4. Overview of Other Data for Development of the Plan

As part of the Islamorada Matters project, sea level rise modeling was conducted to determine the vulnerability of Islamorada infrastructure and habitat to both nuisance flooding and sea level rise at select intervals. This section discusses in more detail the modeling approach, data identified for use in the modeling runs, identified data gaps and adjustments made to address missing or insufficient data.

A) Modeling Approach and Data Utilized in this Effort

A key component of the Islamorada Matters planning process was the performance of a vulnerability assessment for sea level rise scenarios in the years 2030 and 2060 based on existing data. The vulnerability assessment included a comprehensive evaluation of ground elevation relative to current and future tidewater heights for roads, public buildings and other critical building infrastructure, wastewater facilities, water supply, and electrical utility infrastructure using geographic information systems ("GIS") and other tools. Assessments of habitat change vulnerability were also performed using both tidewater inundation and the Sea Level Affecting Marshes Model ("SLAMM").

The Southeast Florida Regional Climate Change Compact ("SFRCCC"') currently plans for a 2030 sea level rise planning scenario minimum of three (3) inches and a maximum of seven (7) inches for all communities within Monroe, Miami-Dade, Broward, and Palm Beach counties.[18] The minimum 2060 sea level rise planning scenario is nine (9) inches, while the maximum is twenty-four (24) inches. The base planning year, or the assumed zero elevation point, for sea level rise under all SFRCCC scenarios is 2010. More recently, the SFRCCC has developed additional projected scenarios incorporating a wider range of sea level rise projections including a new National Oceanic and Atmospheric Administration ("NOAA") "High Risk" projection that should be used for long-term risk intolerant planning. This would be relevant to infrastructure and/or habitat-related decisions with a longer useful life beyond the 2030 or 2060 timeframe or where significant capital investment is required. During the drafting of this document, those High Risk projections were developed, but since they are not recommended for use in all infrastructure and habitat planning, the SFRCCC's previous 3 - 7" (2030) and 9-24" (2060) projections remain the most appropriate range within those timeframes. For further discussion on the use of these High Risk projections, please see the Village of Islamorada: GIS Vulnerability Assessment for Sea Level Rise Planning report included in Appendix B.

The first step in developing the sea level rise vulnerability assessment was compilation of existing geo-spatial, elevation and tabular datasets. Data obtained for use in this vulnerability assessment included LIDAR Digital Elevation Model ("DEM") data, property parcels, Monroe County sections, aerial photography, land cover and habitat data, road centerline data, critical facilities data, parcels with County and/or Village facilities, government building data, correctional facilities data, law enforcement data, schools data, Islamorada critical facilities data, and stormwater infrastructure data. A full description of those datasets, including the sources of the data, is provided in the Village of Islamorada: GIS Vulnerability Assessment for Sea Level Rise Planning report included in Appendix B.

i. Infrastructure including Government Buildings and Facilities

For this project, the Team developed a building footprints GIS layer for eighty (80) parcels including the visible outlines of structures that various sources (i.e., Monroe County, Village of Islamorada, and UF GeoPlan) have identified and listed as public. This includes all critical infrastructure located within Islamorada such as schools, law enforcement, fire stations, other government buildings, electric and water utilities, and disaster response staging areas. Most buildings in Islamorada, including those that are not elevated on piers or stilts, are built to exceed base flood elevation.

The Team utilized the master road center lines from the Monroe County Property Appraiser's office, a shapefile with new road condition data from the County GIS office, and a series of tidal inundation maps for road infrastructure as developed through the Florida Department of Transportation ("FDOT") Sketch Tool. The FDOT Sketch Tool uses low, intermediate, and high sea level rise curves based upon the USACE sea level rise projection methodology which is also the basis for the low and high curves defined by the SFRCCC's unified sea level rise projections. The low USACE curve is based on a linear extrapolation of tide gauge records. Road segments with inundation risk for the USACE low, intermediate, and high curves are delineated for the years 2040, 2060, 2080, and 2100. To conform with the SFRCCC recommendations for sea level rise projections, the Team only evaluated road inundation risks for the intermediate and high sea level rise scenarios in the FDOT Sketch Tool.

Figure 1: Building footprint outline of the Village of Islamorada Administration Center

Additionally, the Team compared data and elevation approaches utilized for this project and with Islamorada's recent ***Stormwater Assessment for Selected Sites***. In 2014-2015, the Village conducted an analysis of thirteen (13) specific sites for stormwater impact that were identified as current areas of concern for the Village after typical storm events. As part of that assessment, each site was evaluated and recommendations for addressing current impacts were made particular to that site. The goal was to potentially evaluate new stormwater management practices and capital projects limited to these sites that could be implemented in the future. Because that assessment focused on particular rainfall ponding issues, not daily tidal flooding, specific recommendations for areas identified in that assessment are not made in this Plan. Identifying the interaction between higher tides and stormwater drainage potential requires very detailed hydrologic modeling which exceeds the scope of recommendations being made in this Plan.

ii. Habitat

The Team also performed an analysis of potential inundation of land cover types within the Village due to sea level rise using low and high sea level scenarios at 2030 and 2060. This analysis was conducted using habitat and land cover type data, with extracted elevation data from the LIDAR DEM. Land cover types evaluated include freshwater, upland and anthropogenic land covers within the Village.

The SLAMM, an advanced land cover and ecosystem change tool, was used to simulate the impacts of future sea level rise on wetland and upland ecosystems. The SLAMM analysis conducted as part of the Islamorada Matters project builds upon a previous iteration of SLAMM runs performed by the Florida Fish and Wildlife Conservation Commission ("FWC") for the Florida Keys portion of Monroe County. This analysis updates this prior FWC work by using a later version of SLAMM (version 6.2) and revised sea level rise curves that conform precisely to the lower and upper bounds of the SFRCCC.

Islamorada, FL
Photo Source: Project Team

iii. Buildings and Homes

The Coastal Adaptation to Sea level rise Tool ("COAST") modeling software was utilized to mimic floods from storms and sea level rise on community assets, including homes and businesses within Islamorada. Modeling was performed to determine potential impacts on these assets from storm surge and sea level rise in 2030 and 2060, based on SFRCCC high and low sea level rise scenario projections. The software was also used to calculate the cumulative damages to homes and businesses over time, considering both nuisance flooding and Wilma-sized storm events, to help the Village better understand the cost of not adapting, as well as the costs and benefits of implementing various adaptation strategies.

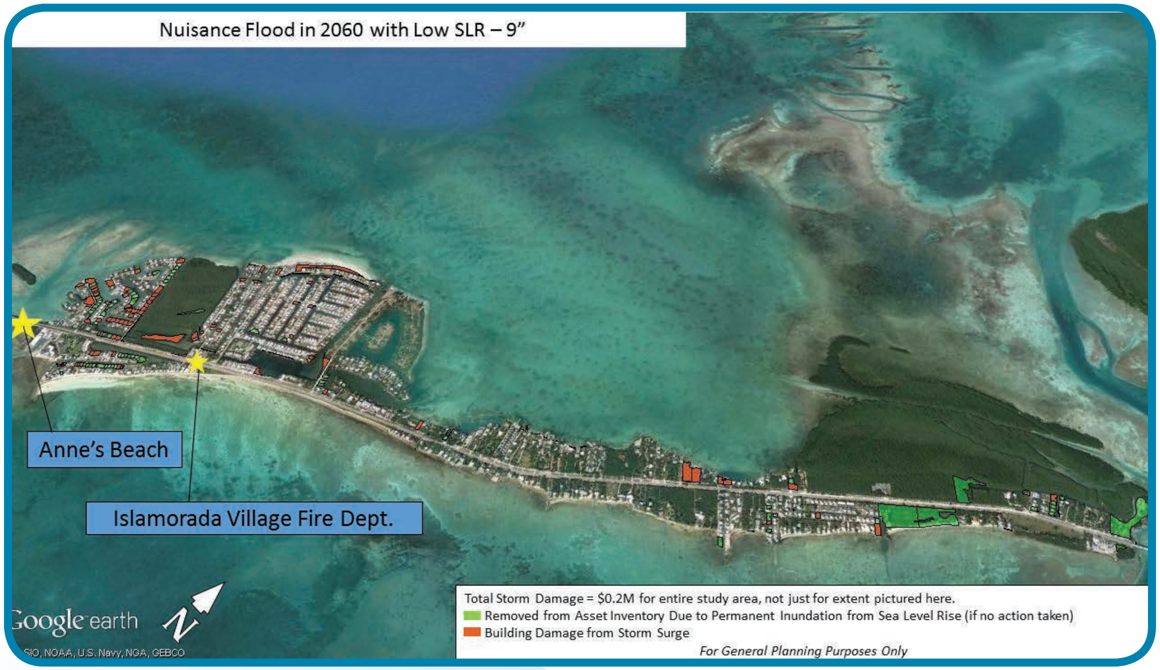

Figure 2. Google Earth image of potential flooding damages from a nuisance flood (low sea level rise scenario) in 2060 for a section of Islamorada, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts (in dollars). Parcels in green indicate those permanently inundated from sea level rise. (See Appendix D for larger image)

B) Identified Data "Gaps" and Process for Addressing

Some analyses could have benefitted from improved data sources at a much greater cost, but in order to develop general vulnerability recommendations, the Team worked to utilize existing data sets as beneficially as possible. A few key areas where the Team had to address missing or insufficient data (data gaps) are provided below.

Vulnerability Assessment Data. Monroe County and the Village of Islamorada initially lacked a GIS building footprint layer. Elevation Certificates were located for a total of twelve (12) public facilities within the jurisdictional boundaries of Islamorada. Elevation Certificates were not located for an additional sixty-eight (68) structures contained on parcels with critical infrastructure or other public facilities within the Village. While the finished flood elevations from Elevation Certificates provides the most definitive basis for evaluating a structure's flood damage vulnerability, use of LIDAR elevation calculations with building footprints (developed for this project for certain public or critical structures) conforms with methods that FEMA has evaluated when Elevation Certificates are not available.

COAST Modeling Data. Several limitations were identified for the COAST modeling results. First, values for individual buildings were sometimes not available, as Monroe County Property Appraiser assessing records combine the values of all buildings on a particular lot into one number. Similarly, total loss of building value and land value for the lot was assumed to occur when daily tidal waters (without any surge) reached the imaginary point centered in the parcel polygon (parcel "centroid"). Third, only structural damage to buildings was included, based upon USACE Depth Damage Functions for still water or static flooding. Fourth, damage to building contents or damage from wind or wave action was not included, meaning that damage figures are conservative in quantifying true loss. Structural Building Value was the only asset analyzed for this type of analysis.

US 1 Near White Marlin Boulevard
Photo Source: Project Team

Roads. The Team replicated the FDOT method to develop a new road segment inundation surface corresponding to low and high sea level rise projections for 2030 and 2060 as defined by the SFRCCC. The FDOT Sketch Planning Tool does not model effects of sea level rise on bridges. GIS data supplied by Monroe County provided point locations to identify bridges, but did not contain the footprint information necessary for more detailed analysis of raw LIDAR returns associated with bridge elevations.

Water Supply. The Florida Keys Aqueduct Authority ("FKAA") provided a full set of data showing the locations of water supply lines, pumps, and other distribution infrastructure. Above ground and below ground (invert) elevations were not provided for water supply infrastructure. GIS data can be used to develop general vulnerability assessments that overlay geographic inundation risk at the years 2030 and 2060 with the locations of FKAA infrastructure. However, current data were not sufficient to conduct comprehensive damage assessments for water supply infrastructure due to saltwater corrosion or other sea level rise stressors.

Despite this challenge, site vulnerability to sea level rise flooding for above ground water infrastructure was modeled for 2030 and 2060. Visualizations and assessments of possible saltwater intrusion risks to FKAA wellfields at SFRCCC sea level rise values for 2030 (3-7 inches) and 2060 (9-24 inches) were assessed using the U.S. Geological Survey ("USGS") scenarios that correspond closest to the low and high values.

Wastewater. The Village provided data with locations of the master repump stations and an elevation certificate for the one wastewater pump station that was functional at the time the Plan was developed. The three (3) additional wastewater pump stations were in various phases of construction during Plan development. These data supported a vulnerability assessment of these facilities. Development of survey-quality electronic datasets of underground wastewater sewer pipe systems, electronic components of wastewater systems, and other components with vulnerability to saltwater exposure is recommended as a next step to support engineering assessments and adaptive maintenance of the wastewater system that address long-term sea level rise stressors.

C) Recommendations for Additional Data Development in the Future

For future planning efforts in the Village, additional data should be developed for more detailed vulnerability analyses in the future. Further recommendations related to data development occur in the individual Focus Area discussions as well.

Building Footprints. The building footprints datasets developed for the Plan provide detailed guidance as to where public structures and critical infrastructure may be at risk of future flooding from sea level rise. It is highly recommended that future flood vulnerability assessments build upon the work in the Plan and continue efforts to develop a more complete digital record of Elevation Certificates for public facilities. Use, integration, and improvement of this Elevation Certificate record will promote higher confidence in flood risk assessments, thereby providing a basis for development of a building by building prioritization for flood retrofit and/or rebuilding as conditions warrant.

Because tidal flooding from sea level rise is a hazard that develops progressively, issues such as unacceptable loss of access and the eventual vulnerability of an individual structure due to tidal flooding will be preceded by many minor, but visible, nuisance flooding events. For this reason, the Team recommends the development and implementation of a geographic database for Islamorada staff (and interested residents) to document the time and location of nuisance flood events that affect parking lots, access roads, commercial and residential areas, and landscapes of public facilities. Coupled with the building footprint layer and associated vulnerability assessment, such a geographically explicit and temporally documented nuisance flood record will provide a strong basis for implementation of targeted and justified public investments to mitigate tidal flooding vulnerabilities.

Ron Levy Aquatic Center at Founders Park, Islamorada, FL
Photo Source: Project Team

Habitat. Summary results for the 2030 and 2060 SLAMM land cover analyses in Islamorada are provided in Appendix B. Although SLAMM is an advanced ecosystem and land cover change model, the Team notes that caution is warranted in terms of how the results of SLAMM should be interpreted within the Florida Keys, including the Village. In particular, further calibration of the model with historic land cover change and field observations is warranted to provide guidance for further updates and revisions of the modeling input parameters. The current results do, however, provide a potential basis for discussing and comparing the magnitude of potential ecosystem changes from sea level rise in the Keys.

D) Peer Review

A Peer Review process was conducted on the Plan's technical methodologies in conjunction with the County's planning process. Specific comments were received by the following individuals to assist in refinement of the vulnerability analysis:

1. Jayanatha Obeysekara, PhD, PE, DWRE, Chief Modeler, Hydrologic & Environmental Systems Modeling, South Florida Water Management District;
2. Jennifer Jurado, PhD, Director, Environmental Protection and Growth Management Department, Environmental Planning and Community Resilience Division, Broward County; and
3. Nicholas G. Aumen, PhD, Regional Science Advisor, USGS.

The Team also received comments and periodic feedback from Jerry Lorenz, PhD, State Research Director, Audubon of Florida and reviewed related work completed by Billy D. Causey, PhD, Regional Director, Southeast Atlantic, Gulf of Mexico and Caribbean Region, NOAA Office of National Marine Sanctuaries. Other Monroe County and Village staff also provided comments at numerous points throughout the planning process, and in particular, to the technical foundation to support the planning process. Appendix C describes and includes responses to Peer Review comments.

E) Vulnerability Assessment Results for Habitat and Facilities

Results for habitat and land cover areas potentially lost to tidal inundation for each 2030 sea level rise scenario revealed that habitats dominated by exotic species are the most vulnerable to sea level rise inundation. Land cover classified as developed showed the greatest amount of possible or likely acreage loss for both 2030 scenarios. Built areas denoted by impervious surface land cover showed a comparatively low percentage of area subject to tidal inundation by 2030 (predominately composed of roads and parking areas). More than 10% of the freshwater wetlands in Islamorada (less than four (4) acres total) could be affected by regular saltwater intrusion under the low sea level rise scenario (3 inches) by 2030. Under the high scenario (7 inches), this percentage increases to 20%.

For 2060, habitats dominated by exotic species continued to show high exposure to sea level rise inundation under both scenarios. Developed land again showed the greatest acreage lost under both 2060 scenarios. Approximately 7.2% (32.7 acres) of tropical hammock forest in Islamorada will likely be lost with two (2) feet of sea level rise. Large habitat areas adjacent to the Atlantic and Florida Bay coasts and much of Lower Matecumbe Key show widespread exposure to possible or likely inundation effects with the higher scenarios of sea level rise because they are not protected by the existing relatively high ridge.

Figure 3: Road segments predicted as vulnerable to nuisance flooding with 24 inches of sea level rise (2060, High Scenario). (See Appendx B for larger image)

Figure 4. Visualization of Sketch Planning Tool nuisance flooding. (See Appendx B for larger image)

Two (2) facilities that showed the most near-term vulnerability to enhanced flood risks from sea level rise were the wastewater pump station located at 142 Sunshine Boulevard and the Fire Station #19 located at 74070 U.S. Highway 1. For both facilities, the first floor elevation is near or below the 2030 extreme event flood threshold for the high sea level rise scenario (6.83 feet above Mean Higher High Water ("MHHW")). This means that these facilities would be exposed to extreme event flooding by 2030 if the highest rate of sea level rise occurs. Under the low sea level rise scenario, extreme event flood exposure would not be seen until between 2046 and 2051.

Results of the Sketch Tool analysis of road vulnerability shows impacts to Village roadways both during nuisance floods during King Tide events and as a result of daily inundation flooding. Because U.S. Highway 1 is the sole road and emergency evacuation route for the Florida Keys, even low-level nuisance flooding is problematic for public safety, health and welfare. Decreased traffic flow, increased accident risk and higher long-term maintenance costs are all concerns with nuisance flooding. These concerns are magnified exponentially with daily tidal flooding, and will likely lead to issues with evacuation times and increased costs for road replacement and eventual elevation. Roadway miles impacted by nuisance flooding and daily inundation flooding within the Village are provided in the tables below.

Table 2: Summary of Road Miles Vulnerable to Nuisance Flooding During King Tide Events*

	Original Road Miles	2030 Low	2030 High	2060 Low	2060 High
U.S. Highway 1	17.2 mi.	0.2 mi.	0.4 mi.	0.5 mi.	3.2 mi.
All Roads	67.0 mi.	2.1 mi.	3.8 mi.	5.2 mi.	24.9 mi.

* King Tide describes the elevation of tides that are higher than 99% of the high tides that occur each year at the Vaca Key tide gauge. For the 2030 Low scenario, the height of a King Tide is calculated at 1.5' above current MHHW, as referenced to the 1992 National Tidal Datum Epoch. For the 2030 High scenario, the height of a King Tide is calculated at 1.91' above current MHHW. For the 2060 Low scenario, the height of a King Tide is calculated at 2.0' above current MHHW. For the 2060 High scenario, the height of a King Tide is calculated at 3.33' above current MHHW.

Table 3: Summary of Road Miles Vulnerable to Inundation Flooding (Daily Tidal Floods)*

	Original Road Miles	2030 Low	2030 High	2060 Low	2060 High
U.S. Highway 1	17.2 mi.	0 mi.	0.02 mi.	0.03 mi.	0.5 mi.
All Roads	67.0 mi.	0.1 mi.	0.3 mi.	0.4 mi.	5.2 mi.

* Daily tidal flooding occurs when a road segment is at an elevation lower than a future MHHW mark as affected by sea level rise. For the 2030 Low scenario, future MHHW is calculated at 0.42' above current MHHW, as referenced to the 1992 National Tidal Datum Epoch. For the 2030 High scenario, future MHHW is calculated at 0.83' above current MHHW. For the 2060 Low scenario, future MHHW is calculated at 0.92' above current MHHW. For the 2060 High scenario, future MHHW tide is calculated at 2.25' above current MHHW.

For nuisance flooding vulnerability in 2030 under the low and high sea level rise scenarios, impacts to U.S. Highway 1 are minimal. Road impacts appear first on secondary roads in the residential portions of the north end of Plantation Key on both sides of U.S. Highway 1. For nuisance flooding vulnerability in 2060 under a high sea level rise scenario, impacts on U.S. Highway 1 can be seen throughout the Village, most prominently on Windley Key, Upper Matecumbe Key and Lower Matecumbe Key. Residential roads throughout Lower Matecumbe Key and southern Plantation Key in the neighborhood just north of Snake Creek (west of U.S. Highway 1) are also significantly impacted under this scenario. Inundation flooding during daily high tides is much less prevalent along both U.S. Highway 1 and secondary residential streets under both scenarios in 2030 and 2060.

Full vulnerability assessment results are provided in the Village of Islamorada: GIS Vulnerability Assessment for Sea Level Rise Planning report included in Appendix B.

F) COAST Sea Level Rise Modeling

The COAST modeling software mimics floods from storm events and sea level rise on community assets, including homes and businesses. The model also performs a vulnerability assessment by calculating cumulative damage to communities over time, from both storm events and sea level rise. This allows communities to better understand the cost of not adapting to or otherwise mitigating the impacts of storms and sea level rise. Finally, the model also calculates damage reductions (essentially the costs and benefits) of implementing various adaptation actions to mitigate storm impacts and sea level rise.

The above calculations are determined by adding sea level rise and storm surge to the nearest known MHHW height, which is a starting or "bottom point" for any analysis of how high waters may rise in the future. For the Upper Keys, this value is available at the NOAA Vaca Key tide gauge.

Several model inputs were identified for use in the COAST model, including:

- LIDAR imagery of Islamorada and surrounding area which was converted to proper vertical units which consisted of a five (5) meter by five (5) meter grid with single elevation value in feet for each square;
- Property values for land and buildings provided by the Monroe County Tax Collector's Office;
- Tide data including the value of the high tide level for Islamorada from the Vaca Key tide station;
- Four (4) sea level rise scenario estimates obtained from the SFRCCC's Unified Sea Level Rise Projection for Southeast Florida; and
- Depth-damage function tables created by the USACE based on damage measurements.

Using the above data, the COAST model was used to perform a vulnerability assessment of homes and commercial building structures and to model adaptation action scenarios. The "asset" selected for analysis was the value of residential and commercial buildings. Sea level rise assumptions were based upon the Unified Sea Level Rise Projection including 3-7" (2030) and 9-24" (2060). Surge values from various sized storms were obtained from the most recent FEMA Flood Insurance Study.

The three (3) adaptation actions modeled included: 1) elevating and floodproofing buildings not already elevated and floodproofed, 2) building offshore barriers close to the coast, and 3) purchasing properties vulnerable to sea level rise through a voluntary buyout program over a phased timeframe.

To determine model inputs, the Team conducted three (3) community workshops in October, November and December 2014. During these workshops, participants voted on modeling parameters and assumptions for "no-action" and the three (3) adaptation actions during Workshops #2 and #3. The modeling results and community engagement process enabled the Team to provide residents with a context for beginning more difficult conversations regarding their vulnerabilities.

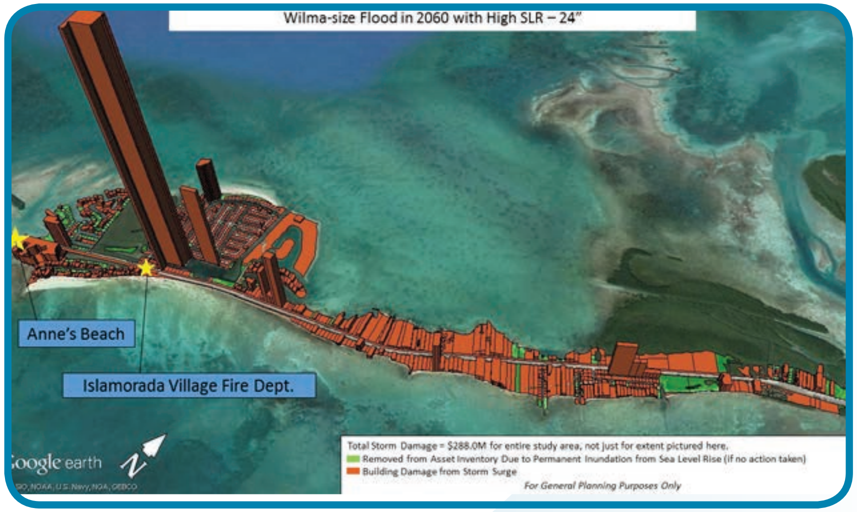

Figure 5. Google Earth image of potential flooding damages from a Hurricane Wilma-size flood (high sea level rise scenario) in 2060 for a section of Islamorada, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts (in dollars). Parcels in green indicate those permanently inundated from sea level rise. (See Appendx D for larger image)

Timescale	SLR Scenario	Cumulative Damage to Buildings by Scenario Date
2014-2030	Low - 3.00”	$544.7 Million
2014-2030	High - 7.00”	$610.2 Million
2031-2060	Low - 9.00”	$1.189 Billion
2031-2060	High - 24.00”	$2.130 Billion
2014-2060	Low - 9.00”	$1.734 Billion
2014-2060	High - 24.00”	$2.741 Billion

Figure 6: Cumulative damage estimated from all possible storms during a given time period with high and low sea level rise.

Vulnerability Assessment Results. Key findings from the “worst case” vulnerability assessment included one-time damage estimates of $2.3 Million from a nuisance flood in 2060 under a high sea level rise scenario of 24” and $288.0 Million from a Hurricane Wilma-size flood in 2060 under the same sea level rise scenario. Cumulative damages over time from storms of various sizes resulted in significantly higher damage estimates by 2060, with $1.734 Billion in damages under a low sea level rise scenario and $2.741 Billion in damages under a high sea level rise scenario. This is because the cumulative damage estimate includes damage from all storms that may occur within a certain time period and assumes repetitive rebuilding and damage to structures not permanently inundated during that period (once complete inundation of a parcel occurs the damage value for that parcel is no longer factored into the damage totals). The value of properties (buildings and land) permanently inundated by only sea level rise by 2060 (from daily flooding at high tide) ranged from $151.1 Million (low scenario) to $295.5 Million (high scenario). Once the modeling indicated such properties would be flooded by the daily high tide, the software no longer subjected it to continuing cumulative damages from that point in time forward. Therefore, these damage figures ($151.1 Million - $295.5 Million) depict the true risk from only sea level rise impacts rather than increasingly frequent damage from multiple levels of storm events over time.

Private Residence, Islamorada, FL
Photo Source: Project Team

Adaptation Scenario Modeling Results. Results of the adaptation action modeling revealed that the action with the best benefit-cost ratio was elevating and floodproofing buildings (accounting for those not already elevated or floodproofed in Islamorada), which had a benefit-cost ratio between 5.24 and 15.28. This means that for every $1.00 spent on elevating and floodproofing, the avoided damages would range from $5.24 to $15.28, depending on the sea level rise scenario (high or low) and construction cost estimates (high or low). Building offshore barriers had the second highest benefit-cost ratios (1.59 to 2.20). The voluntary buyout program had the lowest benefit-cost ratios (0.02 to 0.18). It should be noted that the parameters voted upon by workshop participants directly influenced the benefit-cost ratios as further described in Appendix D and different implementation parameters could provide different benefit-cost ratios (for instance level of participation and when a certain strategy was implemented). These benefit-cost ratios were presented to Islamorada residents, and keypad polling technology was used to evaluate community opinion on the results. After reviewing the COAST model results and participating in the group discussions, residents voted that elevating and floodproofing buildings was their most preferred action. In addition, residents supported Islamorada pursuing sources of funding to help private property owners implement this strategy. A breakdown of the public involvement and participation in the entire planning effort can be found in Section 7.

A copy of the complete Islamorada Matters: Analysis of Damages from Storm Surge and Sea Level Rise in Islamorada using the Coastal Adaptation to Sea Level Rise Tool (COAST) Report is included in Appendix D.