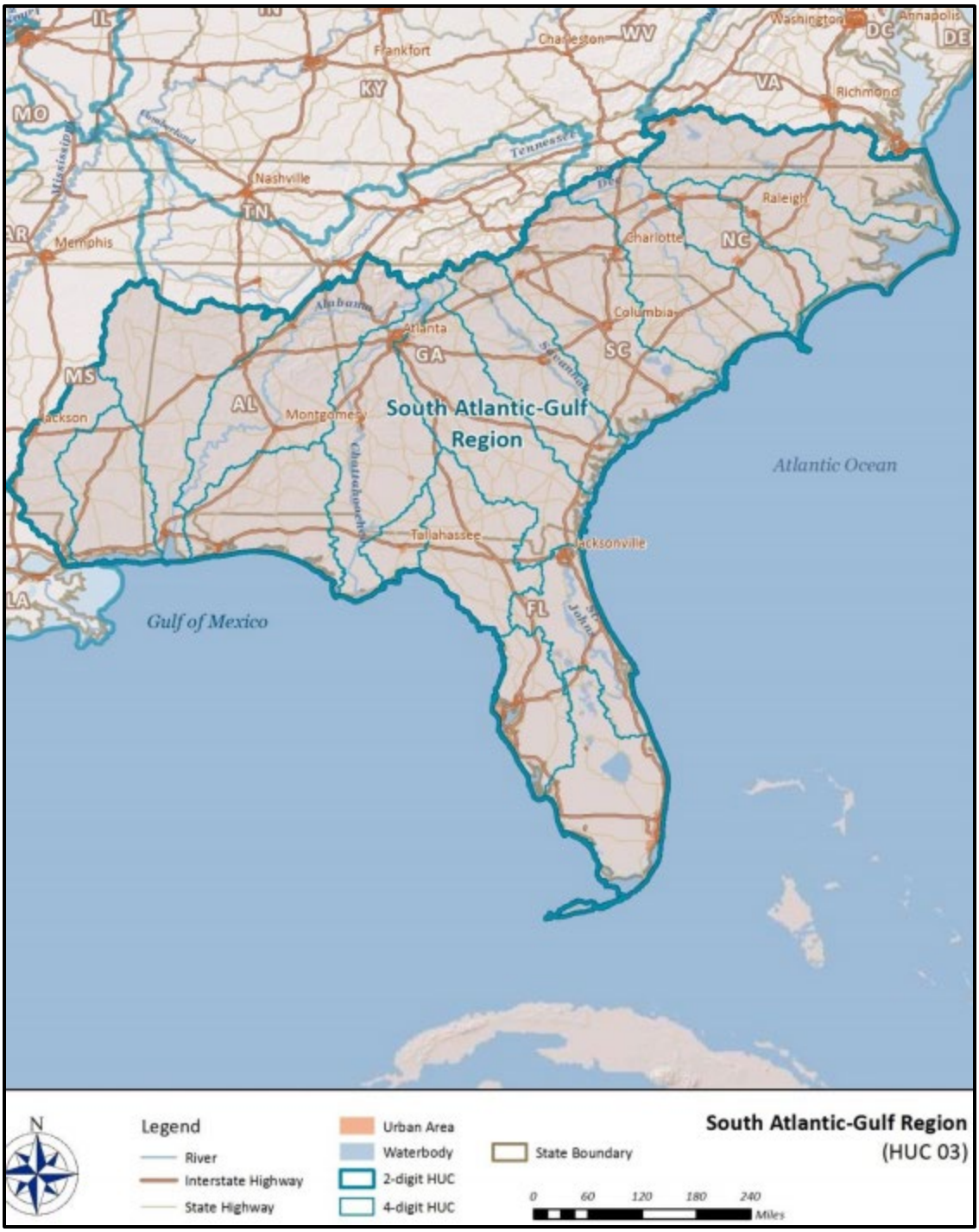

Figure 3.7 Technical Report Reference Map

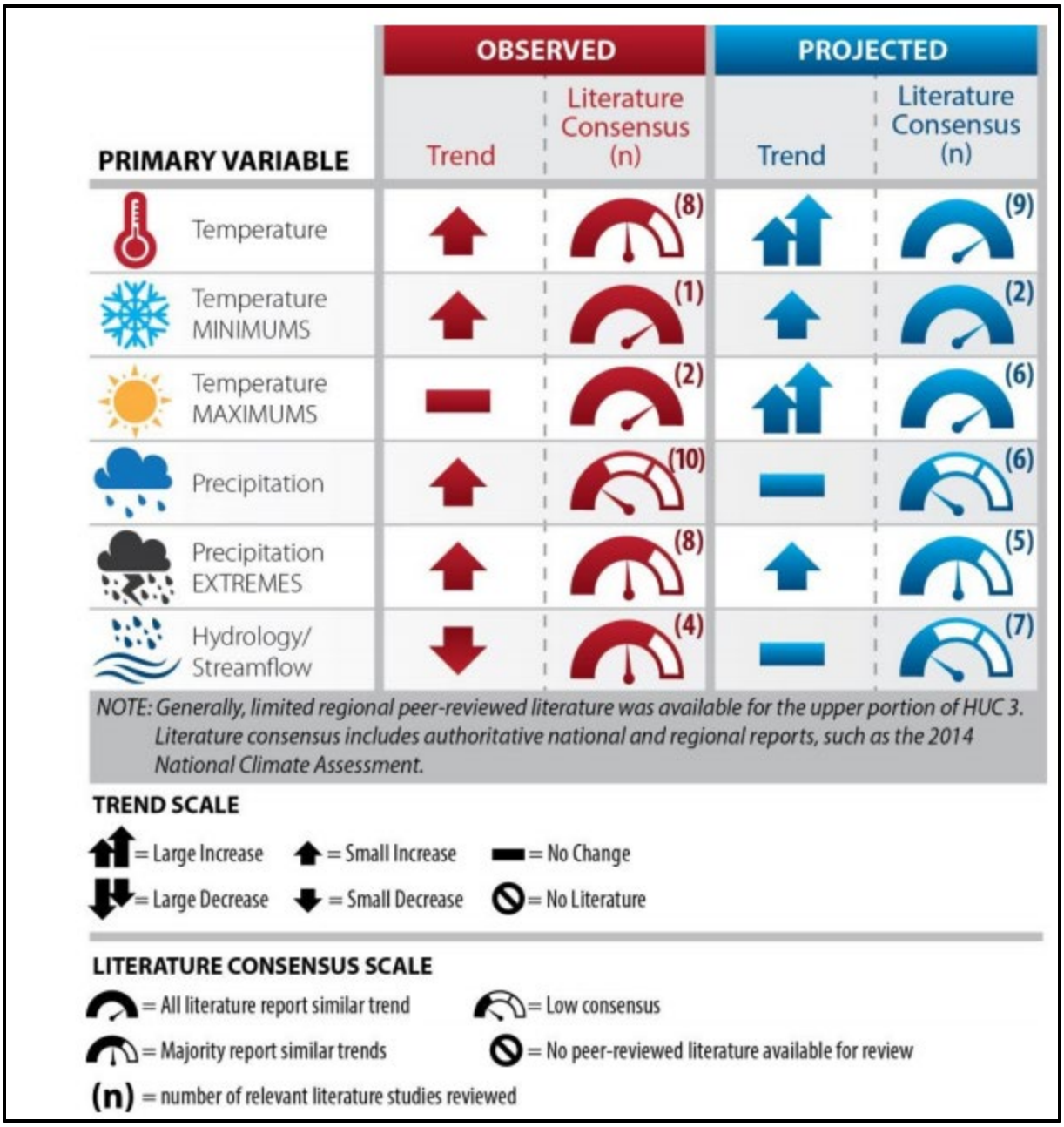

Figure 3.8 Summary matrix of observed and projected climate trends from CWTS-2015-03

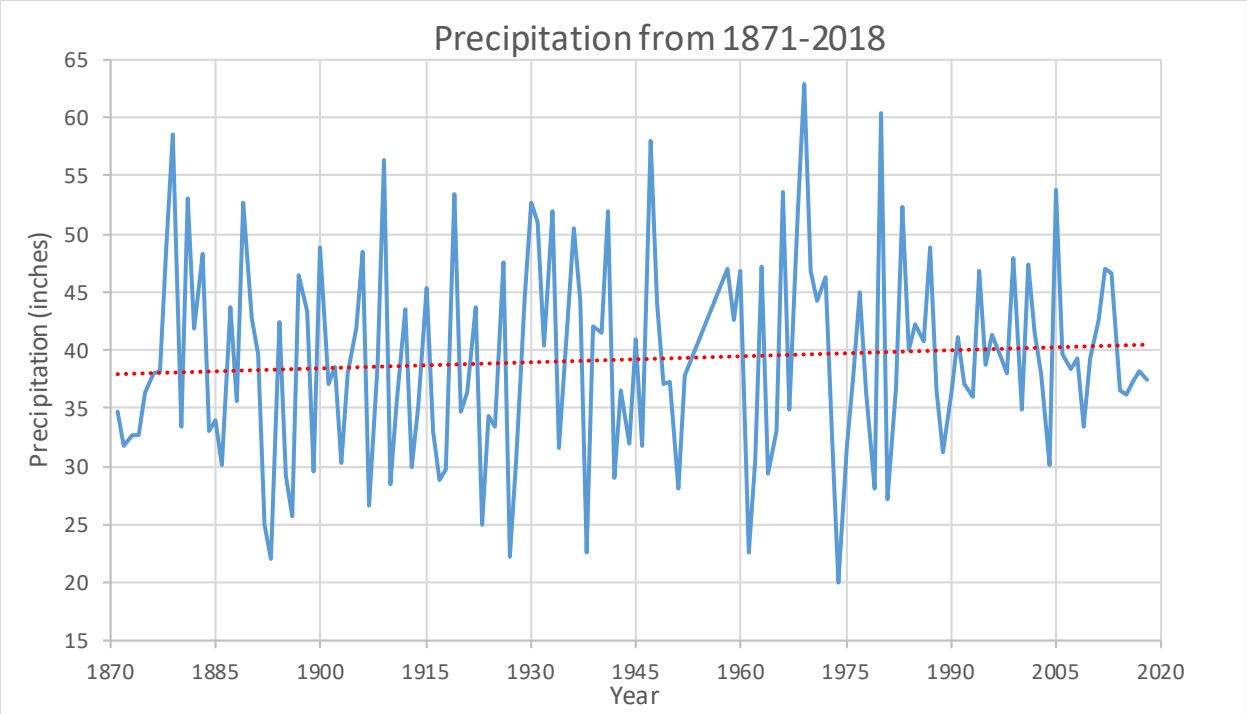

Figure 3.9 Precipitation Trend for Key West

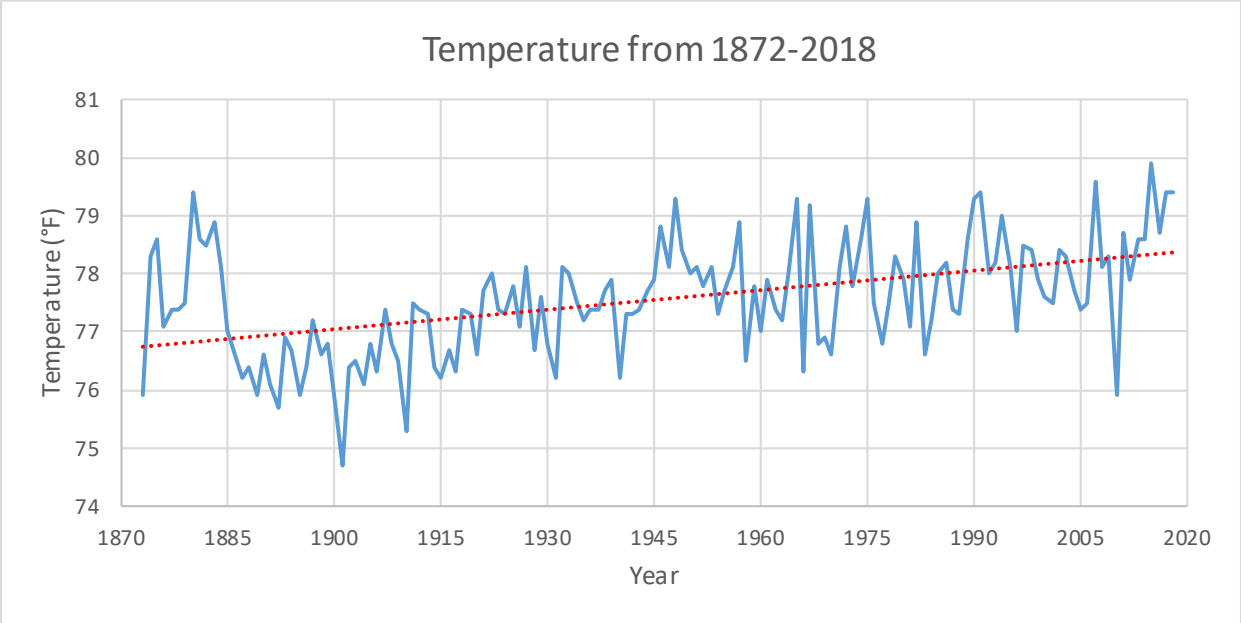

Figure 3.10 Temperature Trend for Key West

The ECB (Engineering and Construction Bulletin) 2018-14 includes the reference to the Climate Hydrology Assessment tool. From the ECB, "The Climate Hydrology Assessment tool allows users to access data concerning past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. This provides qualitative

information about future climate conditions useful to decision-making officials, and allows districts across the country to develop repeatable analytical results using consistent information. The tool reduces potential error while increasing the speed of information development so that data can be used earlier in the decision-making process, ideally in the development of risk registers."

For the Hydrology Tools, both the Nonstationarity Detection Tool and the Climate Hydrology Assessment Tool have USGS stream gages that are listed per HUC watershed. For this study area this tool is not applicable because there are no USGS stream gages that are located in the study area. It is the tide gauge that most represents the water levels in the study area.

3.8 ADAPTATION OF THE COMPONENT OF THE RECOMMENDED PLAN FOR CLIMATE CHANGE

The Florida Keys CSRM Project consists of components that are adaptable to future increases in sea level due to climate change. Currently, 3.29 feet (the high rise in the sea level) were added to the FEMA SFL Stillwater elevations to account for the SLR anticipated for the year 2018 to the year 2079. The shoreline stabilization's top elevations were based off of the road height, not water levels. Florida Department of Transportation (FDOT) and Monroe County have expressed interest in raising US 1. As of this report's publication, no plans have been presented to the USACE to raise US 1 near the shoreline stabilization measures. If the road is raised in the next 50 years behind the measures, more material can be added to match the top of road elevation.

CHAPTER 4 WAVE DATA, MODELING, AND RESULTS

For the Florida Keys CSRM, the wave heights for this project come from the FEMA SFL study. This chapter will discuss how the data influenced the design of the shoreline stabilization measures.

4.1 FEMA SFL STUDY WAVE DATA

The FEMA SFL Study modeling effort, produced not only computed Stillwater elevations for different frequencies (see Chapter 2 and Chapter 3 of this sub-appendix), but significant wave heights (ARI significant wave heights) for each storm frequency as well. The FEMA SFL numerical modeling study produced nearshore wind, wave and water level estimates and the associated marginal and joint probabilities. Data (storms, waves, tides, etc.) was collected from many resources. Once storms were selected and the necessary data input into the ADCIRC model was used to simulate the surge and circulation response to the storms; and SWAN was used to provide the nearshore wave conditions including local wind generated waves. ADCIRC is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions. This model utilizes the finite element method in space allowing the use of highly flexible, unstructured grids. Typical ADCIRC applications have included:

- prediction of storm surge and flooding
- modeling tides and wind driven circulation
- larval transport studies
- near shore marine operations
- dredging feasibility and material disposal studies

The SWAN model runs on the same triangulated mesh that is used with the ADCIRC model. During the model simulations, the water levels from ADCIRC are fed into the SWAN model at 15-minute interval (of model time). The SWAN model computes the wind-driven development of the storm waves, the propagation of the waves over the model domain, and the wave radiation stress gradients where the waves break close to the shore.

Table 4.1 show the FEMA SFL wave data for different save points. **Table 4.2** shows the top of road elevation behind the revetments, the 2018 water level frequencies and the frequency at which the revetment overtops. After water levels reach this elevation, the roads and revetments are submerged and do not experience wave attack until the water recedes.

Table 4.1 Wave Heights

Location	Wave Height (feet)
West Summerland Key	3.97
Bahia Honda Key	4.34
Long Key	3.55
Fiesta Key East	1.57
Fiesta Key West	3.60
Indian Key Fill	2.29

Table 4.2 Top of Road Elevation behind revetments

Measure	Top of Road Elevation (feet, NAVD88)	2018 WL 20 YEAR	2018 WL 50 YEAR	2018 WL 100 YEAR	OVERTOPPING
West Summerland Key	6	4.63	6.07	7.12	50YR
Bahia Honda Key	8				> 100YR
Long Key	4	4.94	6.71	7.87	20 YEAR
Fiesta Key East	10				>100YEAR
Fiesta Key West	5				20 YEAR
Indian Key Fill	10	3.32	4.60	5.55	>100 YEAR

CHAPTER 5 ADJUSTMENTS DURING PRECONSTRUCTION ENGINEERING AND DESIGN (PED)

During PED, the HH&C analysis will be refined and also result in refinement of the design. This chapter will discuss what analysis will be performed during PED.

5.1 WAVE HEIGHTS

The wave heights should be confirmed in the PED phase. If updated or more detailed data sets for wave heights are available, the data should be reevaluated and compared to wave heights used in this study.

5.2 UPDATED SURVEYS

It is recommended that a topographic survey be performed during PED in areas where the revetments will be located. New surveys may require an adjustment in the proposed height of the revetments. A more recent and comprehensive topographic survey will be required in order to develop plans and specifications. An environmental survey will need to be conducted to see where the mangroves exists. The plans will need to be adjusted to allow for the one foot buffer between the mangrove and the toe of the measure.

CHAPTER 6 REFERENCES

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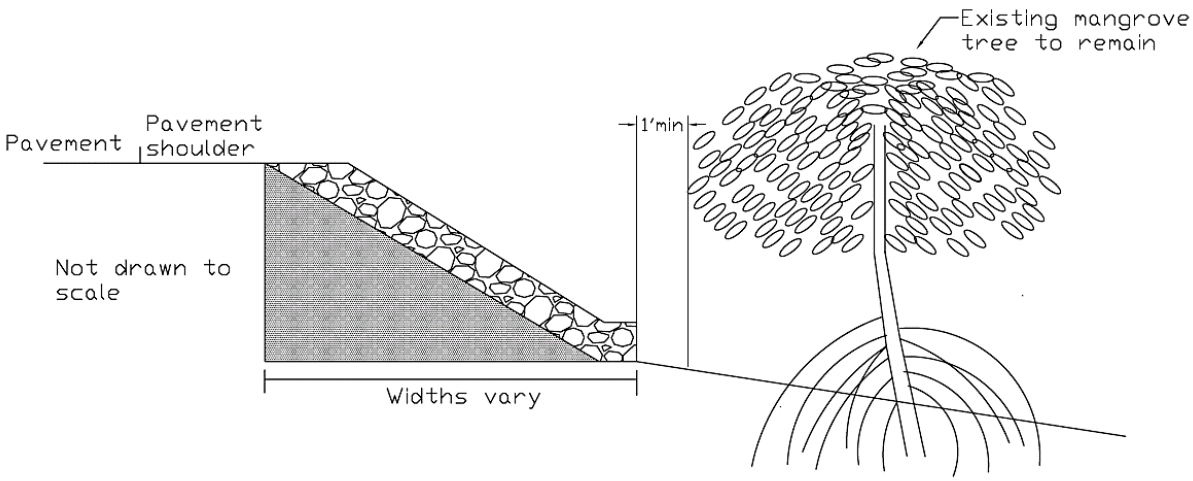
ATTACHMENTS

ATTACHMENT HH&C-1: SAMPLE CROSS SECTION



ATTACHMENT HH&C-2 CALCULATIONS

Florida Keys CSRM | Calculations by | C. Miranda

Revetment Calculations

First find the stable weight or weight of the median stone size needed for the revetment(s) which is calculated by the Hudson Equation (CEM VI-5-67) stated by the equations below:

$$\frac{H_i}{\Delta D_{n50}} = (K_D \cot\alpha)^{1/3}$$

where: H_i = wave height

K_D = stability coefficient

α = structure slope with horizontal

D_{n50} = nominal cube dimension of the median stone size

Δ = relative density of stone which is also defined by the equation $\Delta = \frac{\gamma_r}{\gamma_w} - 1$

γ_r = unit weight of rock

γ_w = unit weight of water

and $W_{50} = D_{n50}^3 \gamma_r$ = weight of median stone

Assume = $H_i = 5$ ft (Based off of FEMA SFL data)

$K_D = 2.0$ (breaking wave) CEM Table VI-5-22

$\alpha = 1:20$

$\cot\alpha = 2.0$

$\gamma_r = 165$ pcf

$\gamma_w = 64$ pcf

Solve for $D_{n50} = \frac{H_i}{\Delta[K_D \times \cot\alpha]^{1/3}} = \frac{5\text{ ft}}{1.578[2\times2]^{1/3}} = \boxed{1.99\text{ ft}}$

$\Delta = \frac{\gamma_r}{\gamma_w} - 1 = \frac{165\text{ pcf}}{64\text{ pcf}} - 1$

$= 1.578$

$W_{50} = D_{n50}\gamma_r = (1.99\text{ ft})^3 \times (165\ \frac{\text{lb}}{\text{ft}^3}) = \boxed{1300\text{ lb}}$

ATTACHMENT HH&C-3 WHITE PAGE ON TIDAL GAUGE SELECTION

To: USACE Climate COP

From: SAJ / NAO SE FL Feasibility Study Teams

Date: 18 January 2019

Subject: South East Florida Sea Level Change Incorporation Strategy

This memo summarizes the selection of an appropriate sea level change record and the plan formulation strategy regarding sea level change for the Southeast Florida Supplemental Feasibility Studies (Miami-Dade Coastal, Miami-Dade Back Bay, and Monroe County).

Sea Level Change Record

A number of long period tide gauges exist in South Florida where three new feasibility studies are under way (Figure 1), two on the Gulf coast, two on the east coast, and two within the Florida Keys in Monroe County. The gauge closest in proximity to Miami-Dade County is the Miami Beach gauge. Typically this gauge and its associated record would be selected to guide the sea level change strategy for the feasibility study due to its proximity and long period of record. However the gauge was discontinued in 1981 and the published sea level trend does not reflect sea level change over the past nearly 40 years and any potential acceleration in sea level change. A new gauge within about 3 miles was subsequently established at Virginia Key in 1994; however, the large temporal gap and spatial differences in gauges makes combining these records prohibitive. Of the other five gauges, the two on the Gulf of Mexico are screened out due to their location on the Gulf of Mexico and distance from the study areas.

Of the three remaining gauges the two in closest proximity to Miami-Dade County, Lake Worth Pier and Vaca Key, have very similar periods of record and similar sea level change trends of approximately 3.7 mm / yr. The Key West gauge has a much longer period of record and much lower sea level change trend of 2.42 mm / yr. Analysis of this gauge via the NOAA "Variation of 50 year trends" tool on the NOAA Tides and Currents website shows that changing the mid-point of a 50 year averaging period (an averaging period similar to Lake Worth Pier and Vaca Key) can produce very different sea level change trends as shown in Figure 2. What is evident from the figure is that the sea level change trend has been increasing with the highest level reported utilizing the most recent averaging period. This points to an increase in the sea level change trend throughout southeast Florida. Vertical land movement data is available at both Miami and Key West from NASA JPL (https://sideshow.jpl.nasa.gov/post/series.html). The land movement at both sites were examined (Figure 3 and 4). The Miami site appears to reflect a distinct shift in horizontal location during the record which leads to a highly uncertain trend in vertical land movement of -1.402 ± -1.348 mm / yr. For Key West the vertical land movement trend is -0.272 ± -0.988 mm / yr. Due to the short record for both locations there is tremendous uncertainty in both records. Nevertheless both locations point to a slight decrease in land surface height over time. Both the Keys and Miami are subject to similar large scale oceanographic forcing. Due to their orientations the predominant wave characteristics are different at each site, but the larger scale physical oceanography is similar. Figure 5 shows a "spaghetti plot" of the trajectories of all NOAA AOML Drifting Buoy Data Assembly Center's archived near-surface buoys from 1978 to 2003. The corresponding speeds of the

trajectories are color-coded which makes the major currents visible. It is evident in the plot that the gauges located in the Keys and those off the SE FL mainland coast are both predominantly subject to the Florida Current.

Based on the increase in sea level change trend observed in Key West and the similarity in sea level change trend for both Vaca Key and Lake Worth Pier along with similar vertical land movement and physical oceanographic conditions throughout the area, it is appropriate to use the sea level change rate at Vaca Key or Lake Worth Pier for the Miami-Dade and Monroe County studies. With Vaca Key located within Monroe County and within similar proximity to the focus areas of the Miami-Dade studies as Lake Worth Pier, the Vaca Key tide gauge and associated sea level change trend will be adopted for the Monroe and (2) Miami-Dade County feasibility studies. While the Vaca Key gauge has been chosen to estimate the potential range of SLC to be evaluated, the other gauges will be useful in determining short and long-term variability of Total Water Levels via NOAA's estimates for Extreme Water Levels.

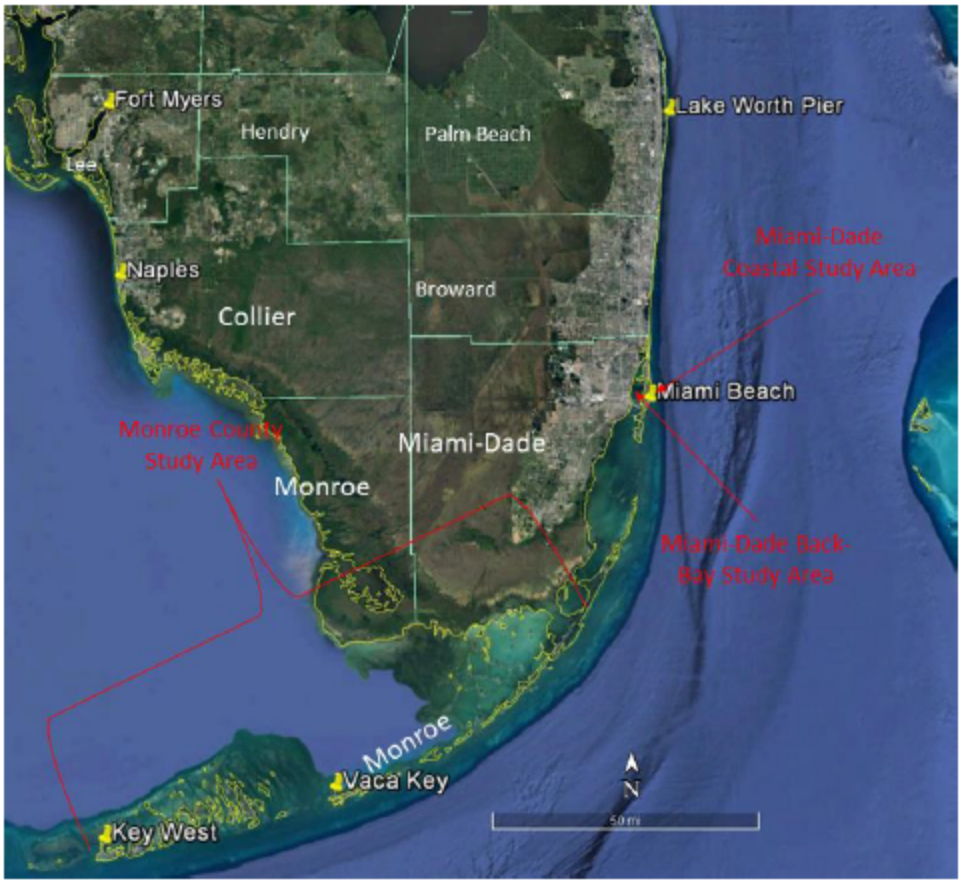


Figure 1: Locations of long period tidal records in South Florida along with county boundaries (https://tidesandcurrents.noaa.gov/sltrends/)

Table 1: South Florida Tide Gauges, Periods of Record, and Relative Sea Level Trend

Tide Gauge	Period of Record	Relative Sea Level Trend (mm / yr)
Fort Myers	1965 – Present	3.10 ± 0.49
Naples	1965 – Present	2.80 ± 0.45
Key West	1913 – Present	2.42 ± 0.15
Vaca Key	1971 – Present	3.69 ± 0.46
Miami Beach	1931 – 1981	2.39 ± 0.43
Lake Worth Pier	1970 – Present	3.70 ± 0.58

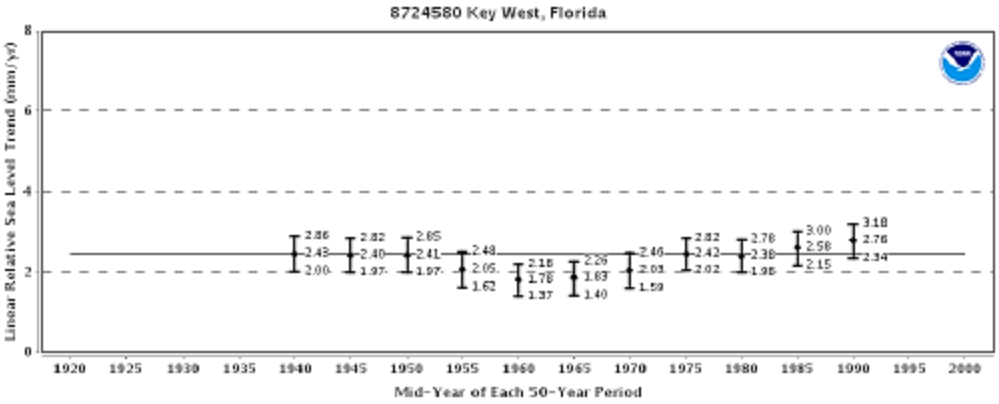


Figure 2: Variation of 50 year trends at the Key West Tide Gauge
(https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?plot=50yr&id=8724580)

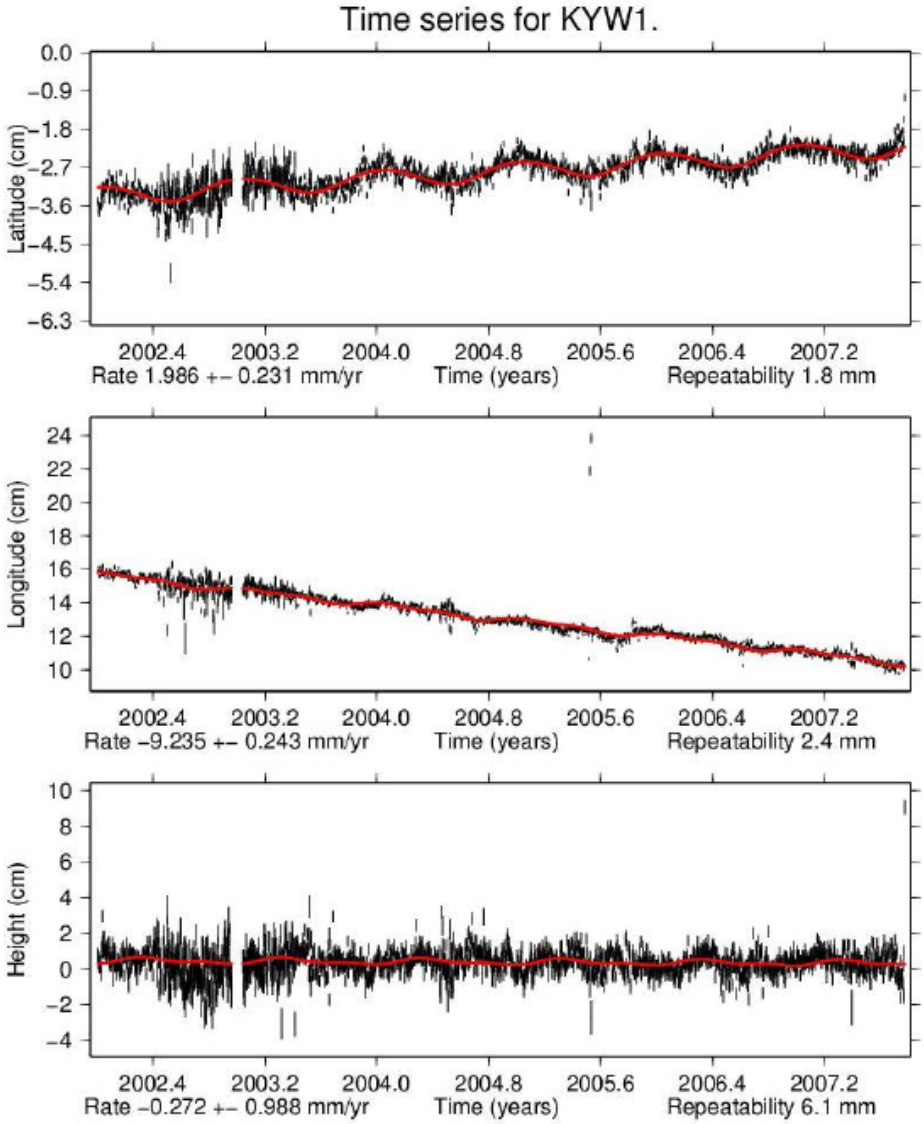


Figure 3: Land Movement at Key West (https://sideshow.jpl.nasa.gov/post/series.html)

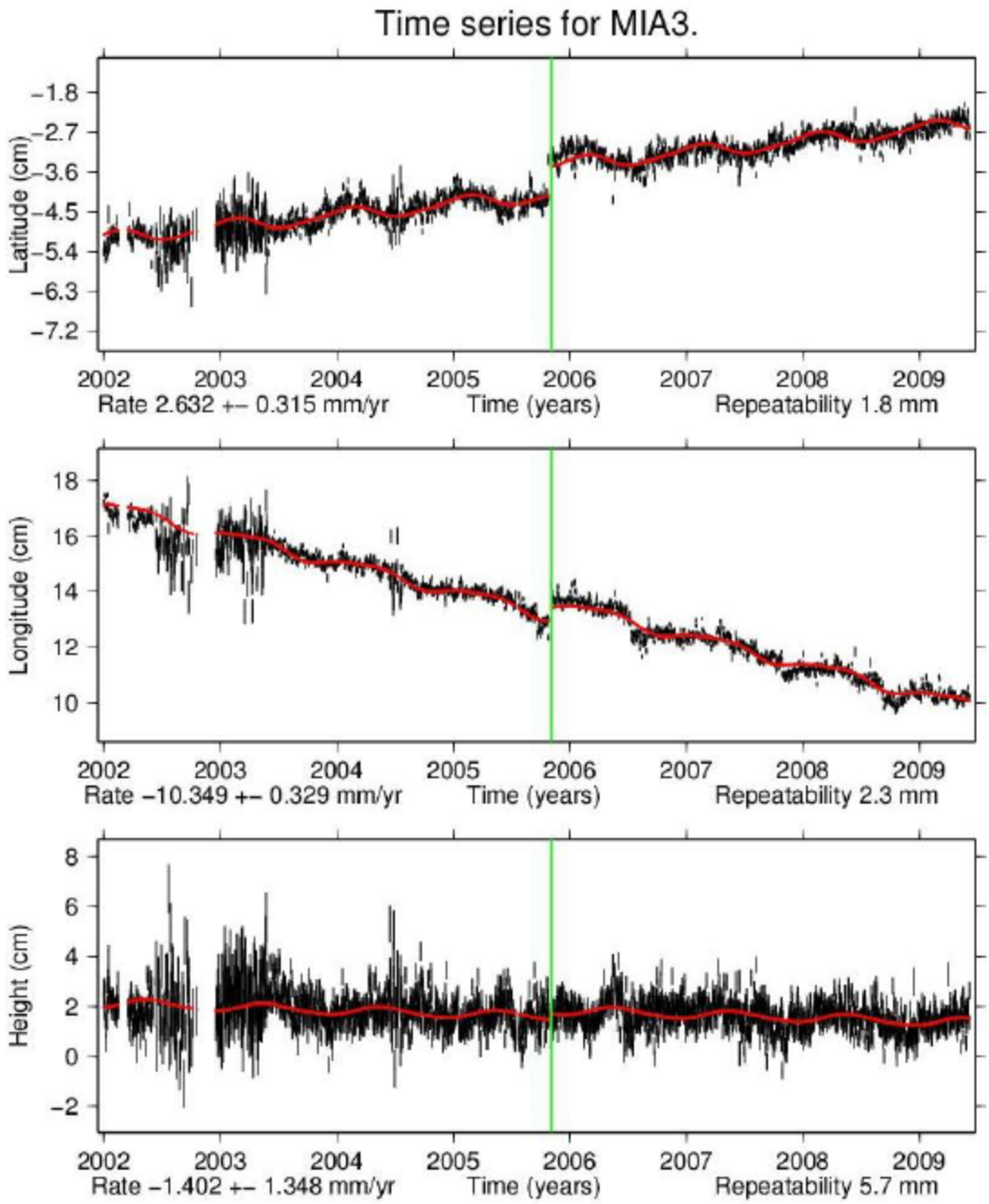


Figure 4: Land movement at Miami (https://sideshow.jpl.nasa.gov/post/series.html)

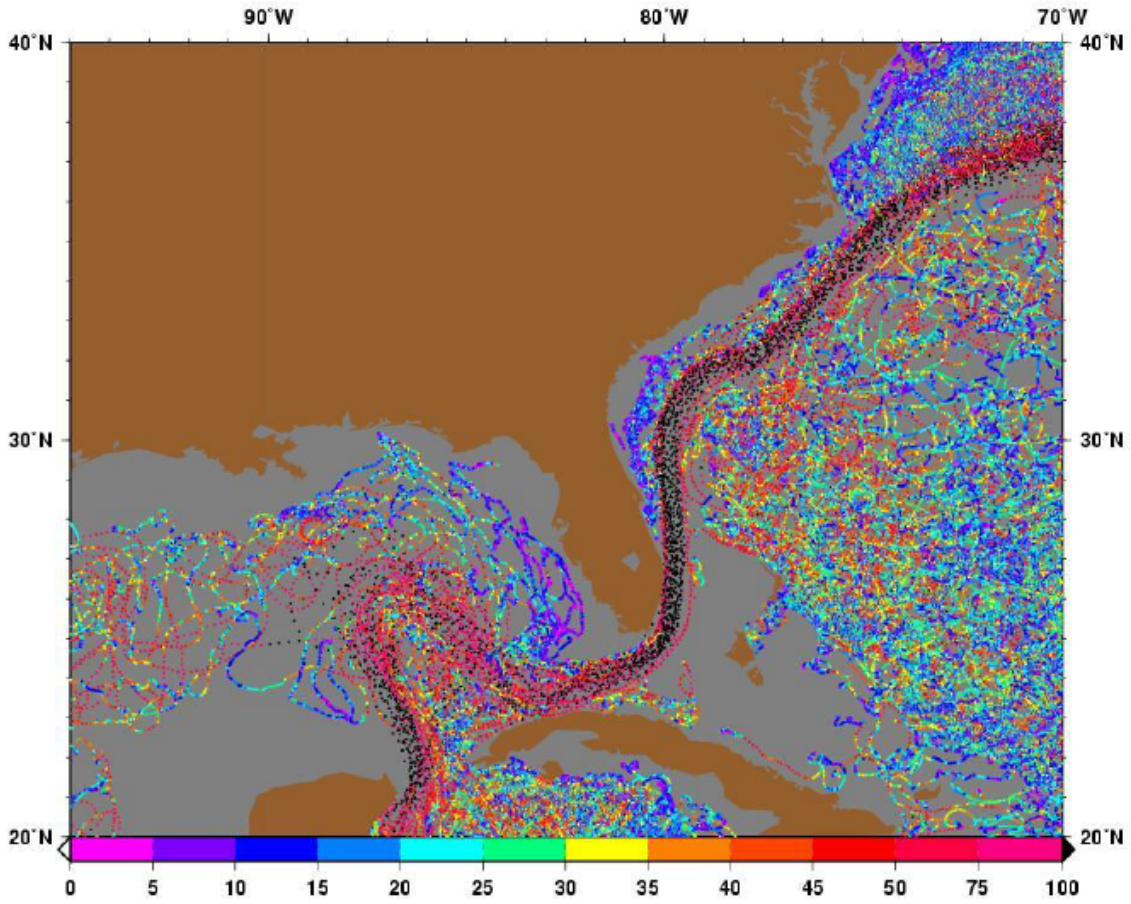


Figure 5: Spaghetti plot of the trajectories of all NOAA AOML Drifting Buoy Data Assembly Center's archived near-surface buoys from 1978 to 2003. The corresponding speeds of the trajectories are color-coded which makes the major currents visible. (https://oceancurrents.rsmas.miami.edu/caribbean/spaghetti-speed/florida.jpg)

Sea Level Change Plan Formulation Strategy

Miami-Dade and Monroe Counties are heavily involved and invested in sea level change research and searching for solutions for their counties. As such, they are members of the South East Florida Regional Climate Change Compact (SEFLRCCC). They released a unified sea level rise projection (Figure 3) in 2015 featuring three global curves adapted specifically for regional use. These curves are the median of the IPCC AR5 RCP8.5 scenario as the low boundary, the USACE High Curve as the upper boundary for short term use until 2060, and the NOAA High Curve as the uppermost boundary for medium to long term use. The USACE Intermediate/NOAA Intermediate Low Curves are shown as reference on the plot but not currently part of the SEFLRCCC guidance. Based on the SEFLRCCC guidance, the possibility of incorporating the NOAA High Curve into the plan formulation strategy has been explored.

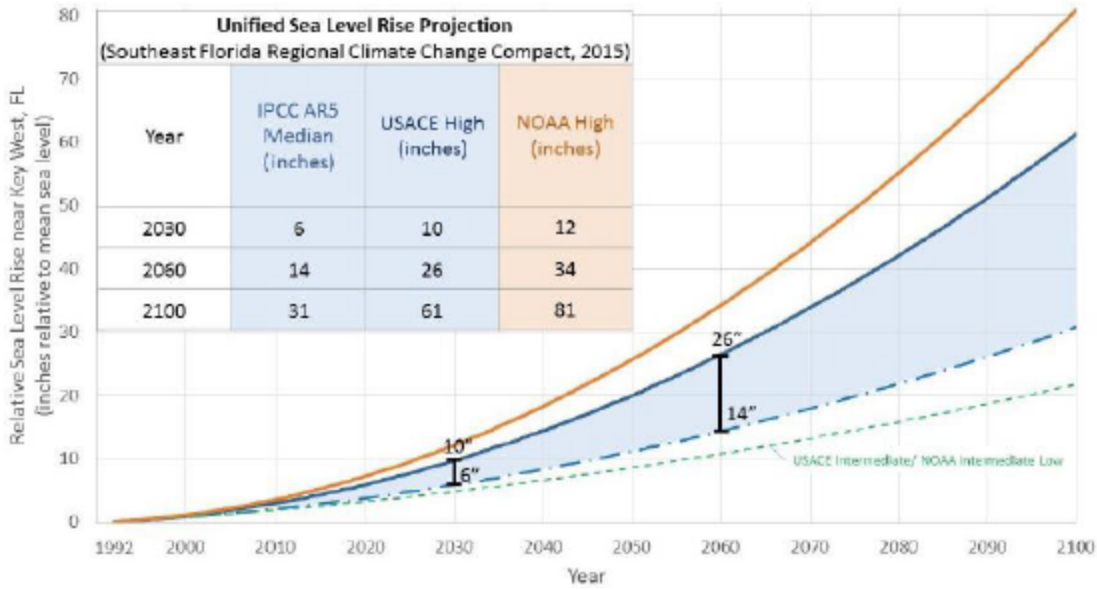


Figure 6: South East Florida Regional Climate Change Compact unified sea level rise projections

To incorporate the direct and indirect physical effects of projected future sea level change (SLC) on design, construction, operation, and maintenance of coastal projects, USACE has provided guidance in the form of Engineer Regulation, ER 1100-2-8162, and Engineer Technical Letter (ETL) 1100-2-1. Three estimates are required by the guidance; a baseline (or "low") estimate, which is based on historic sea level rise (SLR) and represents the minimum expected SLC, an intermediate estimate, and a high estimate representing the maximum expected SLC. These three curves are not only required by guidance but "hard-wired" into the Beach-fx and G2CRM models. Any rigorous assessment of additional curves within Beach-fx or G2CRM would require modifications to the software and potential re-certification prior to application. Given the scope and schedule of these feasibility studies these actions are seen as too much risk to the study schedule. As such these studies will work with the three USACE curves, formulating to one and assessing sensitivity to the other two. Additionally the study teams will work with Climate COP to develop a table-top procedure to assess sensitivity to the NOAA High Curve.

For the Vaca Key gauge the USACE Sea Level Tracker application (website) shows both the 19 year moving average and the 5 year moving average of Mean Sea Level (MSL) in Figure 4. Also shown in the figure are the USACE Low, Intermediate, and High Curves as well as the NOAA High Curve superimposed on the plot. The recent trend in both the shorter and longer term moving averages is trending above the USACE Intermediate Curve and toward the USACE High Curve. To visualize the longer planning horizon, the three USACE curves are shown in Figure 5 for Vaca Key out to 2100. In general the engineering features being considered for the back bay studies are less adaptable and must be designed considering a longer term planning horizon which includes greater uncertainty in sea level change. While soft engineering options considered for the coastal studies are more adaptable, for consistency across the region and based on sea level change trends a single unified formulation strategy is suggested. Based on all presented, the project teams recommend to formulate alternatives to the USACE High Curve and test sensitivity to the USACE Intermediate and Low Curves while working with the Climate COP to develop sensitivity tests for the NOAA High Curve.

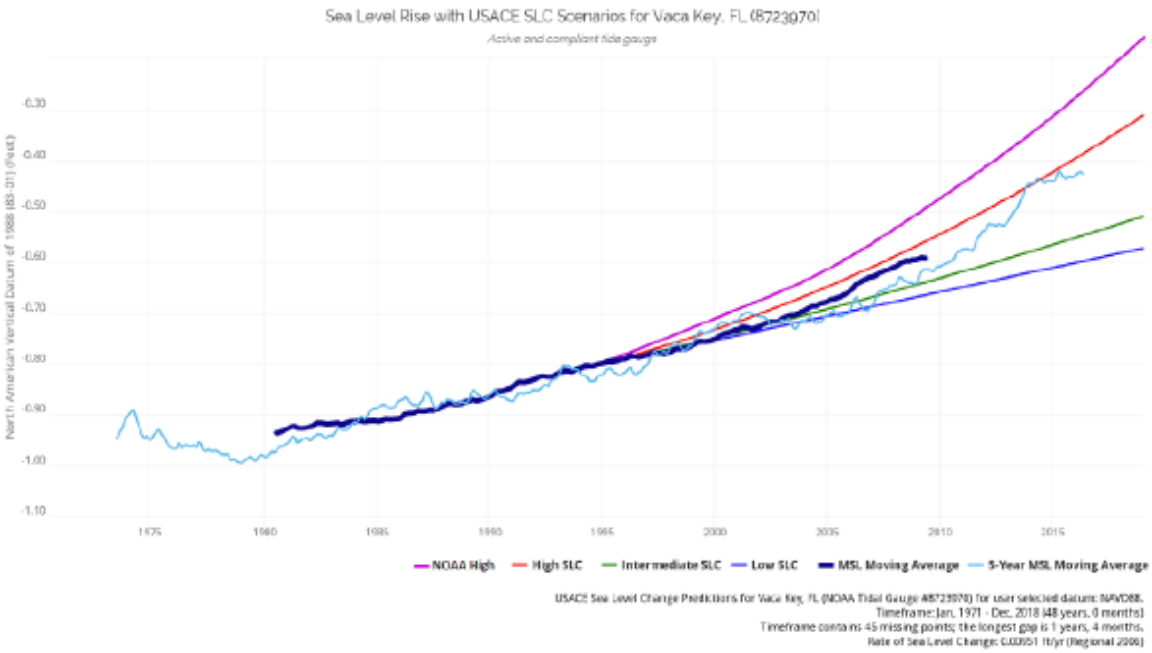


Figure 7: USACE Sea Level Tracker for Vaca Key with NOAA High Curve superimposed

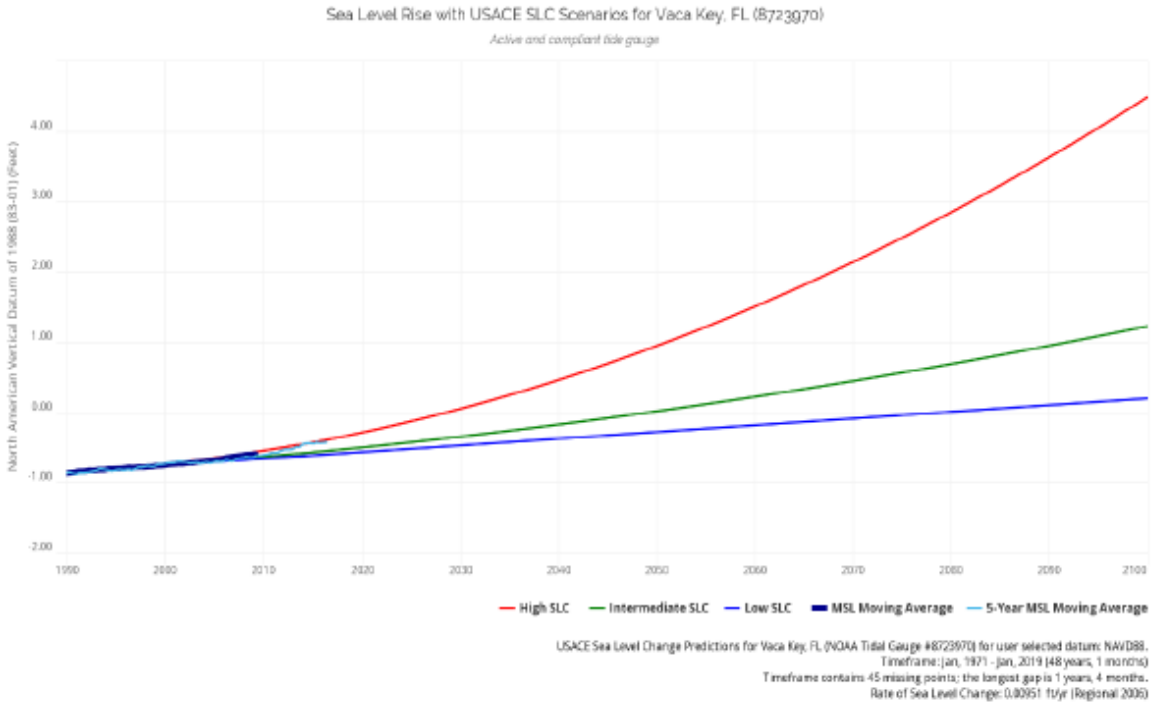


Figure 8: USACE Sea Level Tracker for Vaca Key for the long term planning horizon

Based on the conclusions described above and in accordance with ER 1100-2-8162, the plan formulation strategy in these three feasibility studies will have five broad steps:

1.) The future without project (FWOP) condition will be simulated in all three USACE SLR scenarios (low, intermediate, and high). This will allow the team to understand how future damages are likely to occur over time and space in the absence of a Federal project. The quantified FWOP will also make it possible to determine which management measures (dunes and/or nourishment, seawalls, breakwaters, etc.) could be economically viable in which planning reaches. At this stage of the formulation process, a number of measures are likely to be screened out based on the spatial and temporal distribution of damages in the three scenarios.
2.) Various management measures will be combined into project alternatives. The alternatives will be compared and evaluated based on the High USACE SLR curve.
3.) A Tentatively Selected Plan will be selected based on the alternative that maximizes net benefits in the high curve, provided it is environmentally acceptable and feasible from an engineering standpoint.
4.) The future with project (FWP) condition will be simulated, based on the TSP in all three SLR scenarios. This will provide important information about project performance and economic viability in all three scenarios. The high curve will be the basis for plan selection, but the other two will be used as important sensitivity analyses. The BCR and net benefits of the project will be reported in all three scenarios.
5.) A table top procedure will allow the team to qualitatively consider project performance and effectiveness in the NOAA High scenario. The NOAA High Curve will not be modeled.

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US Army Corps of Engineers®

Norfolk District

FLORIDA KEYS COASTAL STORM RISK MANAGEMENT (CSRM)

DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

COST ENGINEERING SUB-APPENDIX

JUNE 2020

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CHAPTER 1 Introduction

1.1 COST NARRATIVE

Corps of Engineers cost estimates for planning purposes are prepared in accordance with the following guidance:

- Engineer Technical Letter (ETL) 1110-2-573, Construction Cost Estimating Guide for CivilWorks, 30 September 2008
- Engineer Regulation (ER) 1110-1-1300, Cost Engineering Policy and General Requirements, 26 March 1993
- ER 1110-2-1302, Civil Works Cost Engineering, 15 September 2008
- ER 1110-2-1150, Engineering and Design For Civil Works Projects, 31 August 1999
- ER 1105-2-100, Planning Guidance Notebook, 22 April 2000, as amended
- Engineer Manual (EM) 1110-2-1304 (Tables revised 30 March 2007), Civil Works Construction Cost Index System, 31 March 2013
- CECW-CP Memorandum For Distribution, Subject: Initiatives To Improve The Accuracy Of Total Project Costs In Civil Works Feasibility Studies Requiring Congressional Authorization, 19 Sep 2007
- CECW-CE Memorandum For Distribution, Subject: Application of Cost Risk Analysis Methods To Develop Contingencies For Civil Works Total Project Costs, 3 Jul 2007
- Cost and Schedule Risk Analysis Guidance, 17 May 2009

The goals of the cost engineering for the Florida Keys Coastal Storm Risk Management Feasibility Study are to present a Total Project Cost (construction and non-construction costs) for the Tentatively Selected Plan (TSP) at the current price level to be used for project justification/authorization and to project costs forward in time for budgeting purposes. In addition, the costing efforts are intended to produce a final product, or cost estimate, that is reliable and accurate and that supports the definition of the Government's and the non-Federal sponsor's obligations.

1.2 PROJECT DESCRIPTION

The feasibility study formulates, evaluates, and compares reasonable solutions to reduce the risk of coastal storm damages to property and infrastructure and minimize risk to public safety in the study area. The study area is located entirely in Monroe County, Florida.

A number of alternatives were considered by the PDT in order to accomplish the goals of

reducing the risk of coastal storm damages and minimize risk to public safety. These alternatives consist of shoreline stabilization via revetments along segments of Route 1, floodproofing/elevating/acquisition of both critical and noncritical structures found throughout the study areas.

CHAPTER 2 Alternatives

2.1 Alternative 1 – Route 1 Revetments (Structural)

Alternative 1 includes addressing segments of Route 1 identified as vulnerable to coastal storm damage by means of shoreline stabilization, to reduce erosion impacts on the roadway itself. This will greatly decrease the amount of damage to the roadway during coastal storm events. Shoreline stabilization will be achieved by constructing revetments throughout the study area.

2.2 Alternative 2 – Critical Infrastructure (Non-Structural)

Alternative 2 includes the protection of critical infrastructure throughout the study areas. This includes fire stations, medical facilities, police stations, potable water facilities, wastewater facilities, EOC facilities and airport facilities. This alternative makes use of Floodproofing, Elevation and acquisition to protect these structures.

2.3 Alternative 3 – Population/Development (Non-Structural)

Alternative 3 includes the protection of highly populated and developmental areas not deemed as critical infrastructure throughout the study areas. This alternative makes use of Floodproofing, Elevation and acquisition to protect these structures.

2.4 Alternatives 4-6 – Screened Out

Alternatives 4-6 were screened out early in the process, and therefore not considered.

2.5 Alternative 7 – Combination of Alternatives 1, 2 & 3

Alternative 7 is a combination of Alternatives 1, 2 & 3.

2.6 Tentatively Selected Plan – Alternative 7

Alternative 7 has been chosen as the tentatively selected plan. It includes 5,500 linear feet of shoreline stabilization via revetments, as well as 232 acquisitions, the floodproofing of 26 critical insfrastructures and 916 non-critical infrastructures, as well as the elevation of 8,902 structures.

CHAPTER 3 Cost Estimate

3.1 Basis of Estimate

The structural construction cost estimate was developed using Micro-Computer Aided Cost Estimating System (MCACES), Second Generation (MII) using the appropriate Work Breakdown Structure (WBS). These cost estimates were developed utilizing cost resources such as RSMeans, MII Cost Libraries, and vendor quotations and are supported by the preferred labor, equipment, materials, and crew/production breakdown to align with current construction methods. Quantities were provided by the PDT and checked by the cost engineer.

The nonstructural cost estimate was developed based on data obtained by the PDT from the USACE NATIONAL NONSTUCTURAL COMMITTEE BEST PRACTICE GUIDE 2020-01 and New Orleans District (2012 Donaldson to the Gulf Study). This data consists of square foot costs for each structure based on type, size and elevation desired.

The MII report is provided at Attachment 1 to this cost engineering appendix.

3.2 Contingency

The goal in contingency development is to identify the uncertainties associated with an item of work or task, forecast the cost/risk relationship, and assign a value to this task that would limit the cost risk to an acceptable degree of confidence. Consideration must be given to the details available at each stage of planning, design, or construction for which a cost estimate is being prepared.

An Abbreviated Risk Analysis (ARA) was conducted in according with the procedures outlined in the manual entitled “Cost and Schedule Risk Analysis Guidance”, dated 17 May 2009. Members of the Norfolk District Project Delivery Team (PDT) participated in a cost risk analysis brainstorming session to identify risks associated with the project. The Risk Analysis utilized the “LOW RISK” category as the project involves typical construction with possible life safety issues. Assumptions were made to the likelihood and impact of each risk

item, as well as the probability of occurrence and magnitude of the impact if it were to occur. Adjustments were made to the analysis upon review by the PDT and the final contingencies were established. The ARA Report is provided as Attachment 2 to this Cost Engineering Appendix.

3.3 PLANNING, ENGINEERING, AND DESIGN (PED)

Costs for Planning, Engineering and Design (PED) have been included based on the standard percentage included in the Total Project Cost Summary (TPCS). The percentage breakout can be found in the TPCS.

3.4 CONSTRUCTION MANAGEMENT (S&A)

Costs for Construction Management (S&A) have been included based on the standard percentage included in the Total Project Cost Summary (TPCS). The percentage breakout can be found in the TPCS.

3.5 TOTAL PROJECT COST SUMMARY (TPCS)

The Total Project Cost Summary (TPCS) addresses the inflation through project completion; accomplished by escalation to the mid-point of construction. The TPCS includes Federal and non-Federal costs for all construction features of the project, PED and S&A, along with the appropriate contingencies and escalation associated with each of these activities. The TPCS is formatted according to the CWWBS. The TPCS was prepared using the MCACES/MII cost estimate, contingencies developed by the ARA, the project design and construction schedule, and estimates of PED and S&A prepared by others. The TPCS for both the Structural and Non-Structural TSPs are provided as Attachments 3 and 4 to this Cost Engineering Appendix.

ATTACHMENT 1
MII Report

Florida Keys CSRM Feasibility Study

Estimated by	USACE - LRH
Designed by	N/A
Prepared by	Bryan R. Adkins
Preparation Date	5/19/2020
Effective Date of Pricing	5/19/2020
Estimated Construction Time	730 Days

This report is not copyrighted, but the information contained herein is For Official Use Only.

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2.1.2 BAHIA HONDA KEY 1
2.1.3 LONG KEY 1
2.1.4 FIESTA KEY WEST 1
2.1.5 FIESTA KEY EAST 1
2.1.6 INDIAN KEY FILL 1
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2.2.2 INDIAN KEY FILL Real Estate 1
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2.2.4 FIESTA KEY EAST Real Estate 2
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2.3 CULTURAL MITIGATION 2
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3.1 ACQUISITION COSTS 2
3.1.1 Real Estate 2
3.1.2 Acquisition 2
3.2 CRITICAL INFRASTRUCTURE 2
3.3 FLOODPROOFING COSTS 2
3.4 ELEVATION 2

Description	Quantity	UOM	DirectCost	ContractCost	Contingency	ProjectCost
Project Cost Summary Report			**3,157,236,308**	**3,160,040,471**	**0**	**3,160,040,471**
2 STRUCTURAL	**1.00**	**LS**	**6,746,159**	**9,550,322**	**0**	**9,550,322**
2.1 ROUTE 1 SHORELINE STABILIZATION (REVETMENTS)	**1.00**	**LS**	**6,585,339**	**9,389,501**	**0**	**9,389,501**
2.1.1 WEST SUMMERLAND KEY	**1.00**	**LS**	**747,829**	**1,064,447**	**0**	**1,064,447**
2.1.1.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.1.2 Revetment	**1.00**	**LS**	**475,827**	**682,172**	**0**	**682,172**
2.1.1.3 Environmental Mitigation	**1.00**	**LS**	**222,002**	**312,005**	**0**	**312,005**
2.1.2 BAHIA HONDA KEY	**1.00**	**LS**	**2,120,692**	**3,014,238**	**0**	**3,014,238**
2.1.2.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.2.2 Revetment	**1.00**	**LS**	**1,646,196**	**2,347,374**	**0**	**2,347,374**
2.1.2.3 Environmental Mitigation	**1.00**	**LS**	**424,496**	**596,593**	**0**	**596,593**
2.1.3 LONG KEY	**1.00**	**LS**	**1,415,951**	**2,014,456**	**0**	**2,014,456**
2.1.3.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.3.2 Revetment	**1.00**	**LS**	**1,006,455**	**1,438,944**	**0**	**1,438,944**
2.1.3.3 Environmental Mitigation	**1.00**	**LS**	**359,496**	**505,241**	**0**	**505,241**
2.1.4 FIESTA KEY WEST	**1.00**	**LS**	**1,313,420**	**1,878,819**	**0**	**1,878,819**
2.1.4.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.4.2 Revetment	**1.00**	**LS**	**1,263,420**	**1,808,548**	**0**	**1,808,548**
2.1.5 FIESTA KEY EAST	**1.00**	**LS**	**660,063**	**948,228**	**0**	**948,228**
2.1.5.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.5.2 Revetment	**1.00**	**LS**	**610,063**	**877,958**	**0**	**877,958**
2.1.6 INDIAN KEY FILL	**1.00**	**LS**	**327,384**	**469,313**	**0**	**469,313**
2.1.6.1 Mob/Demob	**1.00**	**LS**	**50,000**	**70,271**	**0**	**70,271**
2.1.6.2 Revetment	**1.00**	**LS**	**277,384**	**399,042**	**0**	**399,042**
2.2 REAL ESTATE COSTS	**1.00**	**LS**	**66,925**	**66,925**	**0**	**66,925**
2.2.1 WEST SUMMERLAND KEY Real Estate	**1.00**	**LS**	**36,925**	**36,925**	**0**	**36,925**

Description	Quantity	UOM	DirectCost	ContractCost	Contingency	ProjectCost
2.2.2 INDIAN KEY FILL Real Estate	1.00	LS	9,000	9,000	0	9,000
2.2.4 FIESTA KEY EAST Real Estate	1.00	LS	3,000	3,000	0	3,000
2.2.5 LONG KEY Real Estate	1.00	LS	9,000	9,000	0	9,000
2.2.6 BAHIA HONDA KEY Real Estate	1.00	LS	9,000	9,000	0	9,000
2.3 CULTURAL MITIGATION	1.00	LS	93,895	93,895	0	93,895
3 NONSTRUCTURAL	1.00	LS	3,150,490,149	3,150,490,149	0	3,150,490,149
3.1 ACQUISITION COSTS	1.00	LS	395,637,641	395,637,641	0	395,637,641
3.1.1 Real Estate	1.00	LS	105,134,414	105,134,414	0	105,134,414
3.1.2 Acquisition	1.00	LS	290,503,227	290,503,227	0	290,503,227
3.2 CRITICAL INFRASTRUCTURE	1.00	LS	9,902,150	9,902,150	0	9,902,150
3.3 FLOODPROOFING COSTS	1.00	LS	802,376,266	802,376,266	0	802,376,266
3.4 ELEVATION	1.00	LS	1,942,574,092	1,942,574,092	0	1,942,574,092

ATTACHMENT 2
Abbreviated Risk Analysis

Abbreviated Risk Analysis

Project (less than $40M): **Florida Keys CSRM Feasibility Study**
Project Development Stage/Alternative: **Feasibility (Recommended Plan)**
Risk Category: **Low Risk: Typical Construction, Simple**

Alternative: **Recommended Plan**
Meeting Date: **1/7/2020**

Total Estimated Construction Contract Cost = **$ 9,567,513**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
1	16 BANK STABILIZATION	WEST SUMMERLAND KEY	$ 1,064,447		23.65%	$ 251,782	$ 1,316,229
2	16 BANK STABILIZATION	BAHIA HONDA KEY	$ 3,014,238		23.65%	$ 712,980	$ 3,727,218
3	16 BANK STABILIZATION	LONG KEY	$ 2,014,456		23.65%	$ 476,494	$ 2,490,950
4	16 BANK STABILIZATION	FIESTA KEY WEST	$ 1,878,819		23.65%	$ 444,411	$ 2,323,230
5	16 BANK STABILIZATION	FIESTA KEY EAST	$ 948,228		23.65%	$ 224,291	$ 1,172,519
6	16 BANK STABILIZATION	INDIAN KEY FILL	$ 469,313		23.65%	$ 111,010	$ 580,323
7	02 RELOCATIONS	NONSTRUCTURAL	$ 2,754,852,508		31.76%	$ 874,965,543	$ 3,629,818,051.50
8	02 RELOCATIONS	ACQUISITION	$ 290,503,227		48.26%	$ 140,195,119	$ 430,698,346.09
9			$ -		0.00%	$ -	$ -
17	All Other	**Remaining Construction Items**	$ (3,045,177,723)	*0.0%*	0.00%	$ 9,567,513	$ (3,035,610,210)
18	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 2,303,857		0.00%	$ -	$ 2,303,857
19	31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 704,169		0.01%	$ 77	$ 704,246
XX	FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 9,567,513	15547.04%	1487465309	$ 1,497,032,822	
Total Planning, Engineering & Design	$ 2,303,857	0.00%	$ -	$ 2,303,857	
Total Construction Management	$ 704,169	0.01%	$ 77	$ 704,246	
Total	**$ 12,575,539**	**11828%**	**$ 1,487,465,387**	**$ 1,500,040,926**	
		Base	**50%**	**80%**	
	Range Estimate ($000's)	$12,576k	$905,055k	$1,500,041k	

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.	

Florida Keys CSRM Feasibility Study Recom 7-Jan-20

Feasibility (Recommended Plan)

Abbreviated Risk Analysis

Meeting Date: 7-Jan-20

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Register

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Scope Growth					**Maximum Project Growth**		**40%**
PS-1	WEST SUMMERLAND KEY	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-2	BAHIA HONDA KEY	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-3	LONG KEY	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-4	FIESTA KEY WEST	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-5	FIESTA KEY EAST	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-6	INDIAN KEY FILL	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Marginal	Possible	1
PS-7	NONSTRUCTURAL	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Moderate	Possible	2
PS-8	ACQUISITION	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Design confidence?	Overall project scope is both simple and straightforward. Bank revetments are not complicated. Scope changes are not likely, unless mangroves are discovered. In the event that mangroves	Significant	Possible	3
PS-17	Remaining Construction Items	• Project accomplish intent?	• Defer soil borings/geotech exploration to pre-construction PED for beach projects only • Usage of G2CRM • Inclusion of inland bay areas in study scope	1.) Significant increase to C&S for inland bay water quality monitoring (H). 2.) Impacts to resources will affect E&D and require mitigation (M). 3.) Finidng significant site will require archeological mitigation IAW the National Historic Preservation Act (M).	Moderate	Likely	3
PS-18	Planning, Engineering, & Design	• Design confidence?	• Defer soil borings/geotech exploration to pre-construction PED for beach projects only • Usage of G2CRM • Inclusion of inland bay areas in study scope	1.) New borrow sites may be required which would increase costs for develping those sand sources (M). 2.) Discovery of subsurface conditions from the ones assumed could negatively impact C&S (L). 3.) Coastal/H&H engineers unfamiliar with software, could increase cost and schedule (M). 4.) Structural issues due to karst geology may induce piping failures (M). 5.)	Moderate	Possible	2
PS-19	Construction Management	• Potential for scope growth, added features and quantities?	• Potential for scope growth, added features and quantities? • Project accomplish intent?	Potential Scope Growth would result in greater duration for construction management personnel.	Marginal	Possible	1
Acquisition Strategy					**Maximum Project Growth**		**30%**
AS-1	WEST SUMMERLAND KEY	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule? • 8a or small business likely? • High-risk acquisition limits competition, design/build?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2
AS-2	BAHIA HONDA KEY	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2
AS-3	LONG KEY	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2
AS-4	FIESTA KEY WEST	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2

AS-5	FIESTA KEY EAST	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2
AS-6	INDIAN KEY FILL	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Moderate	Possible	2
AS-7	NONSTRUCTURAL	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Significant	Possible	3
AS-8	ACQUISITION	• Contracting plan firmly established?	•(Real Estate) Obtaining Perpetuity Easements • Contracting plan firmly established? • Limited bid competition anticipated? • Accelerated schedule or harsh weather schedule?	Acquisition Strategy is unknown at this time. Conversations with Contracting Personnel indicate potential IDIQ or RFP methods. There is a potential limit of interested bidders, decreasing overall competitiveness.	Significant	Likely	4
AS-19	Construction Management	• Bid schedule developed to reduce quantity risks?	• Contracting plan firmly established? • 8a or small business likely? • Requirement for subcontracting?	Contract Acquisition strategy can affect the overall requirements for construction management. Expedited Schedule, or multiple contract awards can increase the requirement of onsite	Marginal	Possible	1
Construction Elements						**Maximum Project Growth**	**15%**
CE-1	WEST SUMMERLAND KEY	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-2	BAHIA HONDA KEY	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-3	LONG KEY	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-4	FIESTA KEY WEST	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-5	FIESTA KEY EAST	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-6	INDIAN KEY FILL	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-7	NONSTRUCTURAL	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Special mobilization? • Potential for construction modification and claims?	Overall Construction is both simple and straightforward. Construction Elements include site clearing and revetment placement. Potential issues include site access and material handling.	Marginal	Possible	1
CE-19	Construction Management	• High risk or complex construction elements, site access, in-water?	• Accelerated schedule or harsh weather schedule? • High risk or complex construction elements, site access, in-water? • Water care and diversion plan?		Negligible	Unlikely	0
Quantities for Current Scope						**Maximum Project Growth**	**20%**
Q-1	WEST SUMMERLAND KEY	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-2	BAHIA HONDA KEY	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-3	LONG KEY	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2

Q-4	FIESTA KEY WEST	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-5	FIESTA KEY EAST	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-6	INDIAN KEY FILL	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-7	NONSTRUCTURAL	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Moderate	Possible	2
Q-8	ACQUISITION	• Possibility for increased quantities due to loss, waste, or subsidence?	• Level of confidence based on design and assumptions? • Possibility for increased quantities due to loss, waste, or subsidence? • Appropriate methods applied to calculate quantities? • Sufficient investigations to develop quantities? • Quality control check applied?	Depending on multiple site studies yet to be done, given quantities are likely to change.	Significant	Possible	3
Specialty Fabrication or Equipment						**Maximum Project Growth**	**50%**
FE-1	WEST SUMMERLAND KEY	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-2	BAHIA HONDA KEY	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-3	LONG KEY	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-4	FIESTA KEY WEST	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-5	FIESTA KEY EAST	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-6	INDIAN KEY FILL	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Moderate	Unlikely	1
FE-7	NONSTRUCTURAL	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?	No specialty fabrication is expected to be used or needed. Project scope/construction means do not require any specialty equipment. It is unlikely work will have to be done from the	Marginal	Unlikely	0
Cost Estimate Assumptions						**Maximum Project Growth**	**25%**
CT-1	WEST SUMMERLAND KEY	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-2	BAHIA HONDA KEY	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-3	LONG KEY	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-4	FIESTA KEY WEST	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2

CT-5	FIESTA KEY EAST	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-6	INDIAN KEY FILL	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-7	NONSTRUCTURAL	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Possible	2
CT-8	ACQUISITION	• Lack confidence on critical cost items?	• Reliability and number of key quotes? • Assumptions related to prime and subcontractor markups/assignments? • Assumptions regarding crew, productivity, overtime? • Lack confidence on critical cost items?	Current Working Estimate is based on historical contract awards. Assumptions related to prime/sub contractors have been made, but could be different in execution. At this phase of the project, the cost estimate seems to be sound based on the current scope of work, with few critical assumptions being made.	Moderate	Likely	3
External Project Risks						**Maximum Project Growth**	**20%**
EX-1	WEST SUMMERLAND KEY	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route closings, or availabilty of material could impact day to day routines during construction.	Moderate	Unlikely	1
EX-2	BAHIA HONDA KEY	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Moderate	Unlikely	1
EX-3	LONG KEY	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Moderate	Unlikely	1
EX-4	FIESTA KEY WEST	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Moderate	Unlikely	1
EX-5	FIESTA KEY EAST	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Moderate	Unlikely	1
EX-6	INDIAN KEY FILL	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Moderate	Unlikely	1
EX-7	NONSTRUCTURAL	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Significant	Possible	3
EX-8	ACQUISITION	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials? • Potential for market volatility impacting competition, pricing?	Potential risk realted to unforseen severe or adverse weather due to the location of the revetments. At this phase of the project, there is also a concern for funding and/or support obstacles. Each site will have abnormally long haul routes due to how isolated they are, so any sudden increase in fuel, route	Significant	Likely	4
EX-19	Construction Management	• Potential for severe adverse weather?	• Potential for severe adverse weather? • Political influences, lack of support, obstacles? • Unanticipated inflations in fuel, key materials?	Multiple items can affect the overall duration of construction, resulting in the duration of construction management increasing or decreasing.	Negligible	Unlikely	0

ATTACHMENT 3
Structural TPCS

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: Florida Keys CSRM Study - Structural
PROJECT NO: 476673
LOCATION: U.S. Route 1, Monroe County, Keys

DISTRICT: NAO Norfolk District
POC: CHIEF, COST ENGINEERING
PREPARED: 5/19/2020

This Estimate reflects the scope and schedule in report; TSP

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2020									
						Effective Price Level Date: 1 OCT 19									
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 12/1/2018 ($K)	TOTAL FIRST COST ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*				*M*	*N*	*O*
16	BANK STABILIZATION	$9,389	$2,347	25%	$11,736	2.5%	$9,627	$2,407	$12,034	$0	$12,034	16.8%	$11,241	$2,810	$14,052
18	CULTURAL RESOURCE PRESERVATION	$94	$24	25%	$118	2.5%	$96	$24	$120	$0	$120	16.8%	$113	$28	$141
		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$9,483	$2,371		$11,854	2.5%	$9,724	$2,431	$12,155	$0	$12,155	16.8%	$11,354	$2,838	$14,192
01	LANDS AND DAMAGES	$67	$17	25%	$84	2.5%	$69	$17	$86	$0	$86	10.1%	$76	$19	$94
30	PLANNING, ENGINEERING & DESIGN	$1,280	$320	25%	$1,600	3.9%	$1,330	$332	$1,662	$0	$1,662	15.9%	$1,541	$385	$1,927
31	CONSTRUCTION MANAGEMENT (S&A)	$1,375	$344	25%	$1,719	3.9%	$1,428	$357	$1,785	$0	$1,785	21.3%	$1,732	$433	$2,165
	PROJECT COST TOTALS:	$12,205	$3,051	25%	$15,256		$12,551	$3,138	**$15,688**	$0	**$15,688**	17.1%	$14,703	$3,676	$18,378

ESTIMATED FEDERAL COST:	**100%**	**$18,378**
ESTIMATED NON-FEDERAL COST:	**0%**	**$0**
ESTIMATED TOTAL PROJECT COST:		**$18,378**

_____ CHIEF, COST ENGINEERING

_____ PROJECT MANAGER

_____ CHIEF, REAL ESTATE

_____ CHIEF, PLANNING

_____ CHIEF, ENGINEERING

_____ CHIEF, OPERATIONS

_____ CHIEF, CONSTRUCTION

_____ CHIEF, CONTRACTING

_____ CHIEF, PM-PB

_____ CHIEF, DPM

**** CONTRACT COST SUMMARY ****

**** TOTAL PROJECT COST SUMMARY ****

LOCATION: U.S. Route 1, Monroe County, Keys
This Estimate reflects the scope and schedule in report; TSP

POC: CHIEF, COST ENGINEERING

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			12/18/2018	Program Year (Budget EC):			2020					
		Effective Price Level:			10/1/2018	Effective Price Level Date:			1 OCT 19					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	TSP													
16	BANK STABILIZATION	$9,389	$2,347	25%	$11,736	2.5%	$9,627	$2,407	$12,034	2025Q2	16.8%	$11,241	$2,810	$14,052
18	CULTURAL RESOURCE PRESERVATION	$94	$24	25%	$118	2.5%	$96	$24	$120	2025Q2	16.8%	$113	$28	$141
		$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
		$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$9,483	$2,371	25%	**$11,854**		$9,724	$2,431	$12,155			$11,354	$2,838	$14,192
01	LANDS AND DAMAGES	$67	$17	25%	$84	2.5%	$69	$17	$86	2023Q2	10.1%	$76	$19	$94
30	PLANNING, ENGINEERING & DESIGN	$1,280	$320	25%	$1,600		$1,330	$332	$1,662			$1,541	$385	
2.5%	Project Management	$237	$59	25%	$296	3.9%	$246	$62	$308	2023Q2	12.8%	$278	$69	$347
1.0%	Planning & Environmental Compliance	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
1.0%	Engineering & Design	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
1.0%	Reviews, ATRs, IEPRs, VE	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
1.0%	Life Cycle Updates (cost, schedule, risks)	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
1.0%	Contracting & Reprographics	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
3.0%	Engineering During Construction	$284	$71	25%	$356	3.9%	$296	$74	$369	2025Q2	21.3%	$358	$90	$448
2.0%	Planning During Construction	$190	$47	25%	$237	3.9%	$197	$49	$246	2025Q2	21.3%	$239	$60	$299
1.0%	Project Operations	$95	$24	25%	$119	3.9%	$99	$25	$123	2023Q2	12.8%	$111	$28	$139
31	CONSTRUCTION MANAGEMENT	$1,375	$344	25%	$1,719		$1,428	$357	$1,785			$1,732	$433	
10.0%	Construction Management	$948	$237	25%	$1,185	3.9%	$985	$246	$1,231	2025Q2	21.3%	$1,194	$299	$1,493
2.0%	Project Operation:	$190	$47	25%	$237	3.9%	$197	$49	$246	2025Q2	21.3%	$239	$60	$299
2.5%	Project Management	$237	$59	25%	$296	3.9%	$246	$62	$308	2025Q2	21.3%	$299	$75	$373
	CONTRACT COST TOTALS:	$12,205	$3,051		**$15,256**		$12,551	$3,138	$15,688			$14,703	$3,676	**$18,378**

ATTACHMENT 4
Non-Structural TPCS

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: Florida Keys CSRM Study - NonStructural
PROJECT NO: 476673
LOCATION: U.S. Route 1, Monroe County, Keys

DISTRICT: NAO Norfolk District
POC: CHIEF, COST ENGINEERING
PREPARED: 5/21/2020

This Estimate reflects the scope and schedule in report; TSP

Program Year (Budget EC): 2020
Effective Price Level Date: 1 OCT 19

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: **12/1/2018** ($K)	**TOTAL FIRST COST** ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*				*M*	*N*	*O*
02	RELOCATIONS	$3,045,355	$1,026,804	34%	$4,072,159	2.5%	$3,122,710	$1,052,886	$4,175,595	$0	$4,175,595	16.8%	$3,646,153	$1,229,375	$4,875,528
		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$3,045,355	$1,026,804		$4,072,159	2.5%	$3,122,710	$1,052,886	$4,175,595	$0	$4,175,595	16.8%	$3,646,153	$1,229,375	$4,875,528
01	LANDS AND DAMAGES	$105,134	$52,567	50%	$157,701	2.5%	$107,804	$53,902	$161,707	$0	$161,707	13.4%	$122,209	$61,104	$183,313
30	PLANNING, ENGINEERING & DESIGN	$411,123	$138,619	34%	$549,741	3.9%	$427,045	$143,987	$571,032	$0	$571,032	15.9%	$494,991	$166,896	$661,887
31	CONSTRUCTION MANAGEMENT (S&A)	$441,576	$148,887	34%	$590,463	3.9%	$458,678	$154,653	$613,330	$0	$613,330	21.3%	$556,201	$187,535	$743,735
	PROJECT COST TOTALS:	$4,003,188	$1,366,876	34%	$5,370,065		$4,116,236	$1,405,428	**$5,521,664**	$0	**$5,521,664**	17.1%	$4,819,553	$1,644,911	$6,464,464

_____ CHIEF, COST ENGINEERING

_____ PROJECT MANAGER

_____ CHIEF, REAL ESTATE

_____ CHIEF, PLANNING

_____ CHIEF, ENGINEERING

_____ CHIEF, OPERATIONS

_____ CHIEF, CONSTRUCTION

_____ CHIEF, CONTRACTING

_____ CHIEF, PM-PB

_____ CHIEF, DPM

ESTIMATED FEDERAL COST:	**100%**	**$6,464,464**
ESTIMATED NON-FEDERAL COST:	**0%**	**$0**
ESTIMATED TOTAL PROJECT COST:		**$6,464,464**

**** CONTRACT COST SUMMARY ****

**** TOTAL PROJECT COST SUMMARY ****

LOCATION: U.S. Route 1, Monroe County, Keys
This Estimate reflects the scope and schedule in report; TSP

POC: CHIEF, COST ENGINEERING

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			12/18/2018	Program Year (Budget EC):			2020					
		Effective Price Level:			10/1/2018	Effective Price Level Date:			1 OCT 19					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	TSP - Acquisition													
02	RELOCATIONS	$290,503	$145,252	50%	$435,755	2.5%	$297,882	$148,941	$446,823	2025Q2	16.8%	$347,814	$173,907	$521,722
		$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
		$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
		$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$290,503	$145,252	50%	**$435,755**		$297,882	$148,941	$446,823			$347,814	$173,907	$521,722
01	LANDS AND DAMAGES	$105,134	$52,567	50%	$157,701	2.5%	$107,804	$53,902	$161,707	2024Q2	13.4%	$122,209	$61,104	$183,313
30	PLANNING, ENGINEERING & DESIGN	$39,218	$19,609	50%	$58,827		$40,737	$20,368	$61,105			$47,218	$23,609	
2.5%	Project Management	$7,263	$3,631	50%	$10,894	3.9%	$7,544	$3,772	$11,316	2023Q2	12.8%	$8,507	$4,253	$12,760
1.0%	Planning & Environmental Compliance	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
1.0%	Engineering & Design	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
1.0%	Reviews, ATRs, IEPRs, VE	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
1.0%	Life Cycle Updates (cost, schedule, risks)	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
1.0%	Contracting & Reprographics	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
3.0%	Engineering During Construction	$8,715	$4,358	50%	$13,073	3.9%	$9,053	$4,526	$13,579	2025Q2	21.3%	$10,977	$5,489	$16,466
2.0%	Planning During Construction	$5,810	$2,905	50%	$8,715	3.9%	$6,035	$3,018	$9,053	2025Q2	21.3%	$7,318	$3,659	$10,977
1.0%	Project Operations	$2,905	$1,453	50%	$4,358	3.9%	$3,018	$1,509	$4,526	2023Q2	12.8%	$3,403	$1,701	$5,104
31	CONSTRUCTION MANAGEMENT	$42,123	$21,061	50%	$63,184		$43,754	$21,877	$65,631			$53,057	$26,529	
10.0%	Construction Management	$29,050	$14,525	50%	$43,575	3.9%	$30,175	$15,088	$45,263	2025Q2	21.3%	$36,591	$18,296	$54,887
2.0%	Project Operation:	$5,810	$2,905	50%	$8,715	3.9%	$6,035	$3,018	$9,053	2025Q2	21.3%	$7,318	$3,659	$10,977
2.5%	Project Management	$7,263	$3,631	50%	$10,894	3.9%	$7,544	$3,772	$11,316	2025Q2	21.3%	$9,148	$4,574	$13,722
	CONTRACT COST TOTALS:	$476,978	$238,489		**$715,467**		$490,177	$245,089	$735,266			$570,299	$285,149	**$855,448**

**** CONTRACT COST SUMMARY ****

PROJECT: Florida Keys CSRM Study - NonStructural
LOCATION: U.S. Route 1, Monroe County, Keys
This Estimate reflects the scope and schedule in report; TSP

DISTRICT: NAO Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 5/21/2020

Civil Works Work Breakdown Structure	ESTIMATED COST	PROJECT FIRST COST (Constant Dollar Basis)	TOTAL PROJECT COST (FULLY FUNDED)

Filename: Keys_nonStructural_TPCS_v5.21.2020.xlsx
TPCS

**** TOTAL PROJECT COST SUMMARY ****

Estimate Prepared: **12/18/2018** | Program Year (Budget EC): 2020
Effective Price Level: 10/1/2018 | Effective Price Level Date: 1 OCT 19

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	TSP - Critical Infrastructure													
02	RELOCATIONS	$9,902	$3,169	32%	$13,071	2.5%	$10,154	$3,249	$13,403	2025Q2	16.8%	$11,855	$3,794	$15,649
	CONSTRUCTION ESTIMATE TOTALS:	$9,902	$3,169	32%	**$13,071**		$10,154	$3,249	$13,403			$11,855	$3,794	$15,649
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$1,337	$428	32%	$1,765		$1,389	$444	$1,833			$1,609	$515	
2.5%	Project Management	$248	$79	32%	$327	3.9%	$257	$82	$339	2023Q2	12.8%	$290	$93	$383
1.0%	Planning & Environmental Compliance	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
1.0%	Engineering & Design	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
1.0%	Reviews, ATRs, IEPRs, VE	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
1.0%	Life Cycle Updates (cost, schedule, risks)	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
1.0%	Contracting & Reprographics	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
3.0%	Engineering During Construction	$297	$95	32%	$392	3.9%	$309	$99	$407	2025Q2	21.3%	$374	$120	$494
2.0%	Planning During Construction	$198	$63	32%	$261	3.9%	$206	$66	$272	2025Q2	21.3%	$249	$80	$329
1.0%	Project Operations	$99	$32	32%	$131	3.9%	$103	$33	$136	2023Q2	12.8%	$116	$37	$153
31	CONSTRUCTION MANAGEMENT	$1,436	$459	32%	$1,895		$1,491	$477	$1,969			$1,808	$579	
10.0%	Construction Management	$990	$317	32%	$1,307	3.9%	$1,029	$329	$1,358	2025Q2	21.3%	$1,247	$399	$1,646
2.0%	Project Operation:	$198	$63	32%	$261	3.9%	$206	$66	$272	2025Q2	21.3%	$249	$80	$329
2.5%	Project Management	$248	$79	32%	$327	3.9%	$257	$82	$339	2025Q2	21.3%	$312	$100	$412
	CONTRACT COST TOTALS:	$12,675	$4,056		**$16,730**		$13,033	$4,171	$17,204			$15,273	$4,888	**$20,161**

**** CONTRACT COST SUMMARY ****

PROJECT: Florida Keys CSRM Study - NonStructural
LOCATION: U.S. Route 1, Monroe County, Keys
This Estimate reflects the scope and schedule in report; TSP

DISTRICT: NAO Norfolk District
POC: CHIEF, COST ENGINEERING
PREPARED: 5/21/2020

Civil Works Work Breakdown Structure	ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	Estimate Prepared: 12/18/2018; Effective Price Level: 10/1/2018				Program Year (Budget EC): 2020; Effective Price Level Date: 1 OCT 19								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)

**** TOTAL PROJECT COST SUMMARY ****

A	B	C	D	E	F	G	H	I	J	P	L	M	N	O
	TSP - Floodproofing													
02	RELOCATIONS	$802,376	$256,760	32%	$1,059,136	2.5%	$822,757	$263,282	$1,086,039	2025Q2	16.8%	$960,671	$307,415	$1,268,086
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$802,376	$256,760	32%	**$1,059,136**		$822,757	$263,282	$1,086,039			$960,671	$307,415	$1,268,086
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$108,321	$34,663	32%	$142,983		$112,516	$36,005	$148,521			$130,418	$41,734	
2.5%	Project Management	$20,059	$6,419	32%	$26,478	3.9%	$20,836	$6,668	$27,504	2023Q2	12.8%	$23,496	$7,519	$31,014
1.0%	Planning & Environmental Compliance	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
1.0%	Engineering & Design	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
1.0%	Reviews, ATRs, IEPRs, VE	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
1.0%	Life Cycle Updates (cost, schedule, risks)	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
1.0%	Contracting & Reprographics	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
3.0%	Engineering During Construction	$24,071	$7,703	32%	$31,774	3.9%	$25,004	$8,001	$33,005	2025Q2	21.3%	$30,320	$9,702	$40,022
2.0%	Planning During Construction	$16,048	$5,135	32%	$21,183	3.9%	$16,669	$5,334	$22,003	2025Q2	21.3%	$20,213	$6,468	$26,681
1.0%	Project Operations	$8,024	$2,568	32%	$10,591	3.9%	$8,335	$2,667	$11,002	2023Q2	12.8%	$9,398	$3,007	$12,406
31	CONSTRUCTION MANAGEMENT	$116,345	$37,230	32%	$153,575		$120,850	$38,672	$159,522			$146,545	$46,894	
10.0%	Construction Management	$80,238	$25,676	32%	$105,914	3.9%	$83,345	$26,670	$110,015	2025Q2	21.3%	$101,066	$32,341	$133,407
2.0%	Project Operation:	$16,048	$5,135	32%	$21,183	3.9%	$16,669	$5,334	$22,003	2025Q2	21.3%	$20,213	$6,468	$26,681
2.5%	Project Management	$20,059	$6,419	32%	$26,478	3.9%	$20,836	$6,668	$27,504	2025Q2	21.3%	$25,266	$8,085	$33,352
	CONTRACT COST TOTALS:	$1,027,041	$328,653		**$1,355,694**		$1,056,123	$337,959	$1,394,082			$1,237,634	$396,043	**$1,633,677**

**** CONTRACT COST SUMMARY ****

PROJECT: Florida Keys CSRM Study - NonStructural
LOCATION: U.S. Route 1, Monroe County, Keys
This Estimate reflects the scope and schedule in report; TSP

DISTRICT: NAO Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 5/21/2020

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			**12/18/2018**	Program Year (Budget EC):			2020					
		Effective Price Level:			10/1/2018	Effective Price Level Date:			1 OCT 19					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	TSP - Elevation													
02	RELOCATIONS	$1,942,574	$621,624	32%	$2,564,198	2.5%	$1,991,917	$637,413	$2,629,330	2025Q2	16.8%	$2,325,811	$744,260	$3,070,071

Filename: Keys_nonStructural_TPCS_v5.21.2020.xlsx
TPCS

**** TOTAL PROJECT COST SUMMARY ****

	CONSTRUCTION ESTIMATE TOTALS:	$1,942,574	$621,624	32%	**$2,564,198**		$1,991,917	$637,413	$2,629,330			$2,325,811	$744,260	$3,070,071
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$262,247	$83,919	32%	$346,167		$272,404	$87,169	$359,573			$315,745	$101,038	$416,783
2.5%	Project Management	$48,564	$15,541	32%	$64,105	3.9%	$50,445	$16,142	$66,588	2023Q2	12.8%	$56,883	$18,203	$75,086
1.0%	Planning & Environmental Compliance	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
1.0%	Engineering & Design	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
1.0%	Reviews, ATRs, IEPRs, VE	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
1.0%	Life Cycle Updates (cost, schedule, risks)	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
1.0%	Contracting & Reprographics	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
3.0%	Engineering During Construction	$58,277	$18,649	32%	$76,926	3.9%	$60,534	$19,371	$79,905	2025Q2	21.3%	$73,405	$23,490	$96,894
2.0%	Planning During Construction	$38,851	$12,432	32%	$51,284	3.9%	$40,356	$12,914	$53,270	2025Q2	21.3%	$48,937	$15,660	$64,596
1.0%	Project Operations	$19,426	$6,216	32%	$25,642	3.9%	$20,178	$6,457	$26,635	2023Q2	12.8%	$22,753	$7,281	$30,034
31	CONSTRUCTION MANAGEMENT	$281,673	$90,135	32%	$371,809		$292,582	$93,626	$386,208			$354,790	$113,533	$468,323
10.0%	Construction Management	$194,257	$62,162	32%	$256,420	3.9%	$201,781	$64,570	$266,350	2025Q2	21.3%	$244,683	$78,298	$322,981
2.0%	Project Operation:	$38,851	$12,432	32%	$51,284	3.9%	$40,356	$12,914	$53,270	2025Q2	21.3%	$48,937	$15,660	$64,596
2.5%	Project Management	$48,564	$15,541	32%	$64,105	3.9%	$50,445	$16,142	$66,588	2025Q2	21.3%	$61,171	$19,575	$80,745
	CONTRACT COST TOTALS:	$2,486,495	$795,678		**$3,282,173**		$2,556,902	$818,209	$3,375,111			$2,996,346	$958,831	**$3,955,177**