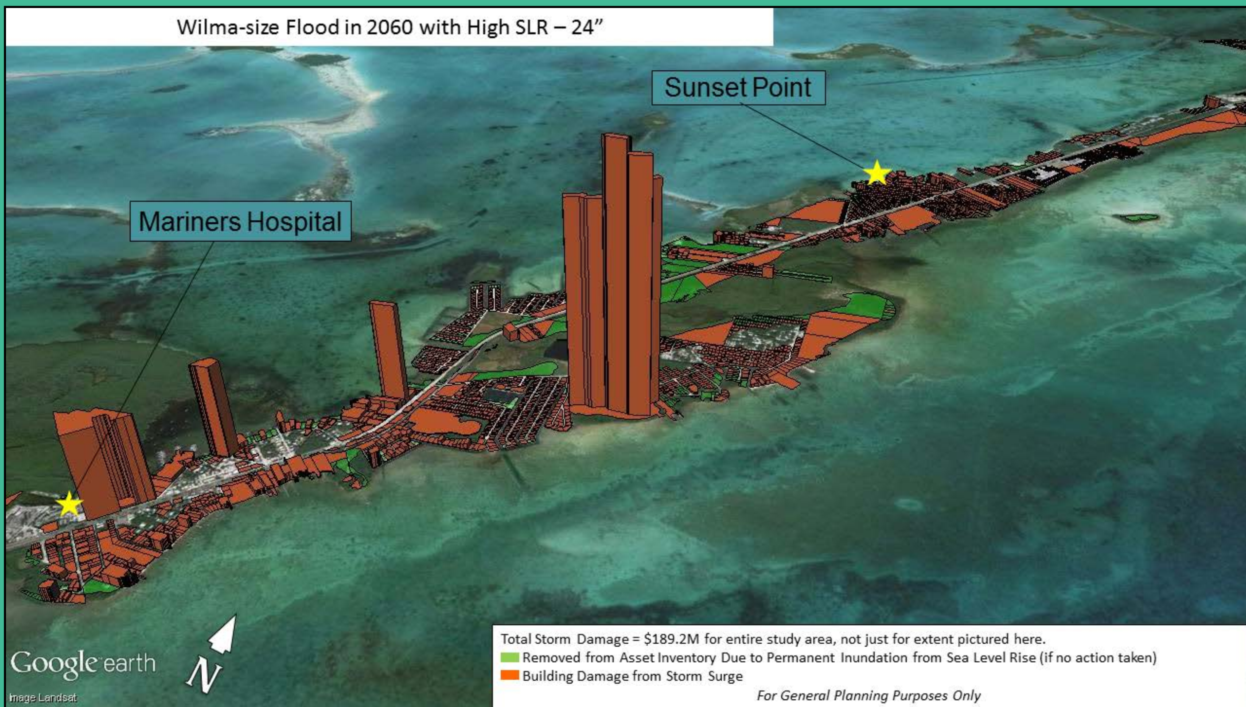

GreenKeys!

ANALYSIS OF DAMAGES FROM STORM SURGE AND SEA LEVEL RISE FOR THE GEOGRAPHIC REGIONS OF KEY LARGO AND STOCK ISLAND, MONROE COUNTY, FL USING THE COASTAL ADAPTATION TO SEA LEVEL RISE TOOL (COAST)

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1 EXECUTIVE SUMMARY

Catalysis Adaptation Partners, LLC (Catalysis) specializes in analyzing impacts from storm surges and long-term sea level rise using its COastal Adaptation to Sea level rise Tool (COAST). COAST modeling software mimics floods from storms and sea level rise on community assets such as homes and businesses, then tallies the cumulative damages over time so communities can better understand the cost to them of not adapting (vulnerability assessment), as well as the costs and benefits (damage reduction) of implementing various adaptation actions.

Catalysis was contracted by Erin L. Deady, P.A. to use COAST to perform a vulnerability assessment of homes and commercial building structures and to model adaptation scenarios within Monroe County in Key Largo as part of the GreenKeys! project. Working with Erin L. Deady, P.A., Catalysis conducted three (3) community workshops in October, November and December 2014, during which County residents in Key Largo voted on modeling parameters and assumptions for "no-action" and three (3) adaptation action scenarios: 1) Elevating and floodproofing buildings; 2) building barriers close to shore; and 3) purchasing properties vulnerable to sea level rise through a voluntary buyout program. Voting occurred during Workshops #2 and #3 (results can be found in the appendix Section 6 of this report) and focused on certain model parameters as well as whether or not actions should be further evaluated.

The "asset" selected for analysis was the value of residential and commercial buildings, obtained from Monroe County tax records. Sea Level Rise assumptions were based upon the Unified Sea Level Rise Projection for Southeast Florida[1]. Those projections included a low and high estimate of sea level rise in 2030 of 3" and 7" respectively, as well as a low and high estimate of sea level rise in 2060 of 9" and 24" respectively. As requested by workshop participants, a lower sea level rise projection was also employed in the analysis based only on the rate of sea level rise that has occurred over the last 100 years, outside of the official Unified Sea Level Rise Projection document. A straight line projection of the tide gauge trend was added to the modeling parameters, for a very low scenario of sea level rise of 1.82" in 2030 and 4.53" in 2060. Surge values from various sized storms were obtained from the most recent Federal Emergency Management Act (FEMA) Flood Insurance Study. Key findings from the worst case vulnerability assessment included one-time damage estimates of $2.0 Million from a nuisance flood in 2060 under a high sea level rise scenario of 24"and $289.2 Million from a Hurricane Wilma-sized 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 $1.673 Billion in damages under the very low sea level rise scenario of 4.53", and $2.130 Billion in damages under a high sea level rise scenario of 24". The value of properties (buildings and land) permanently inundated by sea level rise alone by 2060 (from daily flooding at high tide) ranged from $206.9 Million (very low scenario) to $705.6 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.

The three (3) adaptation actions to model identified by the Project Team and County Staff included:

- Elevating and floodproofing buildings

[1] Southeast Florida Regional Climate Change Compact Counties, Sea Level Rise Ad Hoc Technical Working Group (April 2011).

- Building barriers close to the coast (to protect from storm surge but not sea level rise); and
- Purchase of properties vulnerable to sea level rise through a voluntary buyout program over a phased timeframe.

For each action, costs were determined by the consultant and staff team, and in some cases, modified by workshop participants by polling. Modeling parameters (e.g., building elevation heights, the distance between the barrier and the coast as well as the height of the barrier, the number of residents accepting a buyout for their properties, etc.) also were established by workshop participants through a keypad polling process. Catalysis then used COAST again with the adaptation actions in place to quantify the predicted reduction in damages over the same time period as the vulnerability assessment.

These results were converted into benefit-cost ratios. Ratios greater than 1 represented actions that reduced more in damages in the future than it cost to implement them. Ratios less than 1 represented actions that would cost more than the amount of reduced damages in the future (i.e., not cost effective). The action that had the best benefit-cost ratio was **elevating and floodproofing buildings** (accounting for those not already elevated or floodproofed in the area of Key Largo within Monroe County), which had a benefit-cost ratio between 5.48 and 13.70 (meaning for every $1.00 spent on elevating and floodproofing, the avoided damages would range from $5.48 to $13.70), depending on the sea level rise scenario (high, low or tide gauge trend) and construction cost estimates (high and low). **Building barriers** had the second highest benefit-cost ratios, but with all results below 1 (0.40 to 0.93). The voluntary buyout program had benefit-cost ratios ranging from 0.02 to 1.21. The only result with a value greater than 1 was for the tide gauge trend sea level rise scenario, however. Aside from the model outputs, there were other factors which contributed to these results as discussed in this document. A similar analysis for Stock Island was completed at a later date and can be found in Appendix 6.

These benefit-cost ratios were presented to County residents and keypad polling technology was used to evaluate their opinions. After looking at 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 thought the County should pursue sources of funding to help private property owners implement this strategy.

The modeling results and community engagement process enabled the Project Team to provide the County residents with a context for beginning more difficult conversations and decision-making processes regarding their vulnerabilities. Discussions of factors outside of the model should lead to diverse co-benefits (e.g., choosing to restore mangrove forests to not only improve coastal ecosystems but also protect buildings from wave attenuation) and planning outcomes. Importantly, benefit-cost ratios resulting from this work tend to open difficult conversations about exactly what is most important to a community in planning how to adapt to sea level rise and future storm surges.

However, these results do not mean that the County should begin implementing a program to elevate and floodproof residential and commercial buildings. Catalysis recommends that the County use this information to:

- Further discuss sea level rise vulnerability with County residents and the importance of having a method to weigh different adaptation actions against one another (benefit-cost analysis)

- Develop a framework for using new knowledge to engage with residents so that consensus on an eventual adaptation action is data- and stakeholder-driven
- Share this information with neighboring communities so that more regional communication can take place and strengthen any local momentum towards adaptation
- Document any progress or failures towards adaptation so that other communities around the country have lessons from which they can learn.

2 Methodology and Assumptions used for COAST Model Analysis

Initial development of the COAST software tool was funded by the US Environmental Protection Agency. The tool is used to predict damages from varying amounts of sea level rise and storm surge under a range of candidate adaptation action scenarios that users construct. The software was run for the geographic region of Key Largo, Monroe County by Catalysis, who use it to help communities around the country. COAST is used to calculate the potential damage from one particular storm in the future, as well to calculate the cumulative potential damage from all storms that may occur over a period of years, from today until a point in the future. These storm events can also be modeled to become worse over time based on scenarios that include assumptions for sea level rise, which was the case for the Key Largo geographic region.

2.1 Preparing Model Inputs for the Geographic Region of Key Largo, Monroe County

2.1.1 Add Accurate Elevation Data

A Light Detection and Ranging (LiDAR) image of the area was used, which is a highly accurate map of land elevations made by taking laser measurements from an airplane. With this data layer the COAST model could identify the ground elevation of any point in the study area. The 2008 LiDAR data for the Key Largo geographic region was provided by the National Oceanic and Atmospheric Administration (NOAA) and distributed by the Florida Geographic Data Library (FGDL). It was then converted to the proper vertical units for use in the COAST software by Dr. Jason Evans and his team at the University of Georgia and Stetson University, and consisted of a 5 meter by 5 meter grid, with a single elevation value in feet for each square.

2.1.2 Add Tax Map Parcels and Assessed Building Values from the County

Property values for land and buildings were provided by the Monroe County Tax Collector's Office, and prepared by Dr. Jason Evans and his team, ensuring that the LiDAR images and tax map layers had the same coordinate system and units (feet) for both vertical and horizontal positions. Each property was classified according to general land-use (i.e., residential, commercial and government as categorized by the Monroe County Tax Collector's Office) and the year it was built. Parcels with buildings that had already been elevated according to FEMA requirements were also identified so that those buildings could be treated differently during the modeling process. Given that most properties after 1974 have already been elevated an average of eight (8) feet, this was an important process to assure the accuracy of the model and the benefits from the proposed strategies. Tax assessment values were raised by 15% across the board to adjust the assessed values of buildings to market prices, per the direction of attendees at the first workshop.

2.1.3 Determine Water Levels and Probabilities

The starting value of the high tide level for the geographic region of Key Largo was taken from the nearest tide station in Vaca Key, where the Mean Higher High Water (MHHW) value was -0.36 feet (in NAVD 88 units). This is considered the highest daily average tide; on top of which storm surge and sea level rise were added. Four (4) sea level rise scenarios were obtained from the Unified Sea Level Rise Projection for Southeast Florida, Southeast Florida Regional Climate Change Compact Counties, Sea Level Rise Ad Hoc Technical Working Group (April 2011). These included high and low estimates for both 2030 and 2060. At the first COAST workshop in October, a group of participants requested, and the Project Team agreed, to add a third “very low” sea level rise estimate, not found in the Unified Sea Level Rise Projection. This group wished to see results of modeling a sea level rise scenario using a linear “straight line” trend from the Key West tide gauge, with today’s rate of sea level rise increase remaining constant over time, without any of projected rate increases included in the Unified Projection. Therefore, the following sea level rise scenarios utilized were as follows:

- By the year 2030
  - An additional 1.82 inches (Very Low)
  - An additional 3 inches (*Low)
  - An additional 7 inches (*High)
- By the year 2060
  - An additional 4.53 inches (Very Low)
  - An additional 9 inches (*Low)
  - An additional 24 inches (*High)
  -

*From Unified Sea Level Rise Projection for Southeast Florida, Southeast Florida Regional Climate Change Compact Counties, Sea Level Rise Ad Hoc Technical Working Group (April 2011)

An “exceedance curve” was also established for particular neighborhoods throughout the County’s geographic region of Key Largo, and added into the COAST model. These curves set the height of water expected from storms of different sizes and probabilities for these different areas. The model then has information on how deep the floodwaters may be in each part of the study area, when future storms arrive. For instance, one neighborhood may have a 100-year storm (1% chance of occurring in any given year, or once every hundred years) flood height of ten (10) feet, but an adjacent area may have a flood height of six (6) feet, if it contains higher ground or is more protected from storm surges.

The geographic region of Key Largo was divided into areas based on these flood heights, which came from a digital flood insurance map file (dfirm_fldhaz_jun13.shp) produced by FGDL. The probabilities for the 1-, 10-, 50-, and 100-year storm events came from the latest available Flood Insurance Study for Monroe County (February 18, 2005). The table below represents the flood heights and probabilities for various neighborhoods in the geographic region of Key Largo:

Storm Event	Recurrence Interval	Probability in Any Given Year	Surge Height Above MHHW of -0.36 ft. (NAVD 88 units)	
			Minimum Value	Maximum Value
100 Year Storm	Once every 100 years	0.01	7.0	15.0
50 Year Storm	Once every 50 years	0.02	5.9	6.4
10 Year Storm	Once every 10 years	0.10	3.9	4.5
1 Year Storm	Once every year	1	1.08	1.08

Table 1. Storm events, recurrence intervals, probabilities and surge heights above Mean Higher High Water for the geographic region of Key Largo, FL.

These water levels were established for the creation of simulated storms, with identified sea level rise assumptions added over time.

2.1.4 Provide a Depth-Damage Function: Predicting Damage from Various Flood Depths

Finally, COAST relies on a function to calculate damage predicted to occur on each property, depending on flooding depth at the center of the property during each predicted storm event. This is called a "depth-damage function." COAST used depth-damage function tables created by the US Army Corps of Engineers, based on the Army Corps' damage measurements from years of studying floods and associated insurance claims (see U.S. Army Corps of Engineers, Contract No. DACW29-00-D-0001, Depth-Damage Relationships…in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study, March 7, 2006). Four (4) different depth-damage functions were assigned to each property, according to whether it was classified as either residential or non-residential, and whether it was elevated or not elevated. Dr. Evans' team assigned whether a property was elevated based on the year built (properties constructed in flood zones after 1974 were required to be elevated). It was also assumed that once the daily high tide (mean higher high water) with no storm surge reached the center of a parcel, the entire value of the building or buildings would be permanently lost due to sea level rise, if no action was taken. Therefore buildings on such parcels would no longer be subject to repeated damage, once their centers were permanently inundated.

2.1.5 Ensure Asset Data are Appropriately Structured

COAST creates flood scenarios over many years and measures flood depth at the center of each parcel. In the case of multiple buildings on one lot, and with the version of the software being used at the time, there unfortunately was no way to apportion building value between separate buildings. The County tax parcel database aggregated "building value" for all buildings on a lot. Therefore, for the purposes of this model, the aggregate building value was assigned to the group of buildings on each multi-building lot. Implications of this include that if the model showed the centroid of the parcel as flooded, it calculated damage to all buildings on the parcel using the depth-damage function, as if it were combined into one flooded building located at the center of the parcel. This may have overestimated damage on some parcels, but very few.

2.2 Limitations of COAST Model Results

- The effects of waves, wind, and erosion are not considered in the COAST model, as it calculates new high tide levels due to sea level rise only, using still water flood elevations on the existing terrain.
- Values for individual buildings were not available, as County assessing records combined the values of all buildings on a particular lot into one number.
- 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, known as the parcel "centroid."
- Only structural damage to buildings was included, based upon U.S. Army Corps of Engineers Depth Damage Functions for still water or static flooding. 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. COAST did not estimate damages to other assets such as roads, storm drainage systems, sewers, sewage treatment and pumping facilities, or other utilities.

3 Vulnerability Assessment

One-time flood damage estimates for Key Largo were generated for a “nuisance flood” or “king tide” arriving in the years 2030 or 2060 as if no adaptation action had been taken. A nuisance flood or king tide is defined as the highest tide of the year which occurs when the moon is full and is at perigee (the closest distance to the earth in its orbital path). One-time damage estimates were also generated for a Hurricane Wilma-sized storm surge (6 feet in 2005), made worse over time by sea level rise. COAST created visualizations of the pattern of these predicted damages (Figures 1-4). Parcels in coral represent those flooded from storm surge, with the height of each coral bar showing relative dollar damage. Parcels in green represent those permanently inundated from sea level rise (SLR). All images for all major sections of the Key Largo geographic region are located in the appendix of this report (Section 6.2). Cumulative building damage over time was also calculated, through the years 2030 and 2060. Results are summarized in tables below.

Key Findings of Vulnerability Assessment – If No Action is taken

- By 2030 a nuisance flood would cause $400,000 in damages to buildings even if the rate of sea level rise stayed constant from the past 100 years (linear tide gauge trend, Table 2).
- By 2060 a nuisance flood would cause $2.0 Million in damages to buildings under a high (24”) sea level rise scenario (Table 2).
- By 2030 a Wilma-sized flood would cause $145.2 Million in damages to buildings under a low (3”) sea level rise scenario (Table 3).
- By 2060 a Wilma-sized flood would cause $189.2 Million in damages to buildings under a high (24”) sea level rise scenario (Table 3).
- By 2060, cumulative damages from all possible storms (Table 4) would result in damages ranging from $1.673 Billion (linear tide gauge trend) to $2.130 Billion (high sea level rise).
- By 2060, the total value of all buildings and land that are no longer inhabitable as a result of sea level rise (Table 6) would be between $206.9 Million (linear tide gauge trend) and $705.6 Million (high sea level rise scenario).
- This represents a loss of $0.92 to $3.13 Million in annual tax revenue.

Table 2. One-time damage estimates from nuisance floods in Key Largo in 2030 and 2060 with high and low sea level rise.

Event: 1.08 ft. Surge Nuisance Flood	SLR Scenario *Linear Tide Gauge Trend **Unified Sea Level Rise Projection	One-Time Damage to Building Values
Year 2030	*Very Low - 1.82"	$ 0.4 Million
Year 2030	**Low - 3.00"	$ 0.6 Million
Year 2030	**High - 7.00"	$ 1.3 Million
Year 2060	*Low - 4.53"	$ 1.6 Million
Year 2060	**Low - 9.00"	$ 0.4 Million
Year 2060	**High - 24.00"	$ 2.0 Million

Table 3. One-time damage estimates from Hurricane Wilma-sized floods in Key Largo in 2030 and 2060 with high and low sea level rise.

Event: 6.00 ft. Surge Wilma-Sized Flood	SLR Scenario *Linear Tide Gauge Trend **Unified Sea Level Rise Projection	One-Time Damage to Building Values
Year 2030	*Very Low - 1.82"	$ 142.4 Million
Year 2030	**Low - 3.00"	$ 145.2 Million
Year 2030	**High - 7.00"	$ 144.2 Million
Year 2060	*Very Low - 4.53"	$ 139.9 Million
Year 2060	**Low - 9.00"	$ 144.4 Million
Year 2060	**High - 24.00"	$ 189.2 Million

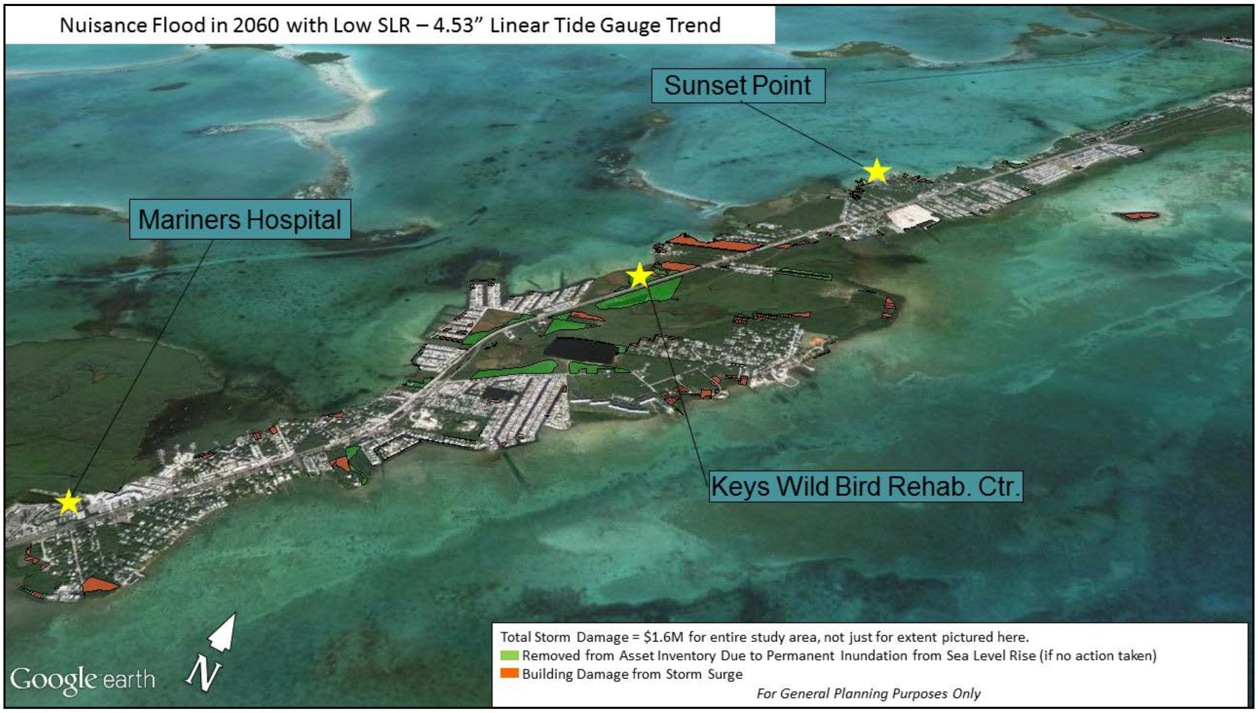


Figure 1. Google Earth image of potential flooding damages from a nuisance flood (linear tide gauge trend) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in dollars. Parcels in green indicate those permanently inundated from sea level rise.

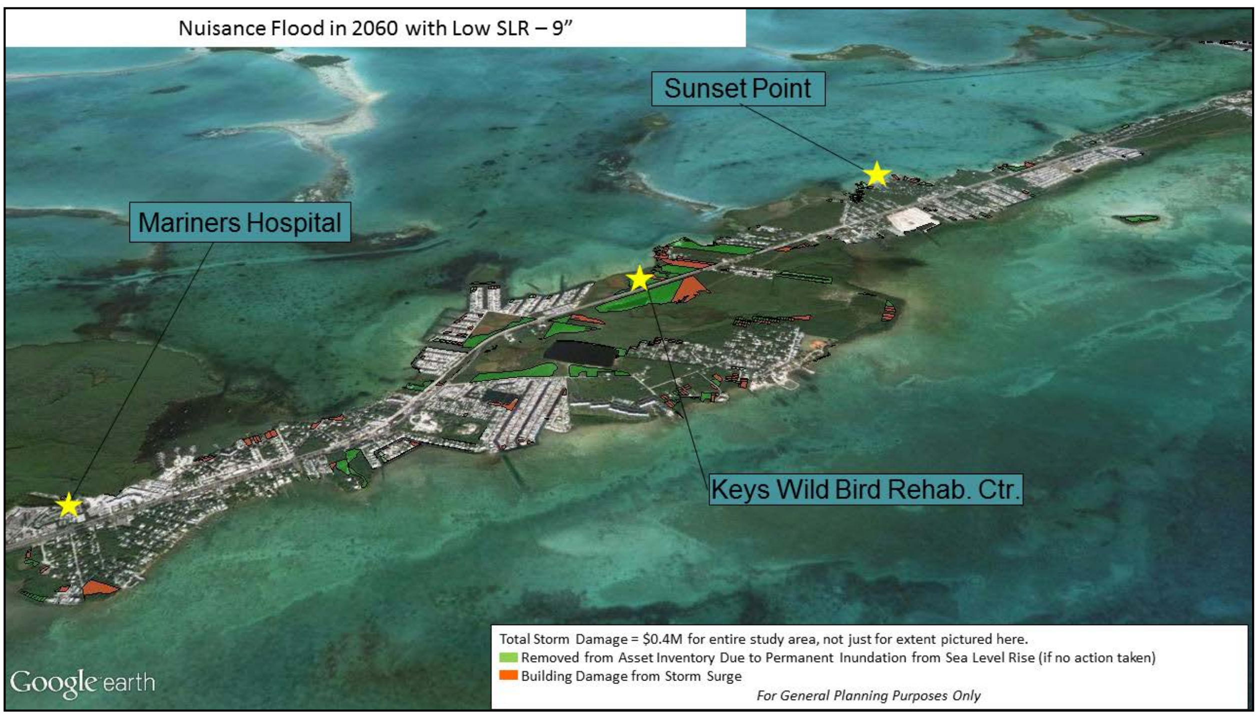


Figure 2. Google Earth image of potential flooding damages from a nuisance flood (low sea level rise scenario) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in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

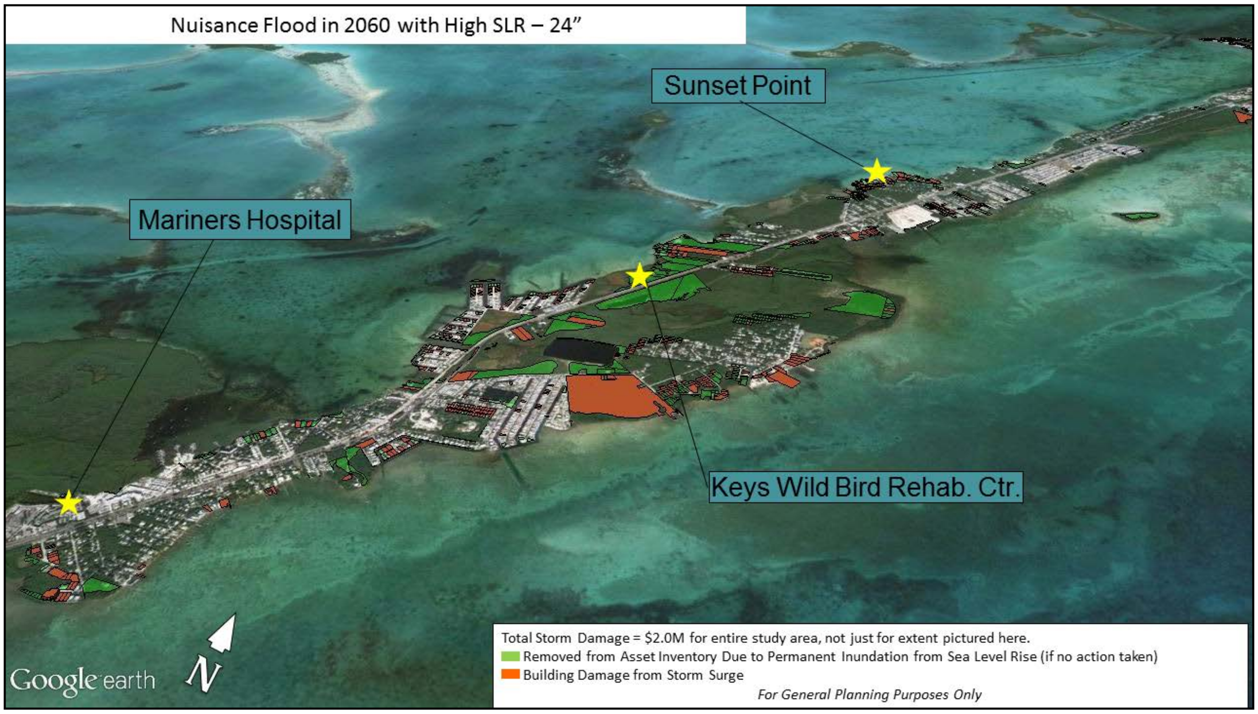


Figure 3. Google Earth image of potential flooding damages from a nuisance flood (high sea level rise scenario) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in dollars. Parcels in green indicate those permanently inundated from sea level rise.

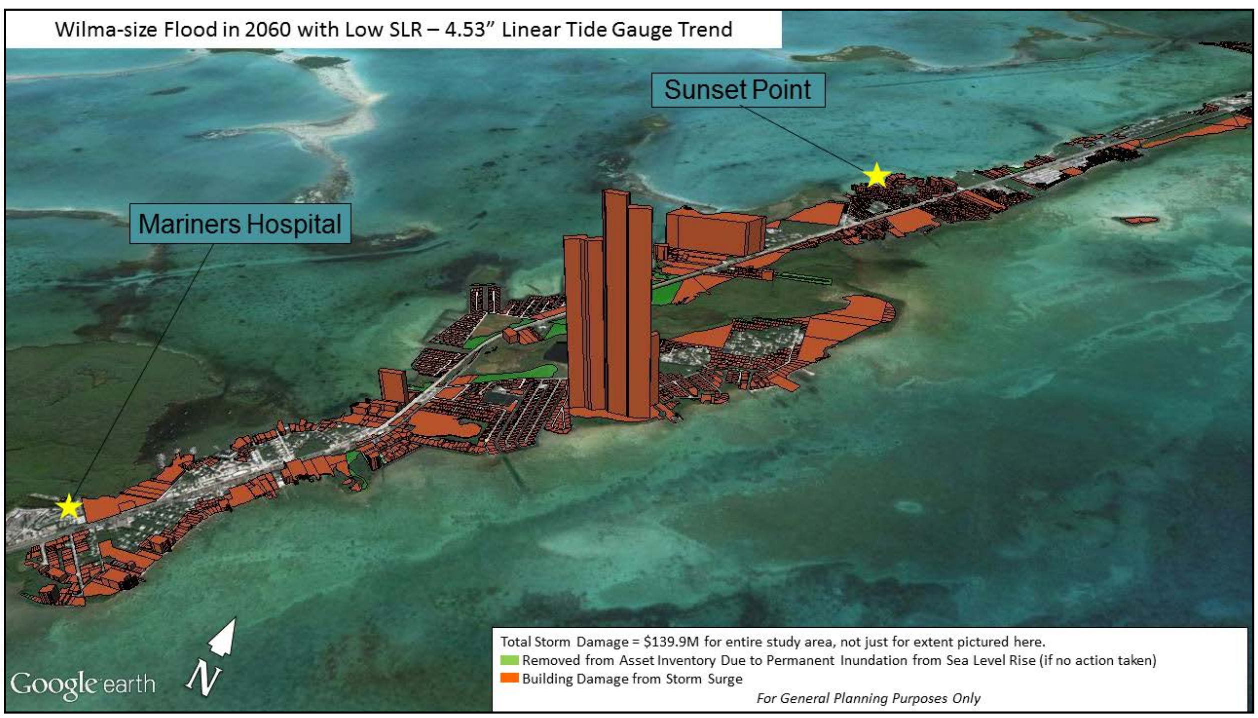


Figure 4. Google Earth image of potential flooding damages from a Hurricane Wilma-sized flood (linear tide gauge trend) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in dollars. Parcels in green indicate those permanently inundated from sea level rise.

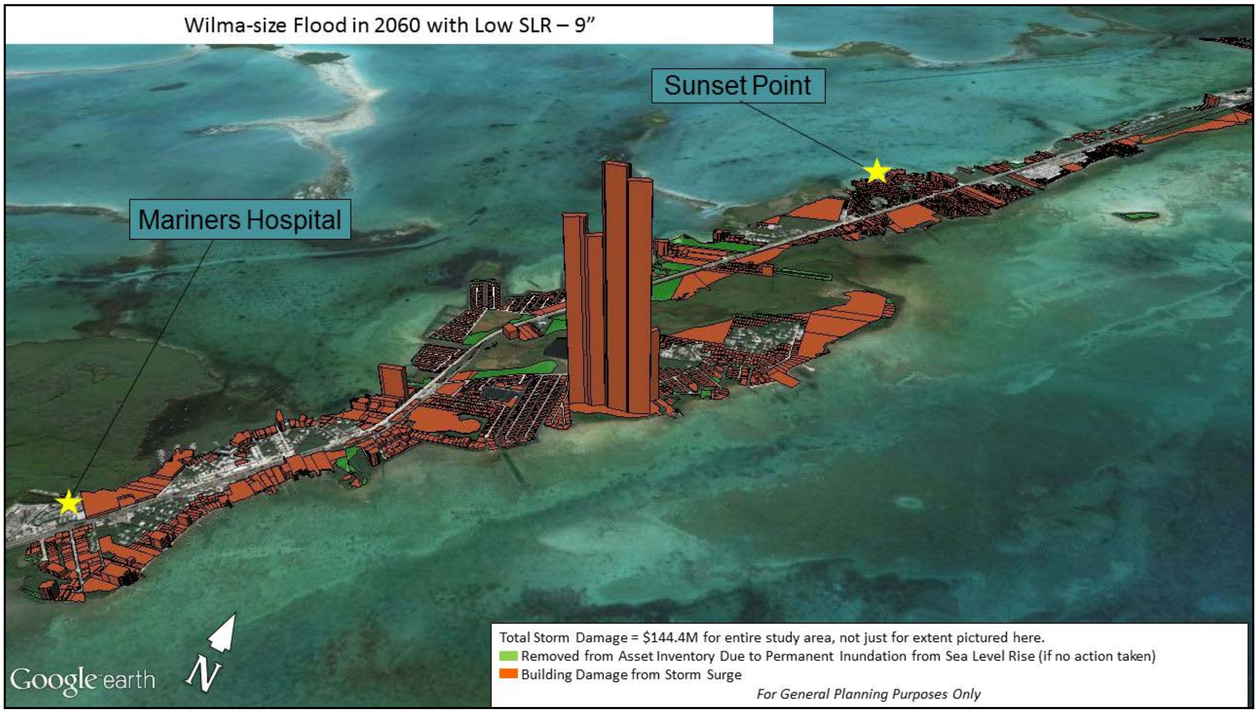


Figure 5. Google Earth image of potential flooding damages from a Hurricane Wilma-sized flood (low sea level rise scenario) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in dollars. Parcels in green indicate those permanently inundated from sea level rise.

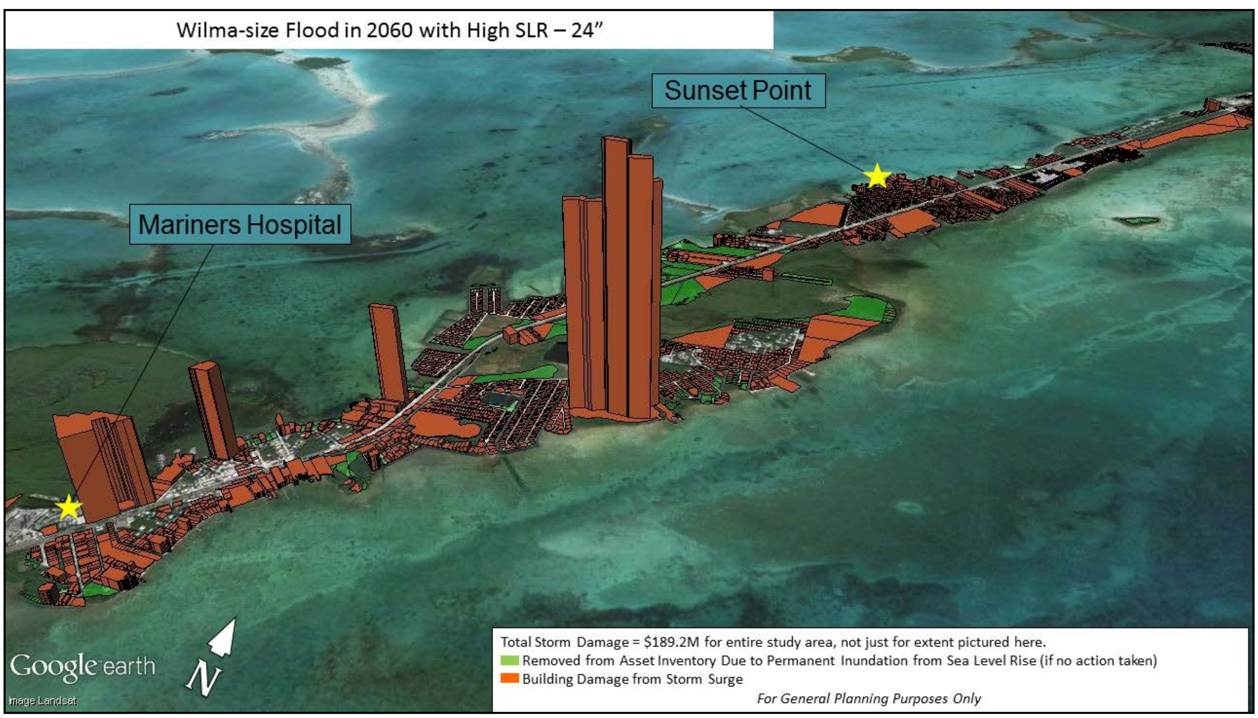


Figure 6. Google Earth image of potential flooding damages from a Hurricane Wilma-sized flood (high sea level rise scenario) in 2060 for a section of Key Largo, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts in dollars. Parcels in green indicate those permanently inundated from sea level rise.

Timescale	SLR Scenario *Linear Tide Gauge Trend **Unified Sea Level Rise Projection	Cumulative Damage to Buildings by Scenario Date
2014-2030	*Very Low-1.82"	$ 575.7 Million
2014-2030	**Low-3.00"	$ 583.3 Million
2014-2030	**High-7.00"	$ 609.2 Million
2031-2060	*Very Low-4.53"	$ 1.097 Billion
2031-2060	**Low-9.00"	$ 1.195 Billion
2031-2060	**High-24.00"	$ 1.521 Billion
2014-2060	*Very Low-4.53"	$ 1.673 Billion
2014-2060	**Low-9.00"	$ 1.778 Billion
2014-2060	**High-24.00"	$ 2.130 Billion

Table 4. Cumulative damage estimates from all possible storms during a given time period with very low, low and high sea level rise.

Timescale	SLR Scenario *Linear Tide Gauge Trend **Unified Sea Level Rise Projection	Value of Buildings Lost to SLR	Value of Land Lost to SLR	No. of Parcels Lost to SLR	Total Value of Builds and Land Lost to SLR
2014-2030	*Very Low-1.82"	$ 10.8 Million	$ 37.3 Million	129	$ 48.1 Million
2014-2030	**Low-3.00"	$ 86.1 Million	$ 45.1 Million	209	$ 131.2 Million
2014-2030	**High-7.00"	$ 84.4 Million	$ 171.2 Million	918	$ 255.6 Million
2031-2060	*Very Low-4.53"	$ 47.8 Million	$ 111.0 Million	588	$ 158.8 Million
2031-2060	**Low-9.00"	$ 171.3 Million	$ 201.2 Million	1041	$ 372.5 Million
2031-2060	**High-24.00"	$ 181.7 Million	$ 268.3 Million	1426	$ 450.0 Million

Table 5. Buildings and land permanently inundated from sea level rise during scenario years 2014-2030 and 2031-2060 with very low, low and high sea level rise.

SLR Scenario *Linear Tide Gauge Trend **Unified Sea Level Rise Projection	Value of Buildings Lost to SLR	Value of Land Lost to SLR	No. of Parcels Lost to SLR	Total Value of Builds and Land Lost to SLR	Annual Tax Revenue Lost to SLR
*Very Low-4.53"	$ 58.6 Million	$ 148.3 Million	717	$ 206.9 Million	$ 0.92 Million
**Low-9.00"	$ 257.4 Million	$ 246.4 Million	1250	$ 503.8 Million	$ 2.24 Million
**High-24.00"	$ 266.1 Million	$ 439.5 Million	2344	$ 705.6 Million	$ 3.13 Million

Table 6. Buildings and land permanently inundated from sea level rise during scenario years 2014-2060 with very low, low and high sea level rise.

4 ADAPTATION ACTIONS

4.1 POSSIBLE STRATEGIES: DO NOTHING, FORTIFY, ACCOMMODATE OR STRATEGICALLY RELOCATE

Options for responding to sea level rise and storm surge can be divided into four (4) categories:

- *Doing nothing* simply involves waiting for a storm incident to happen and responding afterwards to save those structures that are not completely lost due to the incident. *Doing nothing* is not proposed for the geographic region of Key Largo.
- Adaptation approaches that *fortify* use hard or soft structures to prevent flood waters from reaching community assets. Such armoring can be "hard," such as seawalls or bulkheads, or "soft" structures such as geotextiles tubes, giant fabric sandbags designed to be replaced after storms (Fig 7a and 7b). Unfortunately, wetlands and beaches in front of such structures can disappear as they are pinched out between the rising water levels and the fortifying structures behind them.

Figures 7a and 7b. USACE hurricane barrier in Stanford, CT (left) and geotextile tubes in front of apartment complex in Sea Isle

City, NJ (right).

- Adaptation approaches that *accommodate* modify community assets to reduce the impact of flood waters, but they do not protect again sea level rise (only storm surge). Accommodation acknowledges that structures will become wet, but actions are taken to make them resilient, such as elevating structures or their critical systems.

Figures 8a and 8b. Elevated house (left) and floodproofed house (right). Source: http://www.theepochtimes.com/n3/4747-hurricane-sandy-katrina-offer-similar-lessons-for-builders/

- *Strategic relocation* involves relocating existing structures, people and land-uses away from areas at high risk of flooding to a new location to eliminate the risks of flooding, and allowing wetlands, beaches and natural coastal habitats to migrate to higher elevations naturally.

4.2 Use of COAST to Perform a Benefit-Cost Analysis for Three (3) Proposed Strategies

Once an adaptation strategy, or set of strategies, has been identified for a community or portion of a shoreline, COAST can be used to evaluate whether the strategy would be a good investment. Following the above vulnerability assessment stage, the COAST model can be run with adjustments to the depth damage functions. This serves as a proxy estimation of how much cumulative damage might be avoided if the adaptation strategies were put in place. Avoided cumulative damage can then be compared to the cost of the potential strategies, creating a benefit-cost ratio. If this ratio is high (i.e., costs are low and benefits are high) the option may be a good investment and worthy of further study, such as more detailed feasibility plans, construction designs or estimates. It should be noted that the cost estimates obtained for this study use high and low estimates. More detailed work would need to be undertaken to arrive at a more specific adaptation strategies design, with more accurate permitting and construction costs.

4.3 Description of the Three (3) Proposed Adaptation Strategy Scenarios

Audience polling at the County community workshop in November 2014 (Workshop #2) refined three (3) adaptation strategy scenarios that were initially developed by the Project Team and County staff. Agreed upon candidate adaptation strategy scenarios were as follows:

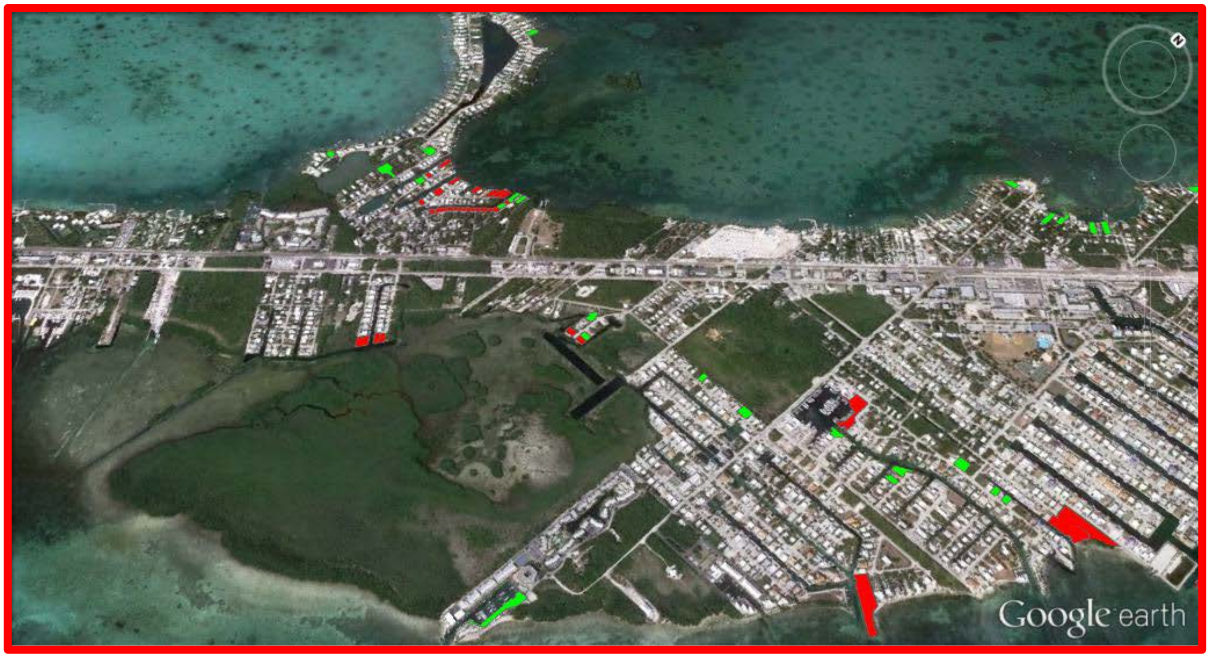
- Action 1: Elevate and Floodproof (Fig. 9a and 9b)
  - 100% of properties in FEMA V-Zones elevated to current code plus three (3) feet
  - 100% of properties in FEMA A-Zones floodproofed to eight (8) feet
- Action 2: Constructed Barriers (Fig. 8a and 8b)
  - Two (2) one (1) mile long emergent breakwater structures built near shore (200 feet off of coast), constructed of limestone block topped with mangrove plantings.
- Action 3: Relocate – Voluntary Buyout (Fig. 9a and 9b)
  - Assumptions were that 10% of properties permanently flooded from sea level rise by 2030 accept the voluntary buyout in 2015
  - Assumptions were that 100% of properties permanently flooded from sea level rise by 2045 accept the voluntary buyout in 2030

Figures 9a and 9b. Action 1 Scenario: Images of two (2) locations in Key Largo area. Parcels in red indicate those that are located in a FEMA V-Zone and had their buildings elevated (189 total) as a result of the candidate action. Parcels in green indicate those that are located in a FEMA A-Zone and had their buildings floodproofed (2283 parcels total) as a result of the candidate action.


Google earth


Google earth

Figures 10a and 10b. Action 2 Scenario: Images of two (2) locations in Key Largo area. Only the parcels located in the V-Zones behind the barriers would have reduced damage as a result of the candidate action.



Figures 11a and 11b. Action 3 Scenario: Images of two (2) locations in Key Largo area. Parcels in red indicate those permanently inundated from sea level rise by 2030 (311 total) subject to voluntary buyouts as a result of the candidate action. Parcels in green indicate those permanently inundated from sea level rise by 2045 (389 total) subject to voluntary buyouts as a result of the candidate action. The details of the buyout program (i.e., who buys the properties) would only be developed if the adaptation was determined to be cost effective.

4.4 Results for Modeling the Three (3) Proposed Adaptation Strategy Scenarios

Table 7 below shows the results for Adaptation Action 1, Elevate and Floodproof. Avoided damages by the year 2060 ranged from $836.3 Million (linear tide gauge trend) to $992.9 Million (high sea level rise). Costs to elevate a building ranged from $60,000 to $160,000[2], and costs to floodproof a building ranged from $26,770 to $53,539[3]. These costs represent low and high estimates for construction only, and are irrespective of building for specific sea level rise scenarios (i.e. based only on today's storm surge heights). Complete pricing information is available in the appendix of this report (Section 6.3). Avoided damage estimates by the year 2060 for three (3) sea level rise scenarios (high, low and a linear tide gauge trend), and with both high and low cost estimates, resulted in six (6) benefit-cost ratios. These ranged from $5.48 (linear tide gauge trend with high cost estimates) to $13.70 (high sea level rise with low cost estimates). These ratios represent long-term savings in the form of damage reduction for every dollar spent today. For example, under the best benefit-cost ratio, for every $1 spent today to elevate and floodproof buildings, $13.70 would be saved by 2060.

Table 7 - Elevate and Floodproof Buildings		
Avoided Damages Low SLR - Tide Gauge Trend (4.53")	**Avoided Damages Low SLR - (9.00")**	**Avoided Damages High SLR - (24.00")**
($ Millions)	($ Millions)	($ Millions)
836.3	871.9	992.9
Low Cost Estimate	**High Cost Estimate**	
$72.5 Million - Total	$152.5 Million - Total	
Avg. Price Per Unit - Elevation	Avg. Price Per Unit - Elevation	
$60,000	$160,000	
Avg. Price Per Unit - Floodproofing	Avg. Price Per Unit - Floodproofing	
$26,770	$53,539	
Benefit-Cost Ratios - Using Low Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
$11.54	$12.03	$13.70
Benefit-Cost Ratios - Using High Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
$5.48	$5.72	$6.51

Table 7. Results from COAST model of Adaptation Action 1 – Elevate and Floodproof buildings. 100% of buildings in FEMA V-Zones were elevated and 100% of buildings in FEMA A-Zones were floodproofed.

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[2] Estimated elevation cost ranges were provided by Parsons Brinckerhoff, and a review of internet contractor websites.

[3] Estimated floodproofing cost ranges were calculated by taking 10% (low) and 20% (high) of the building values and dividing by the number of buildings to be floodproofed. The high and low percentages (10% and 20%) were provided by Parsons Brinckerhoff, and a review of internet contractor websites.

Table 8 shows the results for Adaptation Action 2 – Constructed Barriers. Avoided damages by the year 2060 only ranged between $6.8 Million (linear tide gauge trend) and $12.0 Million (high sea level rise) because a barrier does not protect against sea level rise – it only diminishes wave action from storm events for properties in the FEMA V-Zones located behind the barriers. Costs to build a barrier ranged from $12.9 Million to $17.1 Million (see Section 6.3 for cost breakdown); six (6) benefit-cost ratios were calculated. These ranged from $0.40 (with linear tide gauge trend of 4.53" and high cost estimate) to $3.93 (with high sea level rise of 24"and low cost estimate). The ratios represent long-term savings in the form of damage reduction for every dollar spent today. For example, under the best benefit-cost ratio, for every $1 spent today to build barriers to protect buildings, $0.93 would be saved by 2060. Any adaptation with a benefit-cost ratio of less than one is not considered cost effective.

<table>
<tr><th colspan="6">Table 8 – V-Zone Properties Behind Barriers = Reduced Damage from Wave Heights Reduced by 80%
All Other Properties = Unchanged</th></tr>
<tr><th colspan="2">Avoided Damages
Low SLR - Tide Gauge Trend (4.53")</th><th colspan="2">Avoided Damages
Low SLR -
(9.00")</th><th colspan="2">Avoided Damages
High SLR -
(24.00")</th></tr>
<tr><td colspan="2">($ Millions)</td><td colspan="2">($ Millions)</td><td colspan="2">($ Millions)</td></tr>
<tr><td colspan="2">6.8</td><td colspan="2">8.0</td><td colspan="2">12.0</td></tr>
<tr><th colspan="3">Low Cost Estimate</th><th colspan="3">High Cost Estimate</th></tr>
<tr><td colspan="3">$12.9 Million - Total</td><td colspan="3">$17.1 Million - Total</td></tr>
<tr><td colspan="3">Avg. Price Per Linear Foot</td><td colspan="3">Avg. Price Per Linear Foot</td></tr>
<tr><td colspan="3">$1,221.59[4]</td><td colspan="3">$1,619.32[4]</td></tr>
<tr><th colspan="6">Benefit-Cost Ratios - Using Low Cost Estimate</th></tr>
<tr><td colspan="2">Tide Gauge Trend</td><td colspan="2">Low SLR</td><td colspan="2">High SLR</td></tr>
<tr><td colspan="2">$0.53</td><td colspan="2">$0.62</td><td colspan="2">$0.93</td></tr>
<tr><th colspan="6">Benefit-Cost Ratios - Using High Cost Estimate</th></tr>
<tr><td colspan="2">Tide Gauge Trend</td><td colspan="2">Low SLR</td><td colspan="2">High SLR</td></tr>
<tr><td colspan="2">$0.40</td><td colspan="2">$0.47</td><td colspan="2">$0.70</td></tr>
</table>

Table 8. Results from COAST model of Adaptation Action 2 – Constructed Barriers.

Table 9 shows results for Adaptation Action 3 – Voluntary Buyouts. Avoided damages by the year 2060 ranged from $1.71 Million (with high sea level rise of 24") to $79.7 Million (with linear tide gauge trend of 4.53"). The total cost to purchase homes before they are permanently inundated from sea level

[4] Price per linear foot costs were provided by the Palm Beach County Environmental Resources Management Department.

rise ranged from $144.3 Million to $216.4 Million[5] (see Section 6.3 for total cost breakdown). It is important to note that the details of the voluntary buyout program (e.g., who is buying the properties and how the process works) are not relevant unless the action is deemed cost effective first. It could take many years and several political processes to establish a program like this, so it makes sense to first assume the program is already in place and test whether it is worth the time and effort to establish it.

Avoided damage estimates by 2060 for high and low sea level rise and the linear tide gauge trend, and with either high and low cost estimates for purchasing vulnerable buildings resulted in six (6) benefit-cost ratios. These ranged from 0.02 (with high sea level rise of 24”and high cost estimates) to 1.21 (with linear tide gauge trend of 4.53” and low cost estimates). The 1.21 benefit-cost ratio was the only ratio that represented long-term savings (in the form of damage reduction) for every dollar spent today. Because most of these ratios were less than one, it may make more sense economically to do nothing than to follow through with this particular action. However, this result is based on assumptions chosen by the participants, and there could be some more positive benefits in implementing this action, under a different set of parameters.

Table 9 – Voluntary Buyouts		
Avoided Damages Low SLR - Tide Gauge Trend (4.53")	**Avoided Damages Low SLR - (9.00")**	**Avoided Damages High SLR - (24.00")**
($ Millions)	($ Millions)	($ Millions)
79.7	61.9	1.71
Low Cost Estimate	**High Cost Estimate**	
$144.3 Million - Total	$216.4 Million - Total	
Avg. Price Per Buyout	Avg. Price Per Buyout	
$206,143	$309,143	
Benefit-Cost Ratios - Using Low Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
$1.21	$0.94	$0.03
Benefit-Cost Ratios - Using High Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
$0.81	$0.63	$0.02

Table 9. Results from COAST model of Adaptation Action 3 - Voluntary Buyouts. The scenario was run as if 10% of buildings permanently inundated from sea level rise by 2030 were purchased from owners and 100% of buildings permanently inundated from sea level rise by 2045 were purchased from owners.

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[5] The building and land values for parcels permanently inundated from high sea level rise by 2030 and 2045 were calculated using discount rates for the dates they were to be purchased and multiplied by the appropriate percentages (i.e., participation rates in both phases, and estimated legal costs for the high cost estimate scenario).

5 Discussion and Conclusions

5.1 Comparisons of Modeling Results for the Three (3) Adaptation Actions

The appendix of this report includes keypad polling results from the Key Largo Geographic Region Workshops #2 and #3, in which audience members voted on specific COAST modeling assumptions and responded to the COAST modeling results (See Sections 6.1 and 6.4).

In Community Workshop #3, audience members preferred results of Adaptation Action 1, Elevation and Floodproofing, more than the other two (2) actions. Depending on cost estimates and sea level rise assumptions, benefit-cost ratios for Action 1 were very positive and ranged from 13.7 to 5.5. Benefit cost ratios with a value above $1.0 are considered positive results (benefits greater than costs). As a result of such favorable ratios, eighty-three percent (83%) of participants believed it would be worth the County's time to conduct additional study of an initiative to elevate and floodproof buildings. Similarly, a majority of participants (61%) believed the County should pursue sources of funding to help private property owners elevate their buildings in the FEMA Velocity flood zone, although 39% did not think the County should pursue sources of funding.

Adaptation Action 2, Constructing an Offshore Limestone Barrier with Mangrove Plantings, had unfavorable benefit-cost ratios ranging from 0.4 to 0.93. The most positive of the ratios fell just below one. It should be noted that this action would only have protected buildings located in the FEMA V-Zone and directly behind the barrier. In addition, to make the ratios more favorable the barriers had been "placed" in areas where they protected the highest values of buildings, not necessarily the highest number of buildings. This may make sense financially, however it would be a challenge to build consensus around the barrier locations. Moreover, the barrier would not prevent damages from sea level rise and would only reduce wave action during storms; which was a concern for community members. As a result of these unfavorable ratios, seventy-six percent (76%) of participants believed it would not be worth the County's time to conduct additional study of constructing such barriers.

Adaptation Action 3, Voluntary Buyouts, had a mix of favorable and unfavorable benefit-cost ratios compared to the other actions. Results for this modeled action suggested it would often cost more than the cumulative damage reduction over time, with benefit-cost ratios ranging from $0.02 to $1.21 (only positive in the low cost and linear tide gauge trend sea level rise scenario). However, modeling assumptions for this action significantly influenced the results. For example, if a person were to be able to stay in their home until 2030 despite having accepted a voluntary buyout for that home today, in this scenario money would be invested toward purchase of that house *and* toward repair of damages that occur between today and 2030. The benefit-cost ratio for this action would thus improve if less time were to be allowed between purchasing a house and the date when title for that house transfers. Because of these issues, keypad polling in workshop #3 determined that a majority of participants (53%) did not think the County should pursue funding to support a voluntary buyout program.

5.2 How the COAST Modeling Results Relate to the Larger GreenKeys! Project

COAST modeling results showed that Adaptation Action 1 (elevating and floodproofing buildings) had the most favorable benefit-cost ratio compared to the other two (2) adaptation actions. However in discussions at the public meetings, it became clear that elevation and floodproofing alone could not be considered as a solution to future threats from sea level rise and storm surges. Impacts on roads and other County infrastructure will also need adaptation actions to prevent damage at the same time as private properties are made safer by elevating and floodproofing. If road access and sewer and water services to these properties are lost, making private properties safer by minimizing damage from storm surge will not be a sustainable solution. Therefore it is important to review the COAST modeling results in the larger context of the Monroe County GreenKeys! Project. In future modeling efforts in the Key Largo geographic region of Monroe County or elsewhere, **it may be beneficial to model benefits and costs of joint action for adapting roads and buildings.** Nevertheless, the modeled actions for adapting real estate alone do provide useful results that should help provide momentum toward additional important steps in the County's sea level rise adaptation planning process.

It is also important to review results from this project with the larger adaptation context in mind. That is, adapting to the threats of a changing climate is as much of a governance problem as it is an uncertainty problem. Choosing one adaptation action over another will not be (and should not be) a simple or linear process determined by one report or study. Rather it should be a process that involves multiple stakeholder groups (e.g., private property owners, utilities, local governments and state governments) in a process where concerns and interests, data gathering, and reciprocal learning can be shared between groups so that all parties involved have an opportunity to shape the adaptation action(s) over time.

Additionally, the unique characteristics of the Florida Keys region lend itself, and the local governments that comprise it, to more specific issues. Some of these include, but are not limited to: islands that may be impacted by sea level rise sooner than others, local and state laws that protect specific environments and prohibit building flood fortifications on them (e.g., ocean reefs), and the differing levels of development in varying heights of elevation (e.g., one community might not be impacted by sea level rise as much because development is simply at a higher elevation than neighboring communities). The best method to confront these and other challenges is to increase the communication between groups and develop a forum to share ideas, knowledge and concerns.

One of the main challenges with this process is moving beyond simple vulnerability assessments to a robust benefit-cost analysis that can begin to address real-world solutions and start (or compliment) the overall adaptation process. The analysis presented here is intended to substantively fill this void. But importantly, it is just a first step in this direction; filling the void completely can be expected to take more time. In many cases choosing an adaptation action and determining how it should be implemented can take as long as the actual implementation itself. However this should not deter people from taking their time to evaluate multiple climate change threats and adaptation actions, as long as the lessons learned continue to create momentum towards an overall strategy that can be supported by those it is intended to help. While the low elevation, limited undeveloped land, and geologic formation of the Florida Keys region present challenges for creating a portfolio of adaptation options to consider, they also creates areas of opportunity to easily rule out certain adaptations that are physically impossible to implement (e.g., moving buildings back to less vulnerable pieces of land) and focus on unique and coupled threats (e.g., sea level rise and the porous nature of limestone bedrock).

It is important to remain aware that threats to a community such as sea level rise and storm surge transcend jurisdictional boundaries, political cycles and fiscal calendars. As a result communities need to consistently work together and communicate to ensure individual efforts are not working against one another, but rather in tandem. When communities coordinate their adaptation efforts in this manner benefits can be scaled up and have more of a regional impact – which in turn helps strengthen the individual actions.

5.3 Comparison of COAST Results in the Key Largo Geographic Area to Nearby Locations

During fall 2014, Catalysis also used the COAST model to analyze vulnerabilities and test similar adaptation actions in the next community to the south, the Village of Islamorada. The Key Largo geographic area had 12,289 properties with a total market value of $4.24 billion. The Islamorada Village study area had 5,601 properties with a total market value of $3.67 billion. Even though Islamorada is smaller with 54% fewer properties and 13% lower market value than Key Largo, predicted cumulative dollar damages to buildings from storm surges and sea level rise was actually 28.7% higher with a high sea level rise scenario.

Timescale	SLR Scenario	Cumulative Damage to Buildings Islamorada Study Area	Cumulative Damage to Buildings Key Largo Study Area	Percent Increase (decrease) in Cumulative Damage, Islamorada vs. Key Largo
2014-2060	Low – 9”	$1.734 billion	$1.778 billion	(-2.5%)
2014-2060	High – 24”	$2.741 billion	$2.130 billion	+28.7%

Table 10. Comparison of COAST Model Results for Cumulative Damage to Buildings by 2060, Village of Islamorada versus Key Largo Geographic Area.

Analysis of this situation indicates two (2) factors that would lead to this unexpected result:

1. In general, as one travels south down Route 1 from the beginning of the Keys in Key Largo, the land area becomes lower and flatter and subject to more surge damage compared between the two.
2. A larger percentage of the higher value real estate may be located in lower, more vulnerable areas in Islamorada, than in Key Largo geographic area. In particular, Key Largo has more high value development along Route 1 (on higher ground above the 100 year floodplain) compared to its southern neighbor.

5.4 How COAST Results Have Led to Adaptation Actions in Other Communities, and How GreenKeys! Can Use Them

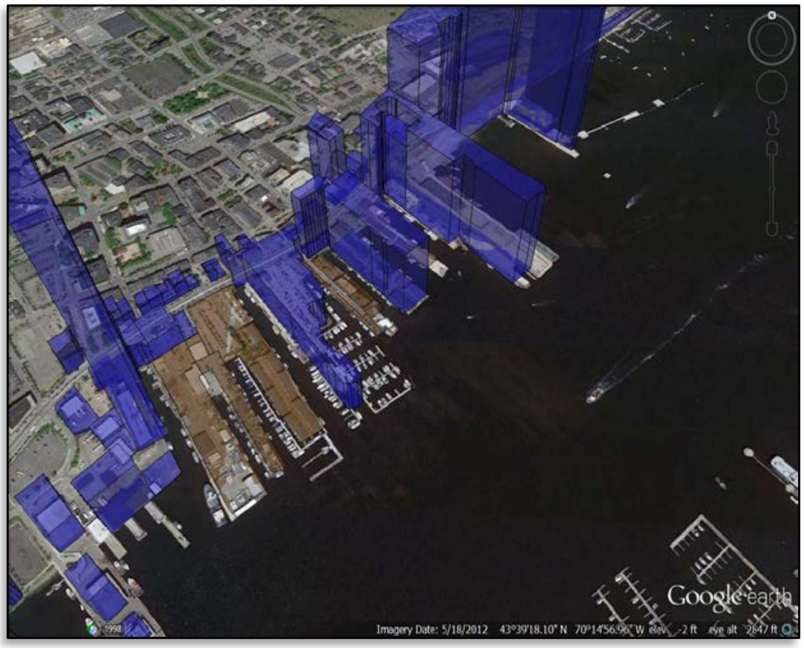
Now that problems of sea level rise and storm surge have been discussed with probabilities and estimated damage figures attached, vulnerabilities will have begun to seem more real than before the effort began.

These model results provide powerful insights and information to seek funding and develop political leadership around adaptation strategies that will protect the community – whether the solution will be fortification, accommodation, strategic relocation, or a combination of these. However the COAST process is not just about these results. This project has built models of the future *in collaboration with* a broad collection of stakeholders and concerned citizens. Now that problems of sea level rise and storm surge have been discussed with probabilities and estimated damage figures attached, vulnerabilities will have begun to seem more real than before the effort began. Candidate adaptation actions have also been evaluated in detail, creating the opportunity for political momentum should community leaders wish to take additional steps in these directions.

Many communities have completed the COAST modeling process during the past three (3) years. Examples of some positive steps taken by other communities that have used COAST include:

- Kingston, New York – Results of the COAST model have led to continuing discussions about further floodproofing and even relocating the main sewage treatment plant, which was identified as an extremely vulnerable asset predicted to be subject to a high level of cumulative damage over the coming decades. Sea level rise issues are being considered for inclusion with ongoing updates to the Master Plan and Waterfront Redevelopment Plan for Kingston.

- Portland, Maine – Results of COAST modeling in the Back Cove area led to inclusion of specifications in requests for proposals for storm drainage work, specifically that designers and engineers must address potential sea level rise conditions in prospective projects. Another product of this effort was a second round of COAST modeling to study the vulnerability of the Commercial Street waterfront (arranged by the local nonprofit Portland Society for Architecture). Results have highlighted opportunities for the City of Portland to revise ordinances and make other changes in the direction of a more resilient working waterfront.



Given the short period the COAST approach has been in use, how long a COAST project takes to implement, and how long it takes to actually implement most adaptation strategies, construction stages of actions modeled by the Catalysis team have not yet occurred in communities that have used the approach. However, COAST modeling results have started many important public conversations. For example when considering adaptations to sea level and storm surge, numerous communities have indicated preferences for which directions they might like to head next. Interestingly, the most cost-effective option is not always the one favored; communities sometimes determine other values are more important, such as maintaining ocean views or protecting natural resources. That is, benefit-cost ratios from this work tend to open difficult conversations about what is most important to a community. Additionally, this type of modeling exercise usually results in broad discussion of vulnerabilities outside the model and helps identify diverse co-benefits of taking action. It is hoped results from this project will galvanize similar conversations and move Monroe County towards its desired courses of action.

Interestingly, the most cost-effective option is not always the one favored; communities sometimes determine other values are more important, such as maintaining ocean views or protecting natural resources.

While the benefit-cost analysis is not meant to necessarily lead Key Largo towards implementing the Elevation and Floodproof Adaptation action, Catalysis does recommend that the County create some additional tasks using this report and its vulnerability assessment and benefit-cost analysis. These include, but are not limited to:

- Further discuss sea level rise vulnerability with County residents and the importance of having a method to weigh different adaptation actions against one another (benefit-cost analysis)
- Develop a framework for using new knowledge to engage with residents so that consensus on an eventual adaptation action is data- and stakeholder-driven
- Share this information with neighboring communities so that more regional communication can take place and strengthen any local momentum towards adaptation
- Document any progress or failures towards adaptation so that other communities around the country have lessons from which they can learn.

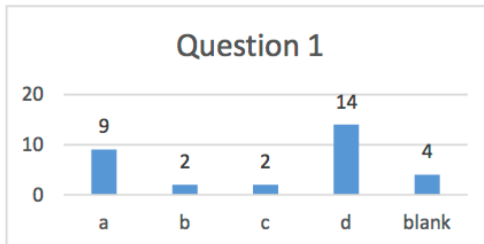
6 APPENDIX: PUBLIC INPUT AND COST CONSIDERATIONS OF PROPOSED STRATEGIES

6.1 KEYPAD POLLING RESULTS FROM COMMUNITY WORKSHOP #2

GreenKEYS! Keypad Polling Results from the COAST community modeling exercise conducted November 5 2014 at the Nelson Government Center in Key Largo, FL

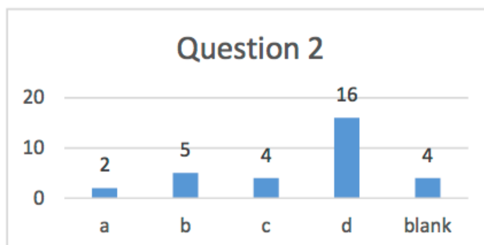
Question #1: Currently in Key Largo, 40% of properties are already elevated. What percentage of additional Key Largo V-zone buildings do you want to see elevated in this model?

1	a	25%	9	29%
	b	50%	2	6%
	c	75%	2	6%
	d	**The draft input of 100%**	**14**	**45%**
	blank		4	13%
	Total		31	100%



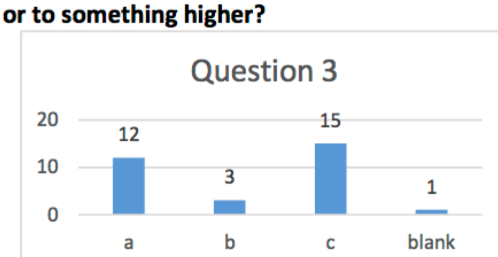
Question #2: What percentage of Key Largo A-zone buildings do you want to see floodproofed in this model?

2	a	25%	2	6%
	b	50%	5	16%
	c	75%	4	13%
	d	**The draft input of 100%**	**16**	**52%**
	blank		4	13%
	Total		31	100%



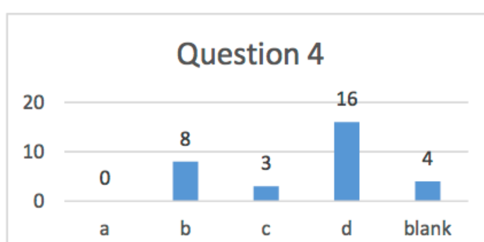
Question #3: Currently in Key Largo, new buildings are required to be elevated to the 100-year flood elevation, which ranges from 6 to 15 feet across the Key. For parcels that will be elevated in the model, do you want them to be elevated up to this code or to something higher?

3	a	Up to current code	12	39%
	b	Up to current code plus 1 f	3	10%
	c	**Up to current code plus 3**	**15**	**48%**
	blank		1	3%
	Total		31	100%



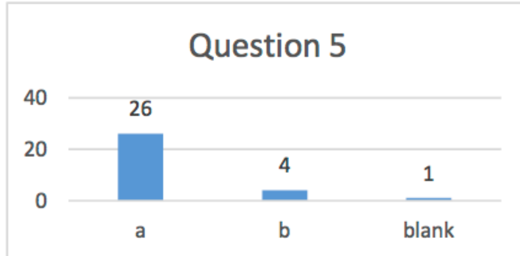
Question #4: The model estimates floodproofing to a certain height. How high would you like to see parcels floodproofed?

4	a	1 ft	0	0%
	b	3 ft	8	26%
	c	6 ft	3	10%
	d	**The draft input of 8 ft**	**16**	**52%**
	blank		4	13%
	Total		31	100%



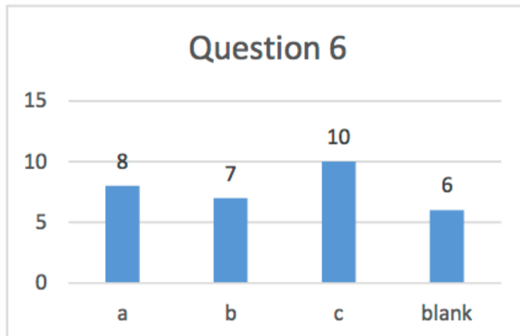
Question #5: Should the planning group model this action?

5	**a**	**Yes**	**26**	**84%**
	b	No	4	13%
	blank		1	3%
	Total		31	100%



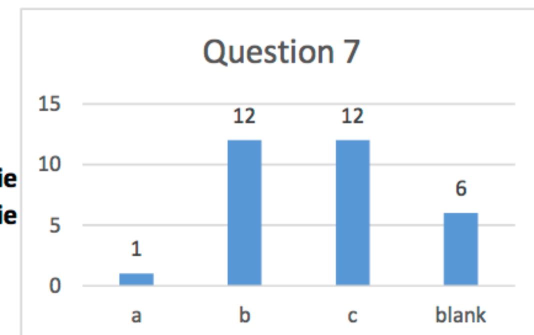
Question #6: Which of the following types of structures would you like to see us model:

		Answer Text	Number of Answers	Percent of Total Votes
6	a	Submergent	8	26%
	b	At water level	7	23%
	c	**Emergent**	**10**	**32%**
	blank		6	19%
	Total		31	100%



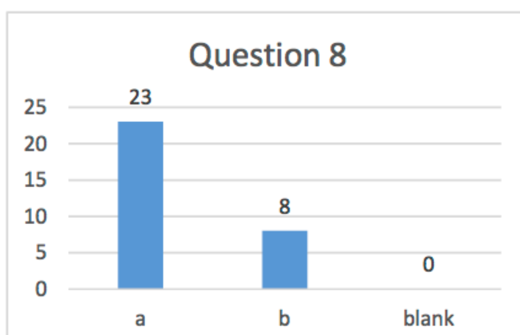
Question #7: How far out from the shore do you think the structures should be?

		Answer Text	Number of Answers	Percent of Total Votes	
7	a	On the shore	1	3%	
	b	**Nearshore**	**12**	**39%**	**tie**
	c	**Offshore**	**12**	**39%**	**tie**
	blank		6	19%	
	Total		31	100%	



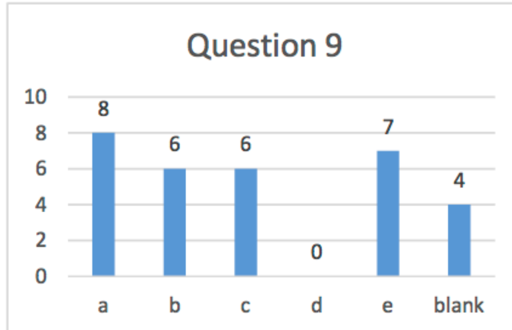
Question #8: Should the planning group model this action?

		Answer Text	Number of Answers	Percent of Total Votes
8	**a**	**Yes**	**23**	**74%**
	b	No	8	26%
	blank		0	0%
	Total		31	100%



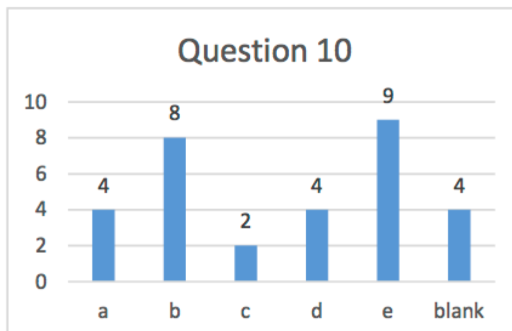
Question #9: What percent of property owners illustrated in red for Key Largo should we model would accept this voluntary buyout in the next few years (Phase 1)?

		Answer Text	Number of Answers	Percent of Total Votes
9	**a**	**10%**	**8**	**26%**
	b	25%	6	19%
	c	50%	6	19%
	d	75%	0	0%
	e	The draft input of 100%	7	23%
	blank		4	13%
	Total		31	100%



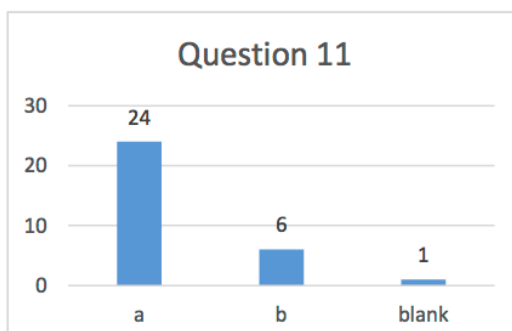
Question #10: What percent of property owners illustrated in green for Key Largo should we model that would accept this voluntary buyout in the year 2030 (Phase 2)?

		Answer Text	Number of Answers	Percent of Total Votes
10	a	10%	4	13%
	b	25%	8	26%
	c	50%	2	6%
	d	75%	4	13%
	e	**The draft input of 100%**	**9**	**29%**
	blank		4	13%
	Total		31	100%

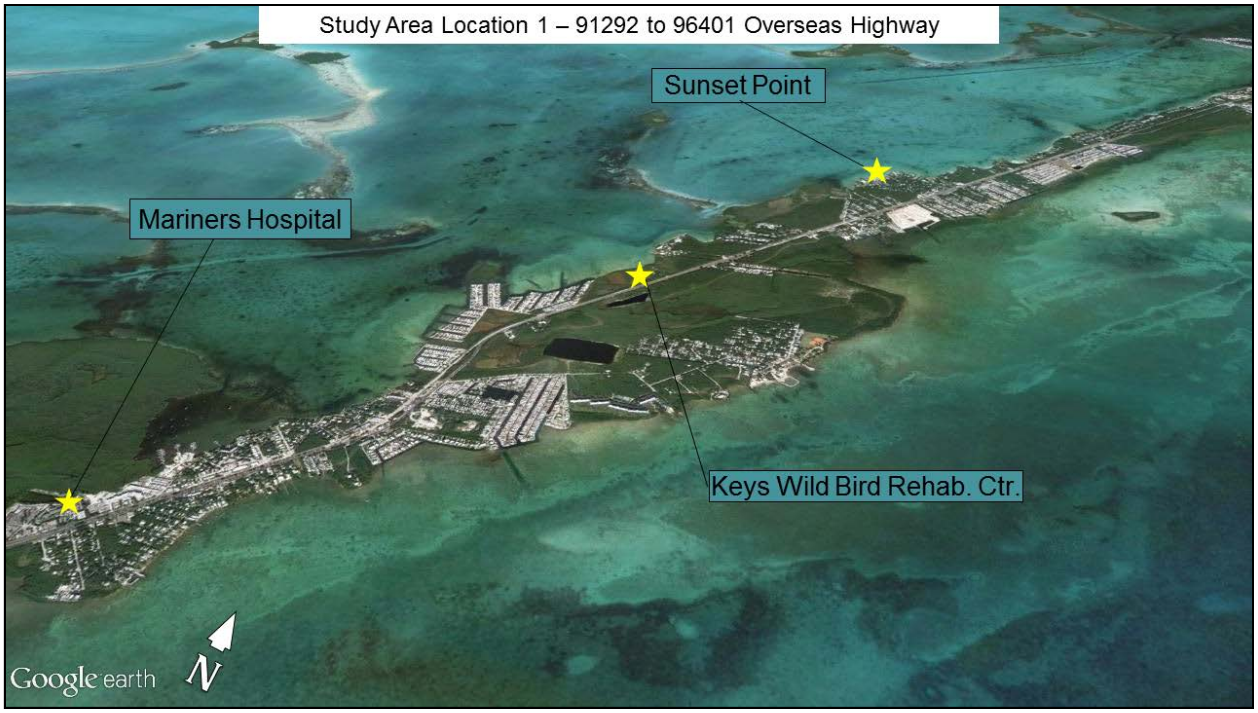


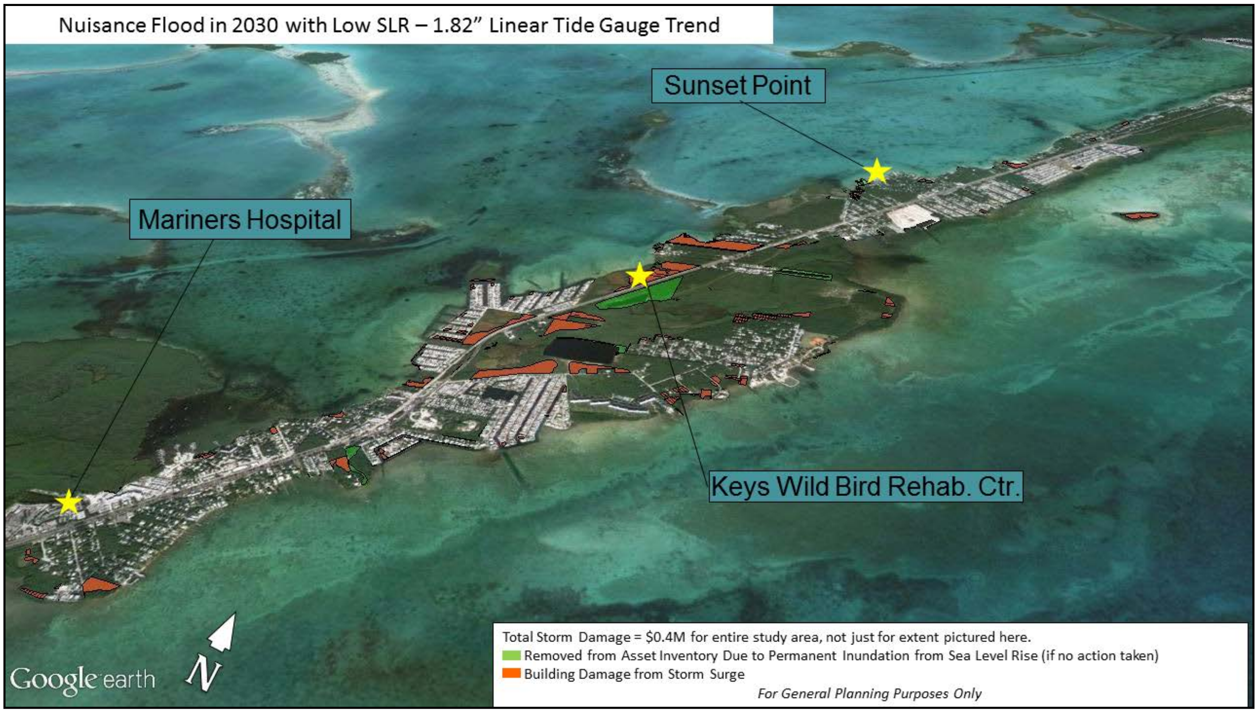
Question #11: Should the planning group model this action?

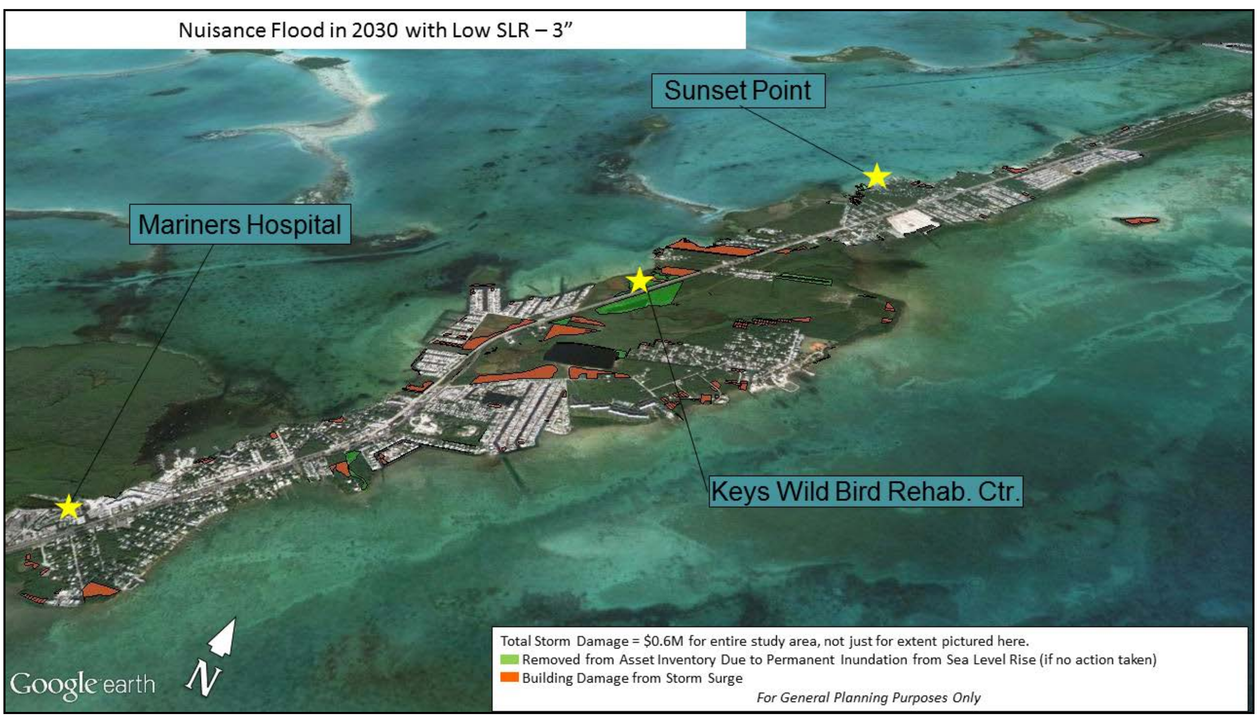
		Answer Text	Number of Answers	Percent of Total Votes
11	**a**	**Yes**	**24**	**77%**
	b	No	6	19%
	blank		1	3%
	Total		31	100%

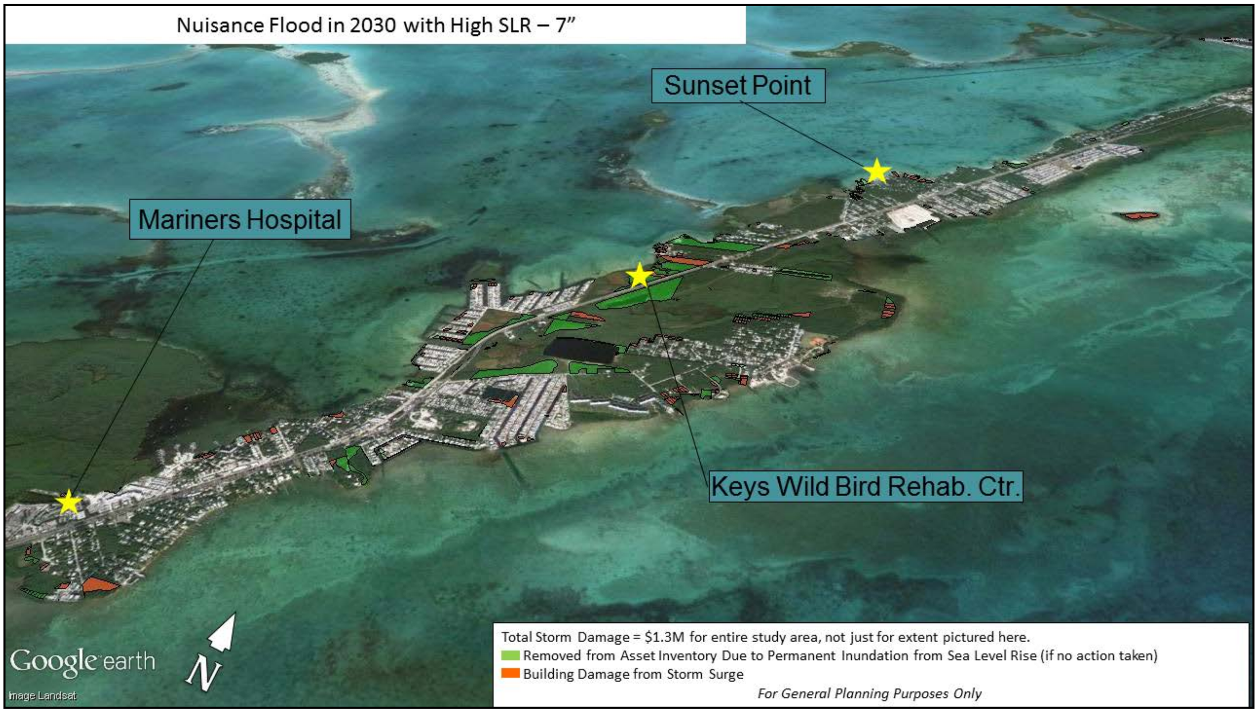


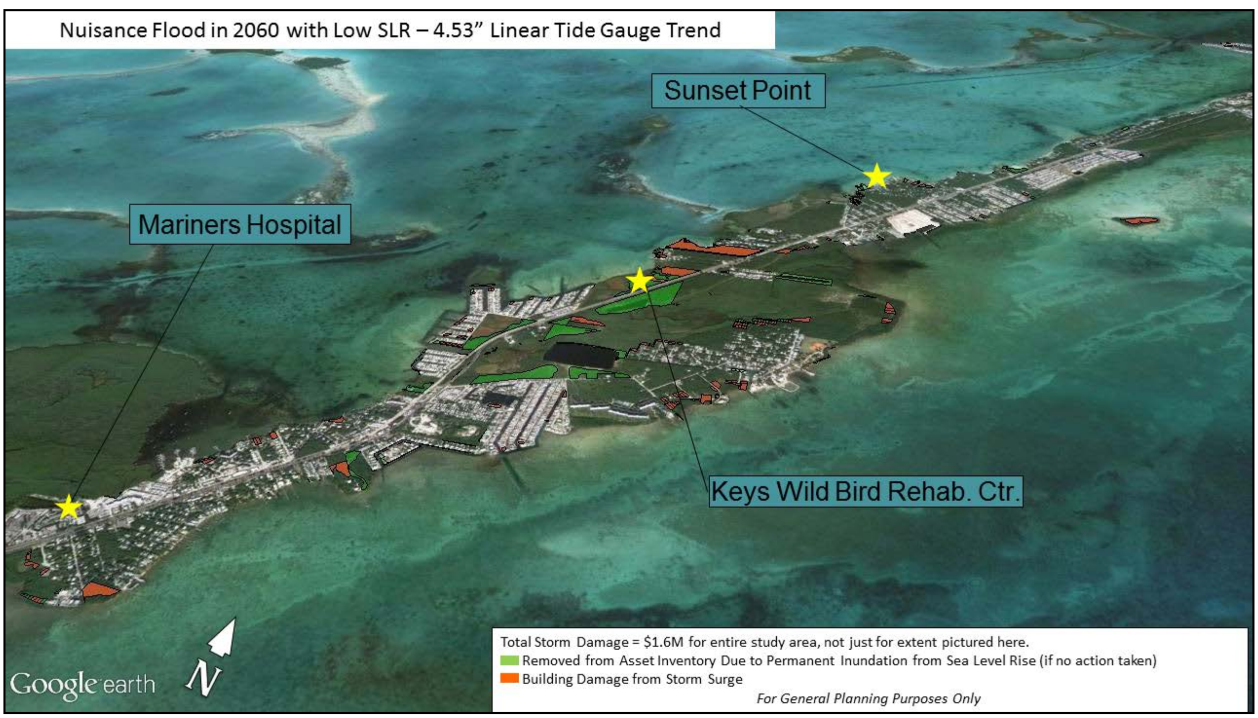
6.2 Maps of Potential One-Time Flooding in the Geographic Area of Key Largo, FL

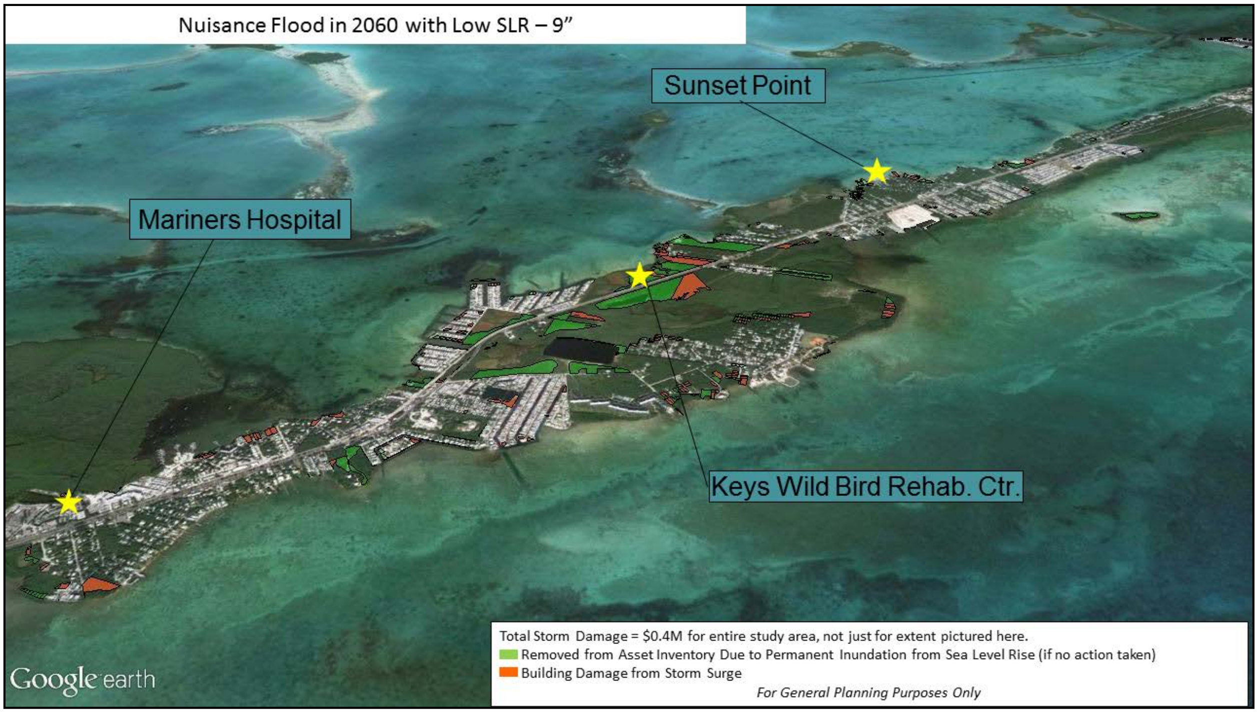


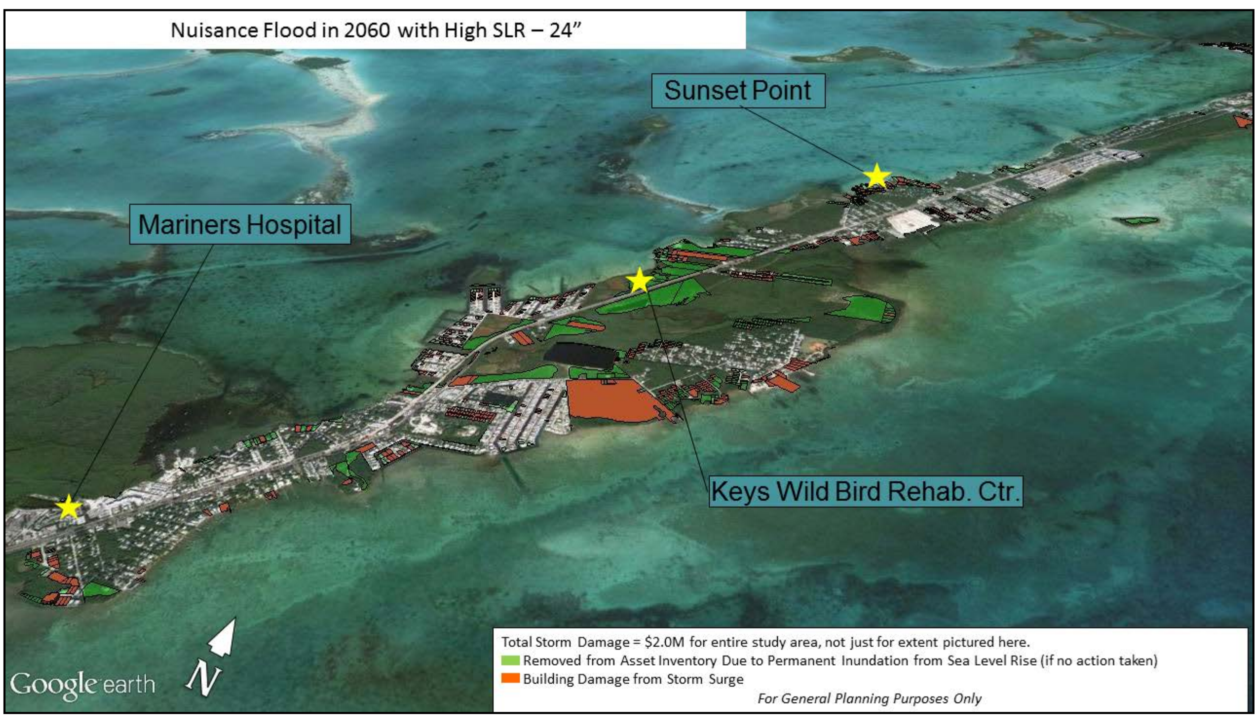

Nuisance Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

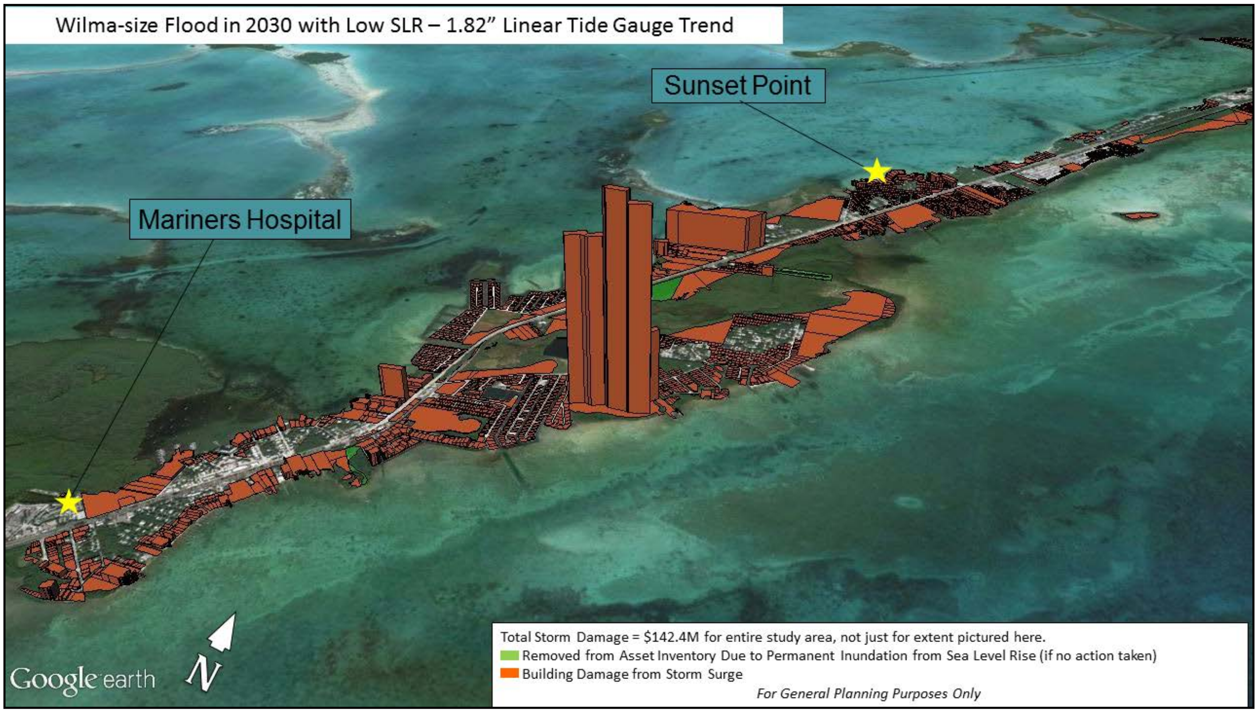

Nuisance Flood in 2030 with Low SLR – 3"
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $0.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

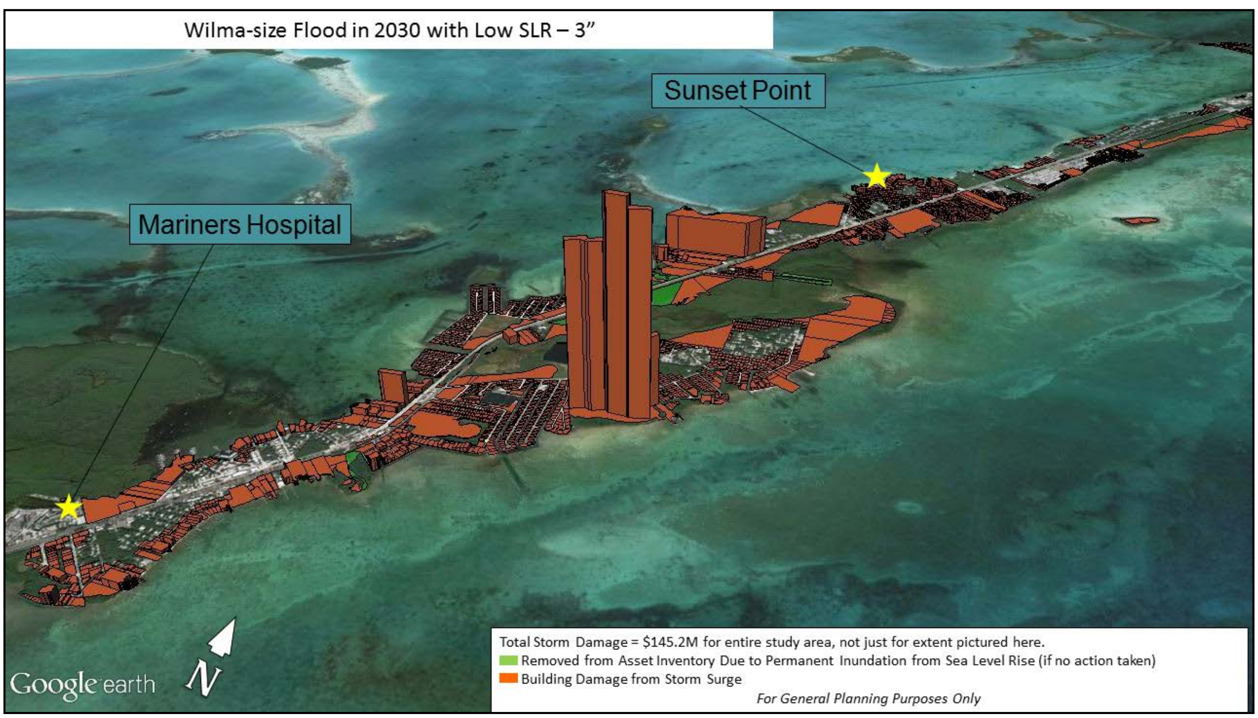

Nuisance Flood in 2030 with High SLR – 7”
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $1.3M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N
Image Landsat

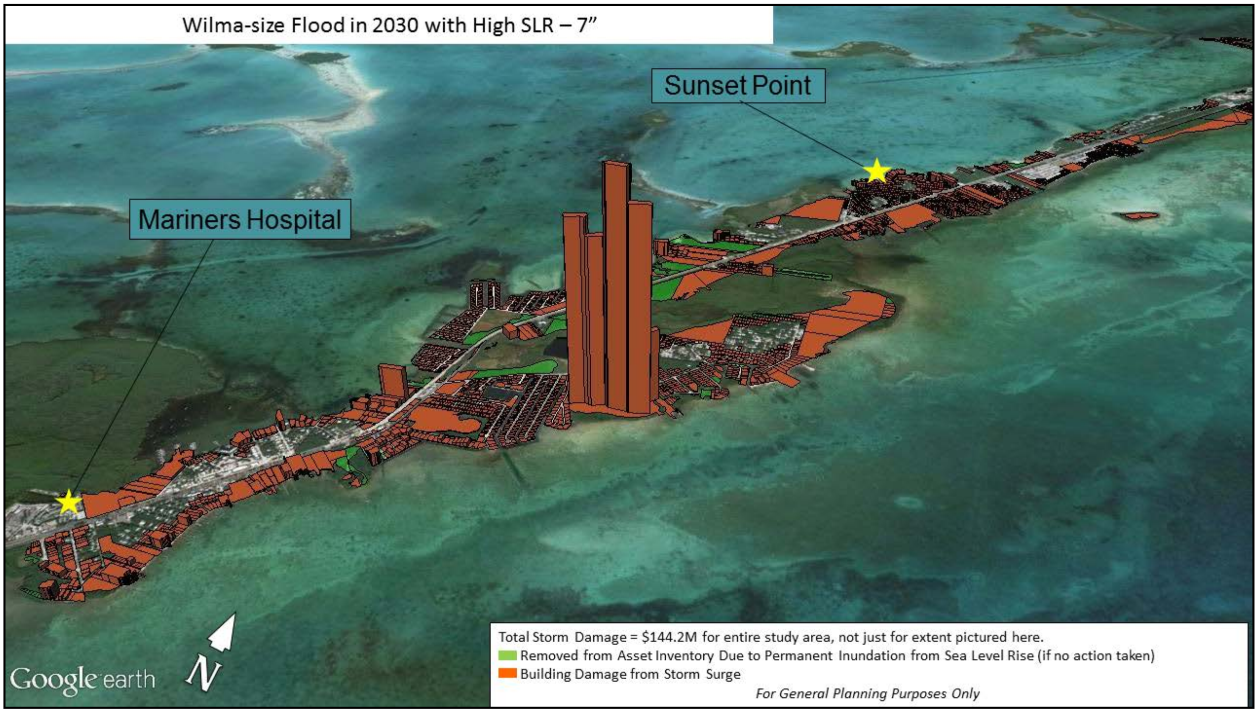

Nuisance Flood in 2060 with Low SLR – 4.53” Linear Tide Gauge Trend
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $1.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

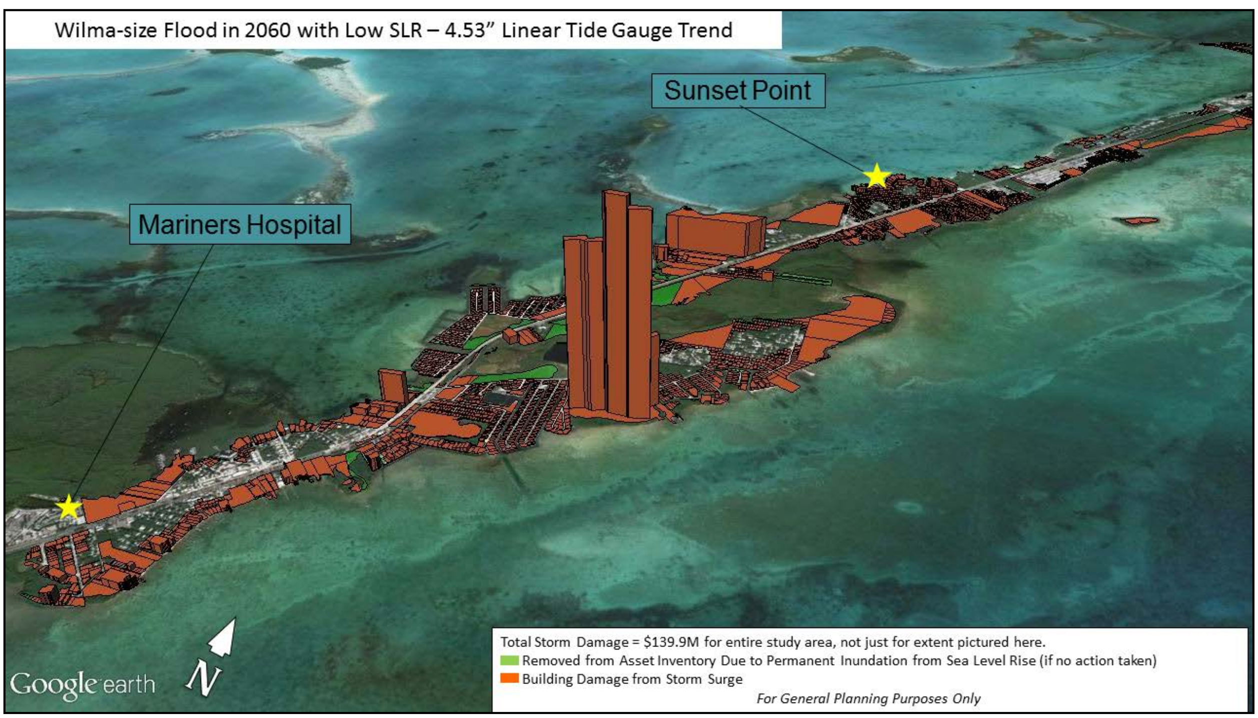

Nuisance Flood in 2060 with Low SLR – 9"
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

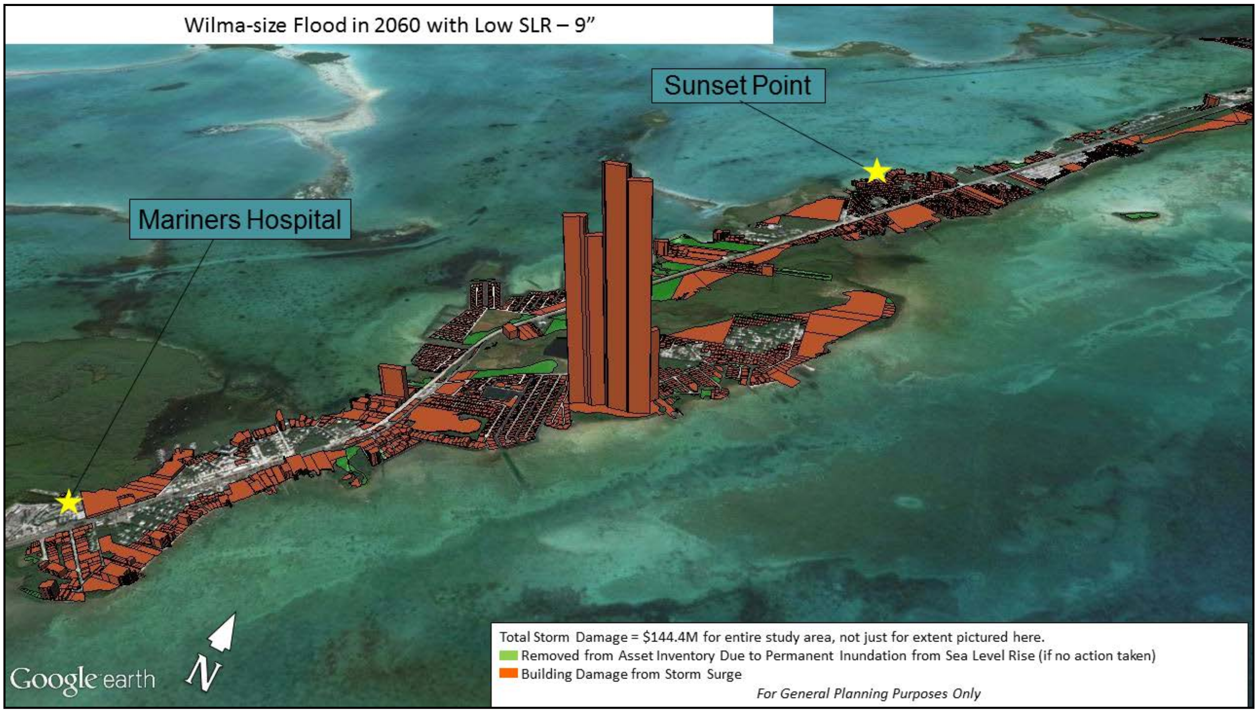

Nuisance Flood in 2060 with High SLR – 24"
Sunset Point
Mariners Hospital
Keys Wild Bird Rehab. Ctr.
Total Storm Damage = $2.0M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

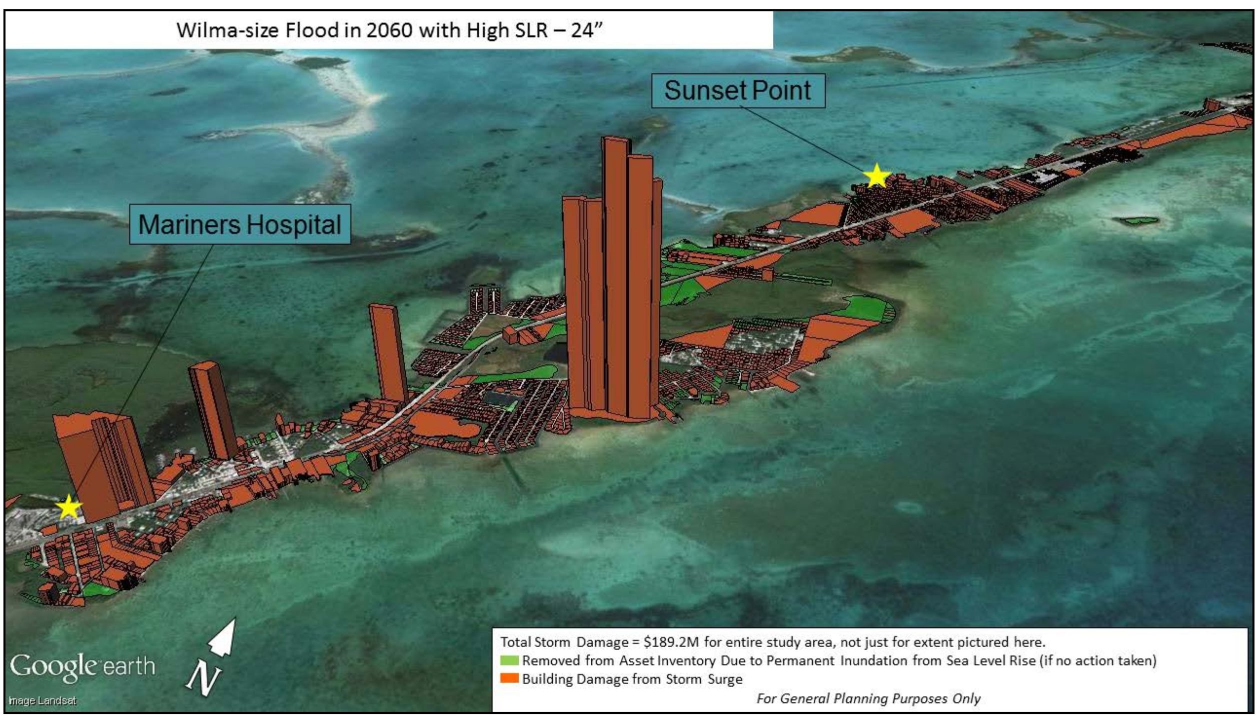

Wilma-size Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Sunset Point
Mariners Hospital
Total Storm Damage = $142.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N


Wilma-size Flood in 2030 with Low SLR – 3"
Sunset Point
Mariners Hospital
Total Storm Damage = $145.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

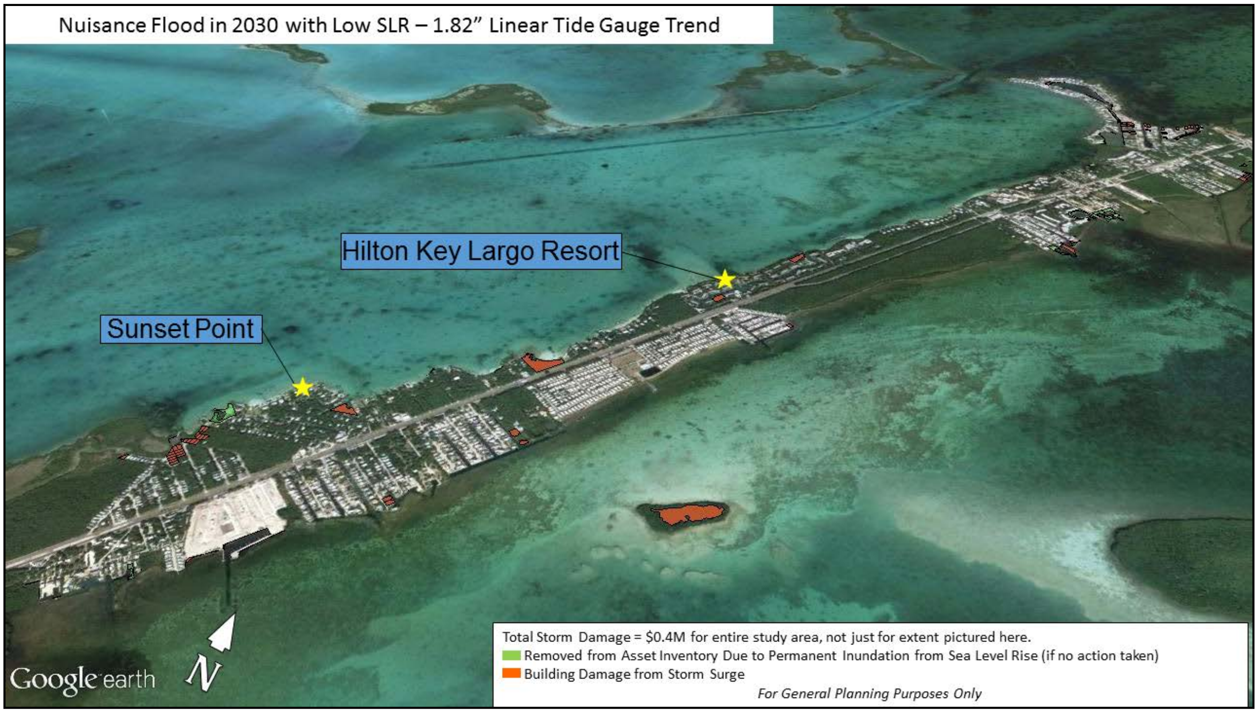

Wilma-size Flood in 2030 with High SLR – 7”
Sunset Point
Mariners Hospital
Total Storm Damage = $144.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

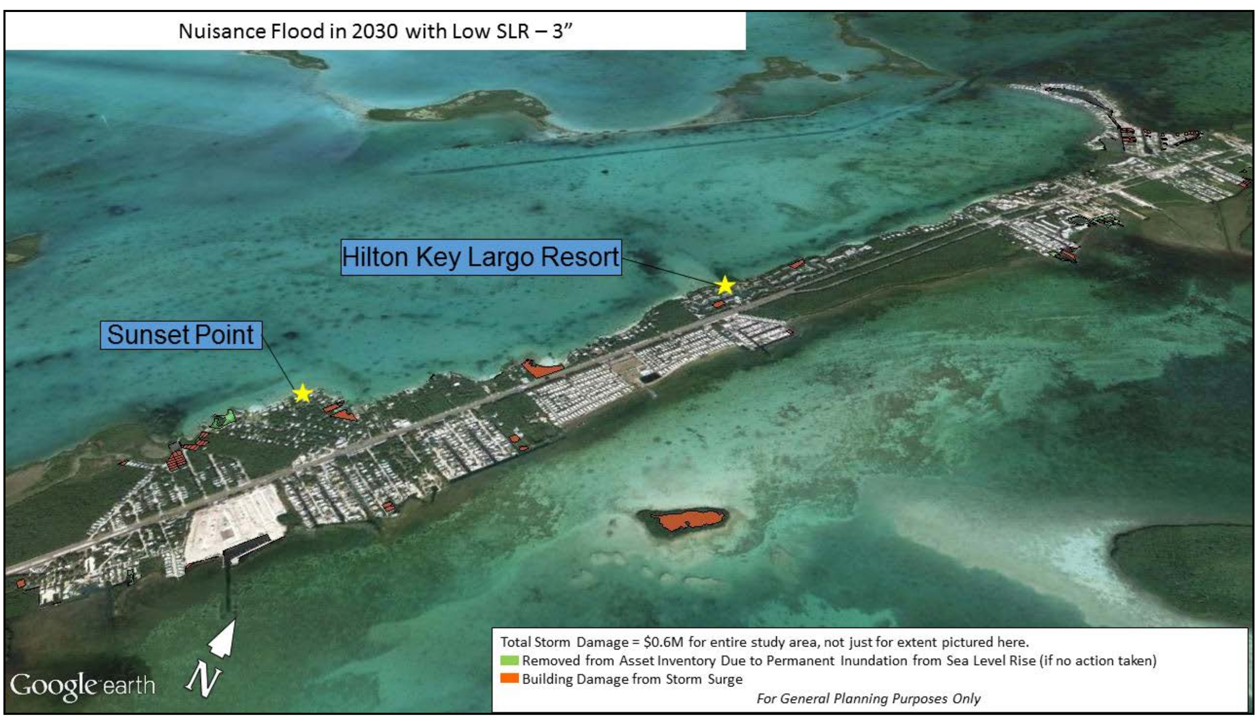

Wilma-size Flood in 2060 with Low SLR – 4.53” Linear Tide Gauge Trend
Sunset Point
Mariners Hospital
Total Storm Damage = $139.9M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

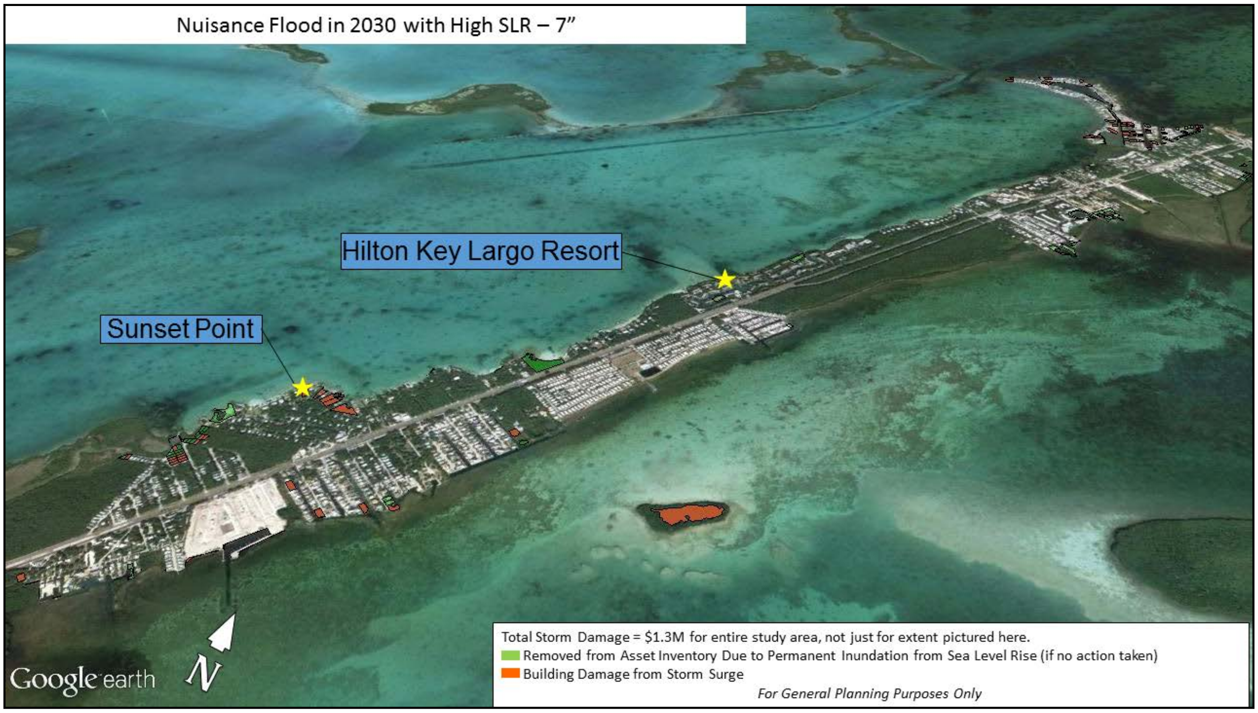

Wilma-size Flood in 2060 with Low SLR – 9”
Sunset Point
Mariners Hospital
Total Storm Damage = $144.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

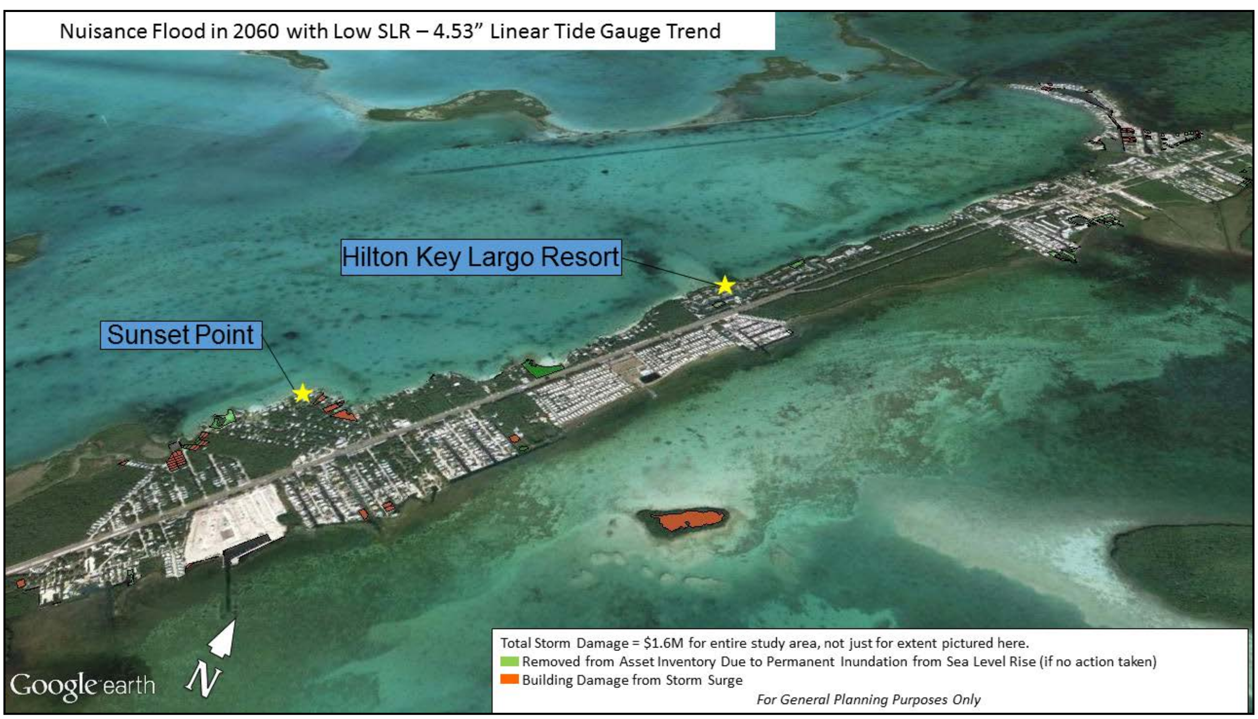

Wilma-size Flood in 2060 with High SLR – 24”
Sunset Point
Mariners Hospital
Total Storm Damage = $189.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N
Image Landsat

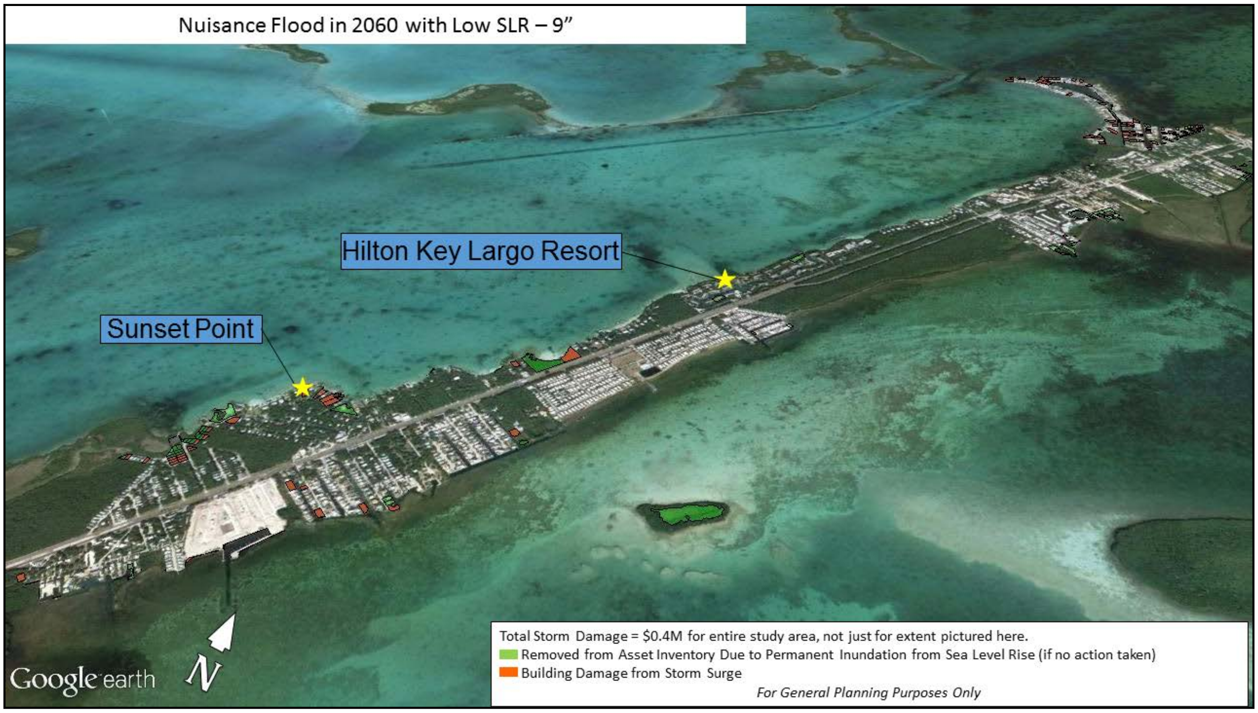

Study Area Location 2 – 94500 to 98600 Overseas Highway
Hilton Key Largo Resort
Sunset Point
N
Google earth

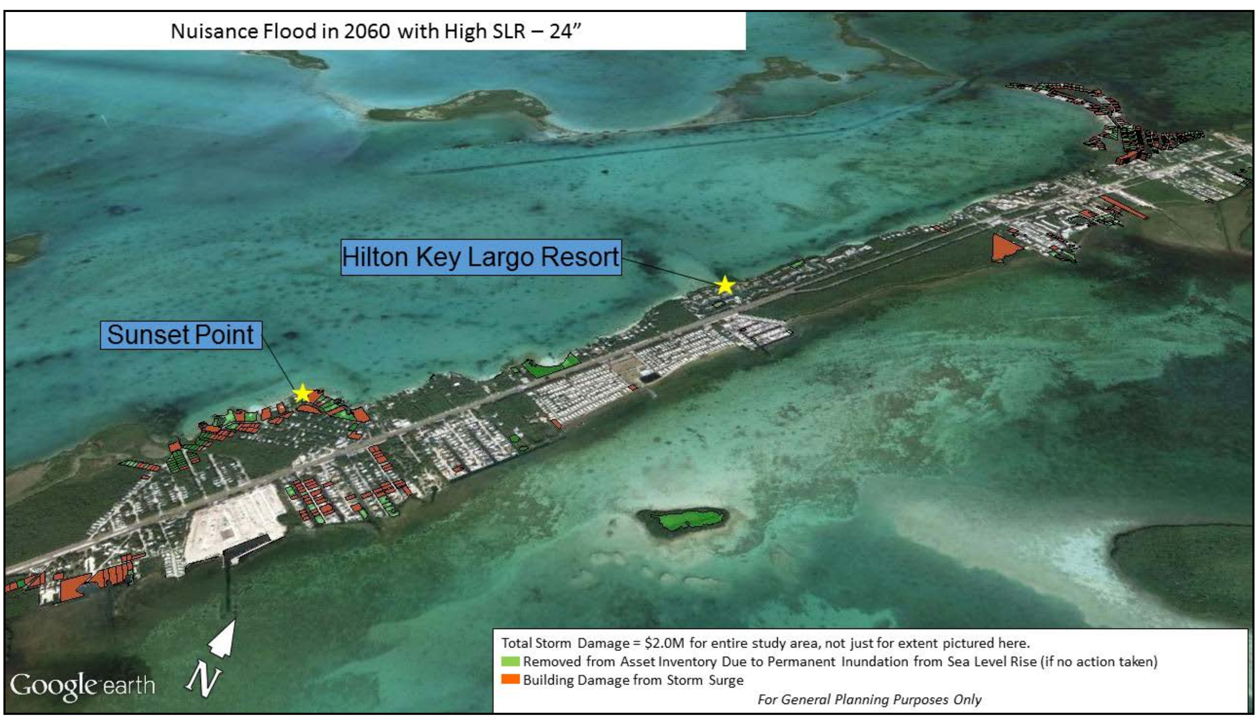

Nuisance Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

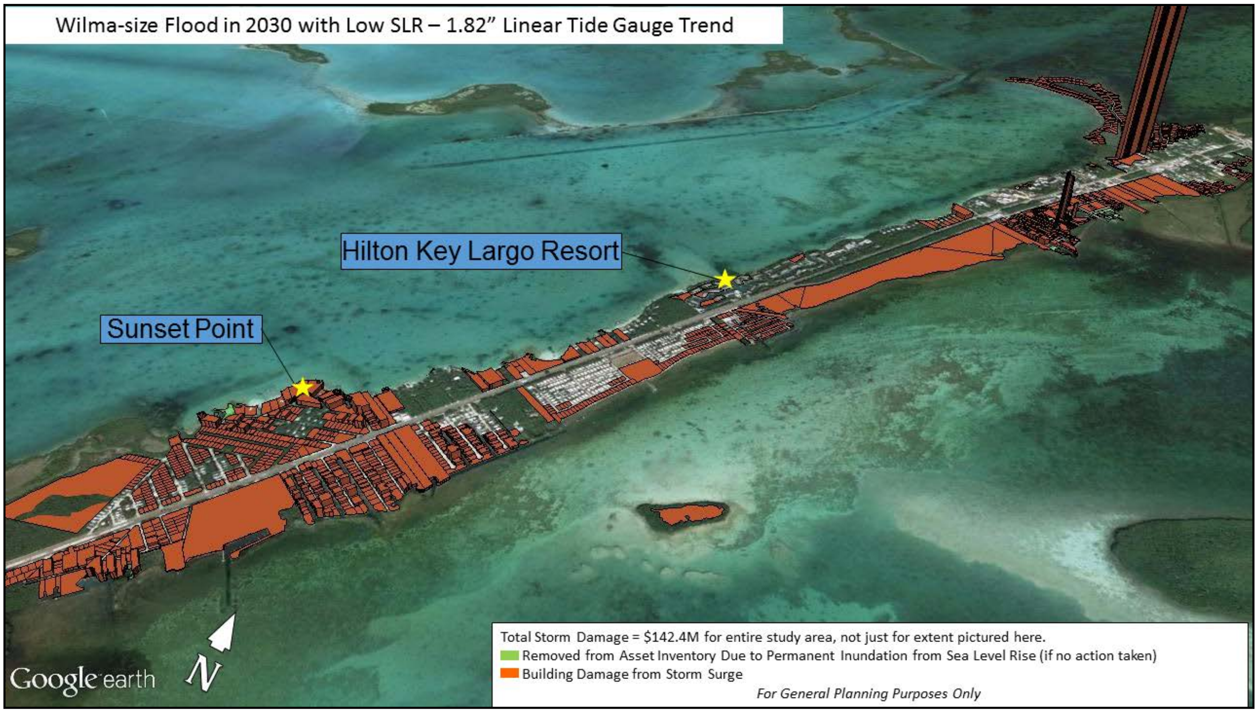

Nuisance Flood in 2030 with Low SLR – 3"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $0.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

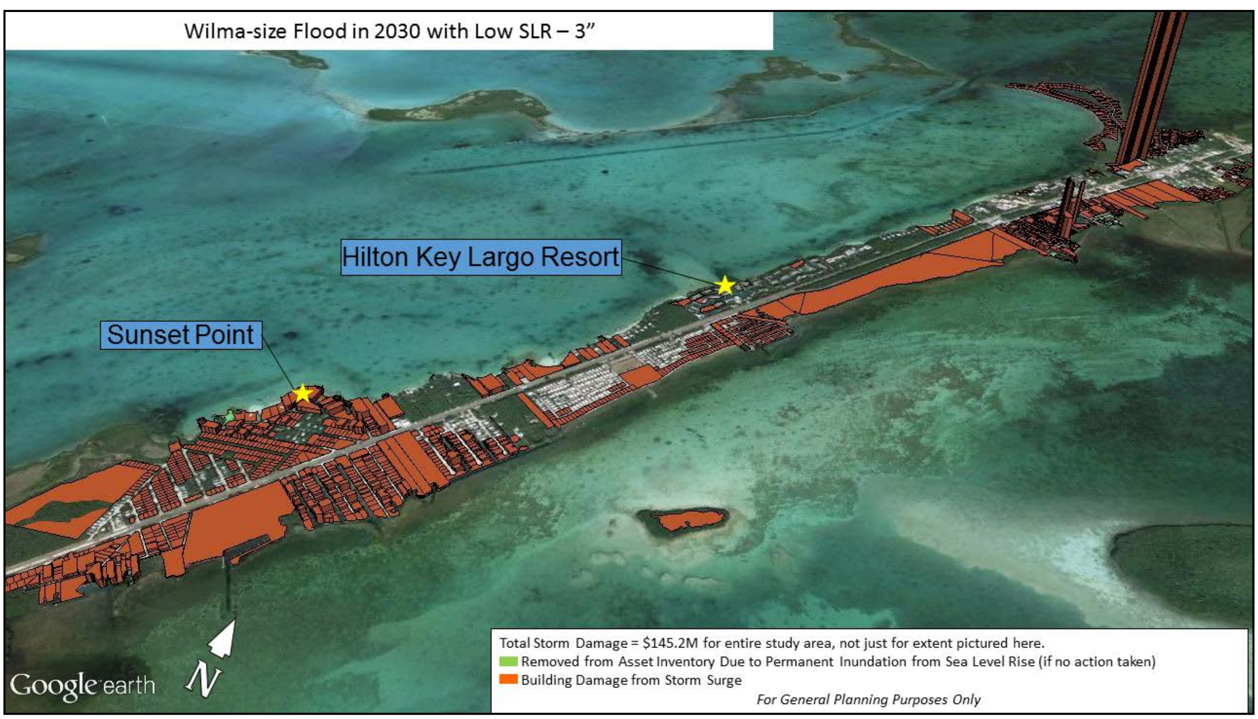

Nuisance Flood in 2030 with High SLR – 7"
Hilton Key Largo Resort
Sunset Point
Google earth
N
Total Storm Damage = $1.3M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only

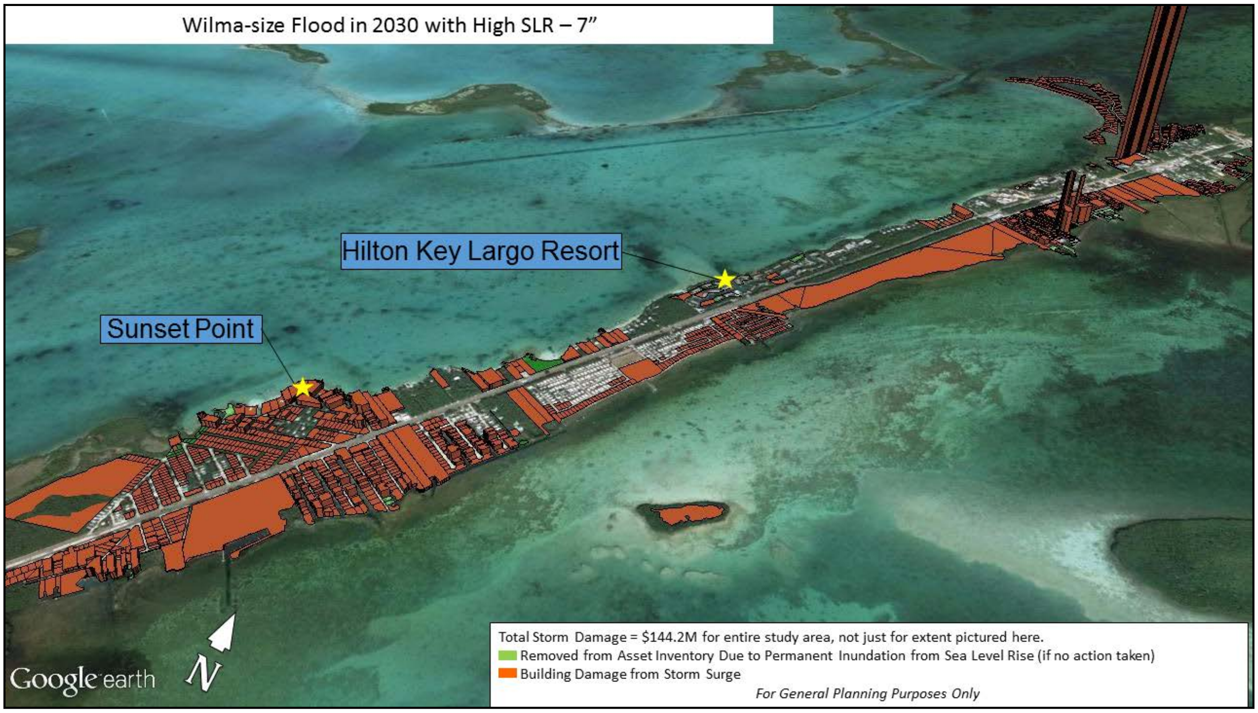

Nuisance Flood in 2060 with Low SLR – 4.53" Linear Tide Gauge Trend
Hilton Key Largo Resort
Sunset Point
Google earth
N
Total Storm Damage = $1.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only

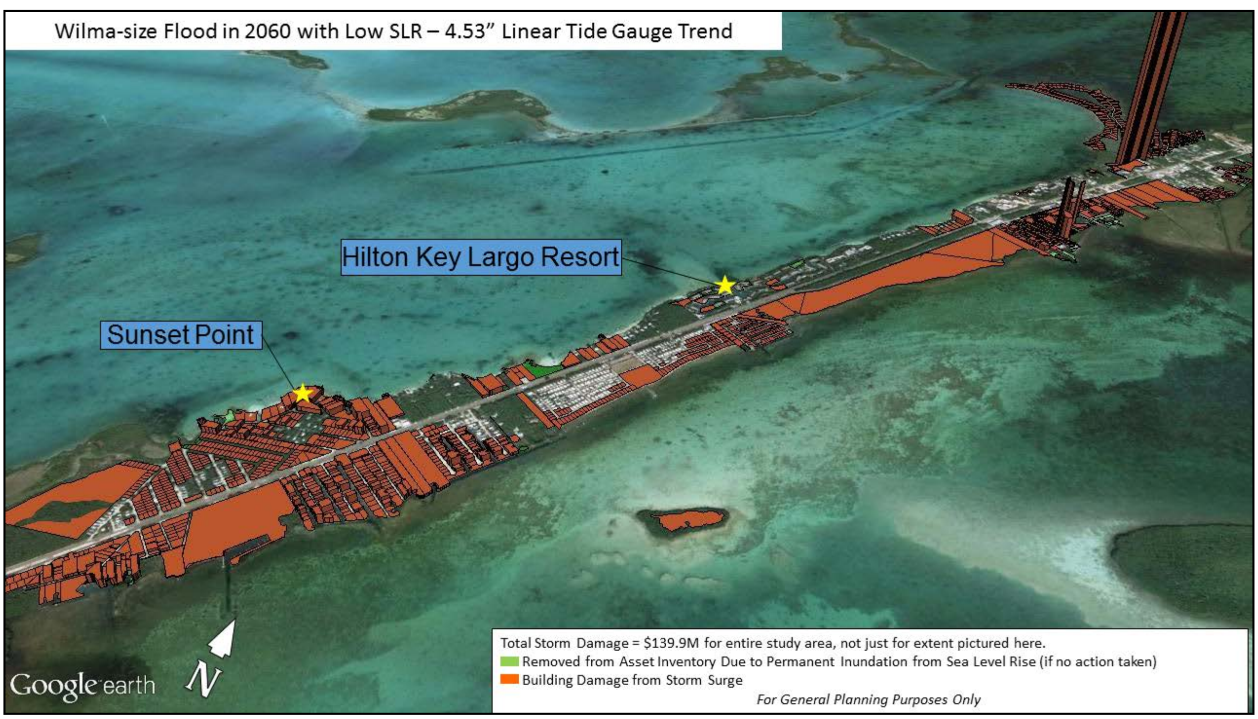

Nuisance Flood in 2060 with Low SLR – 9"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

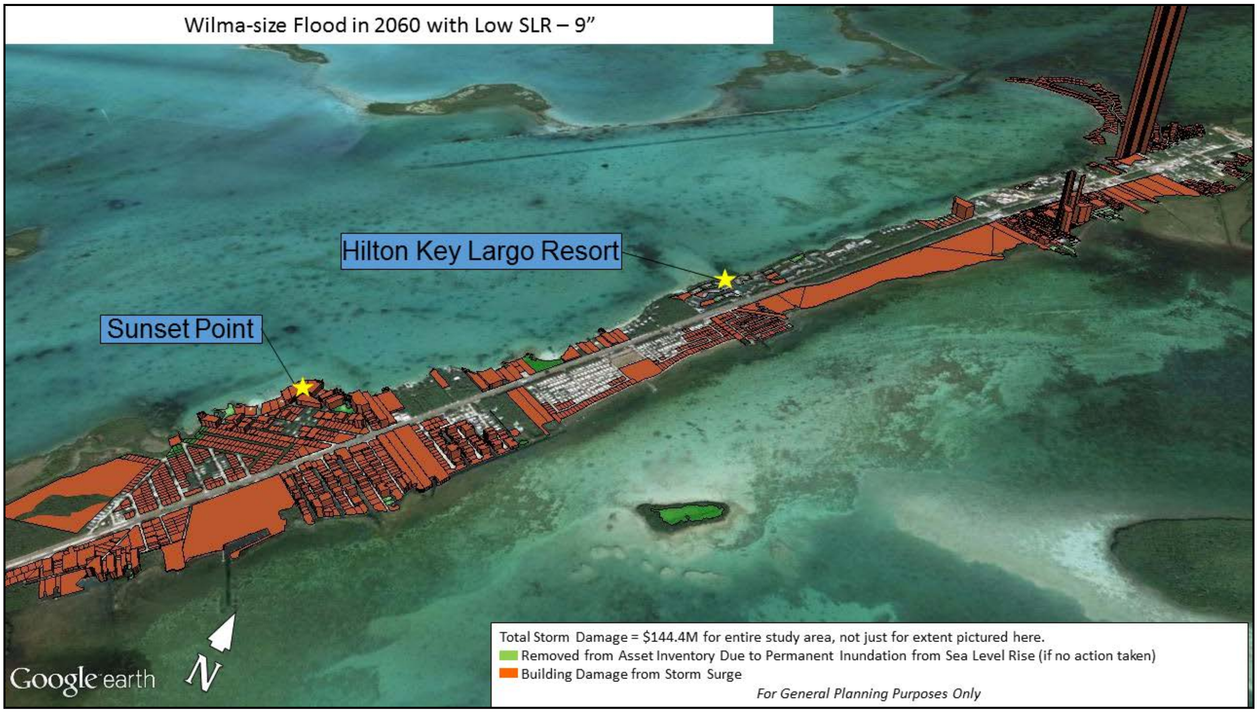

Nuisance Flood in 2060 with High SLR – 24"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $2.0M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

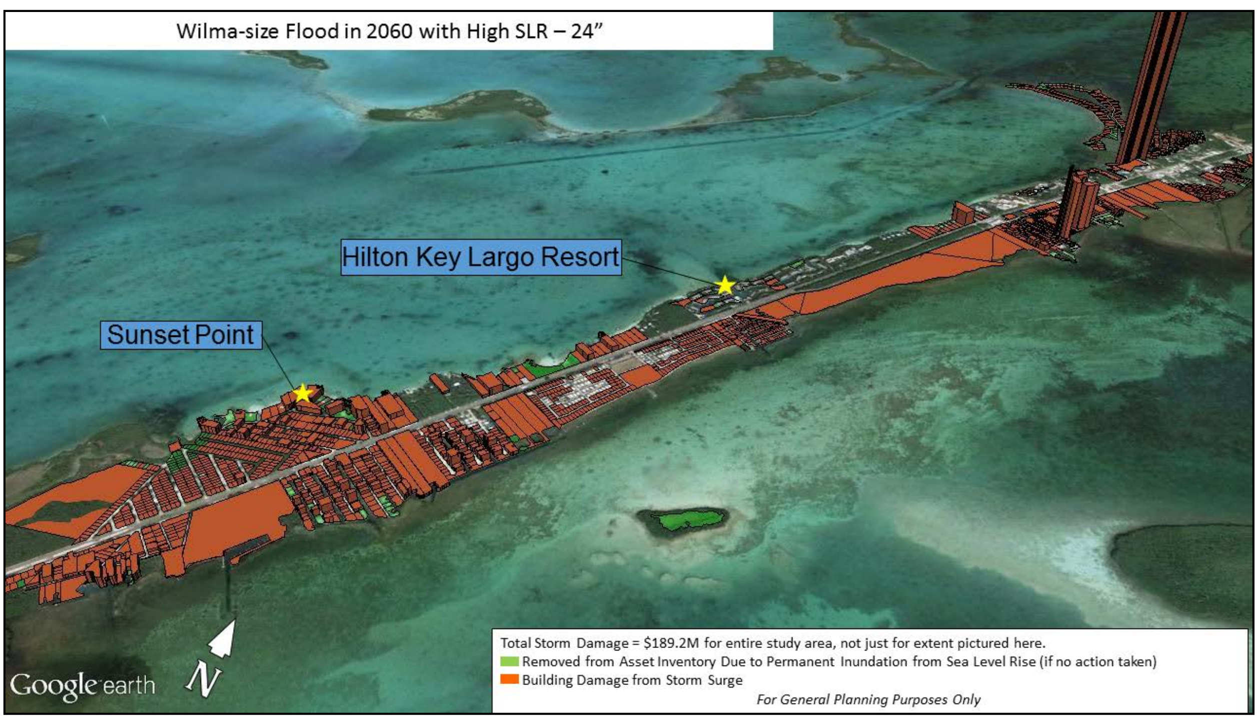

Wilma-size Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $142.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

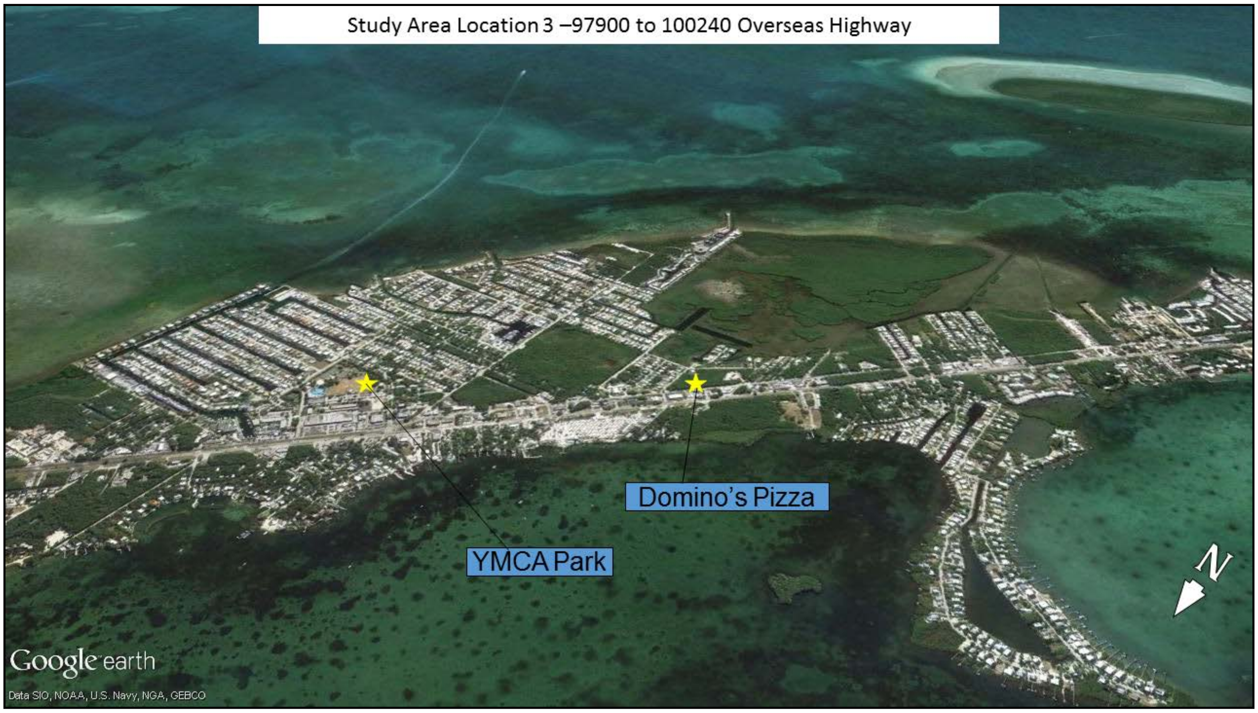

Wilma-size Flood in 2030 with Low SLR – 3"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $145.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

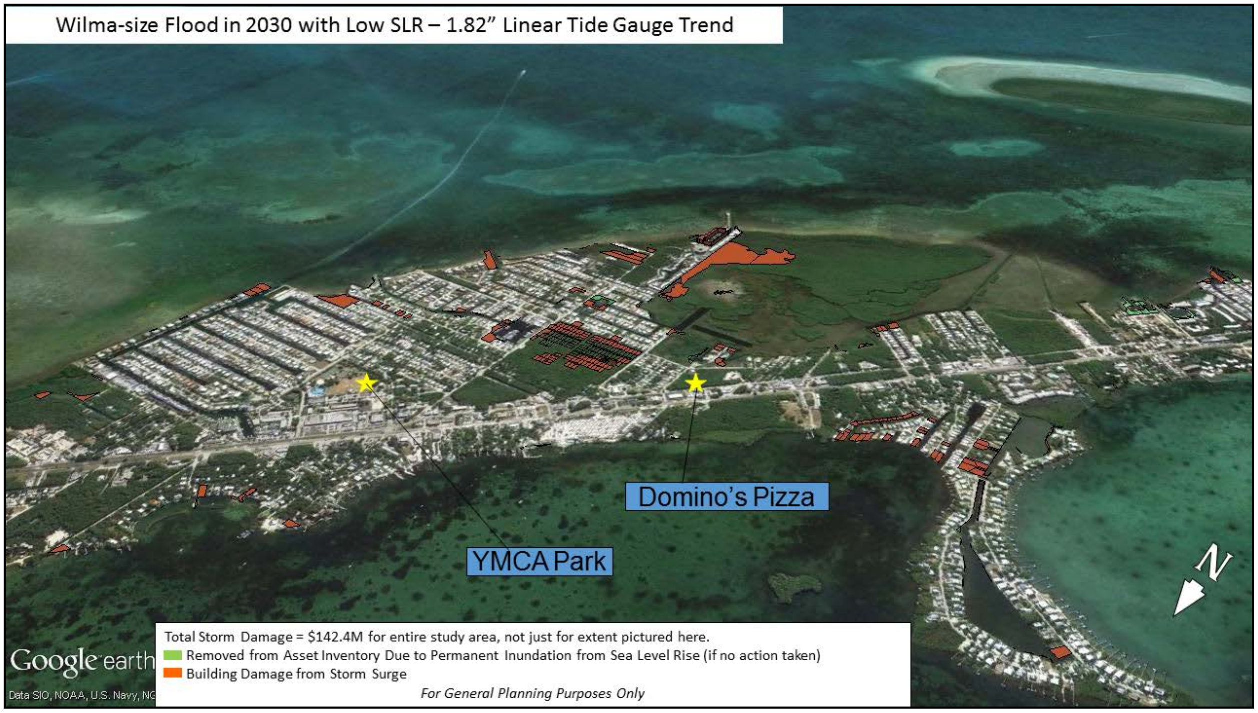

Wilma-size Flood in 2030 with High SLR – 7"
Hilton Key Largo Resort
Sunset Point
Google earth
N
Total Storm Damage = $144.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only

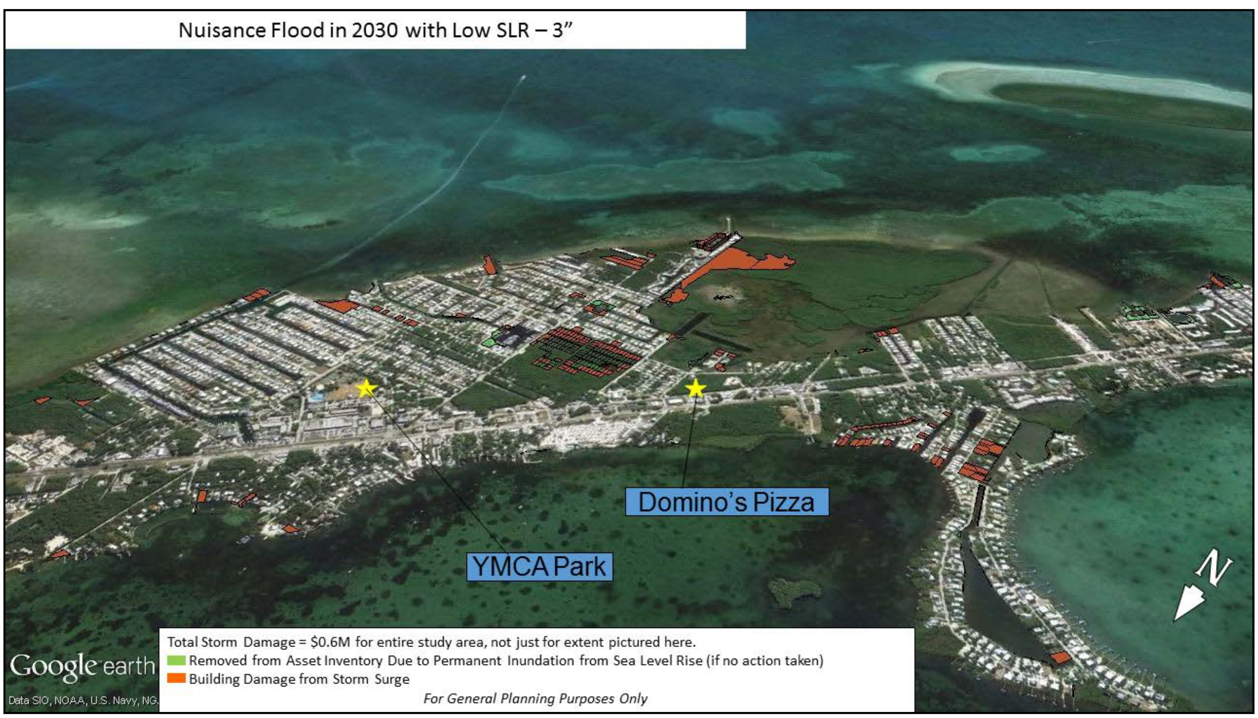

Wilma-size Flood in 2060 with Low SLR – 4.53" Linear Tide Gauge Trend
Hilton Key Largo Resort
Sunset Point
Google earth
N
Total Storm Damage = $139.9M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only

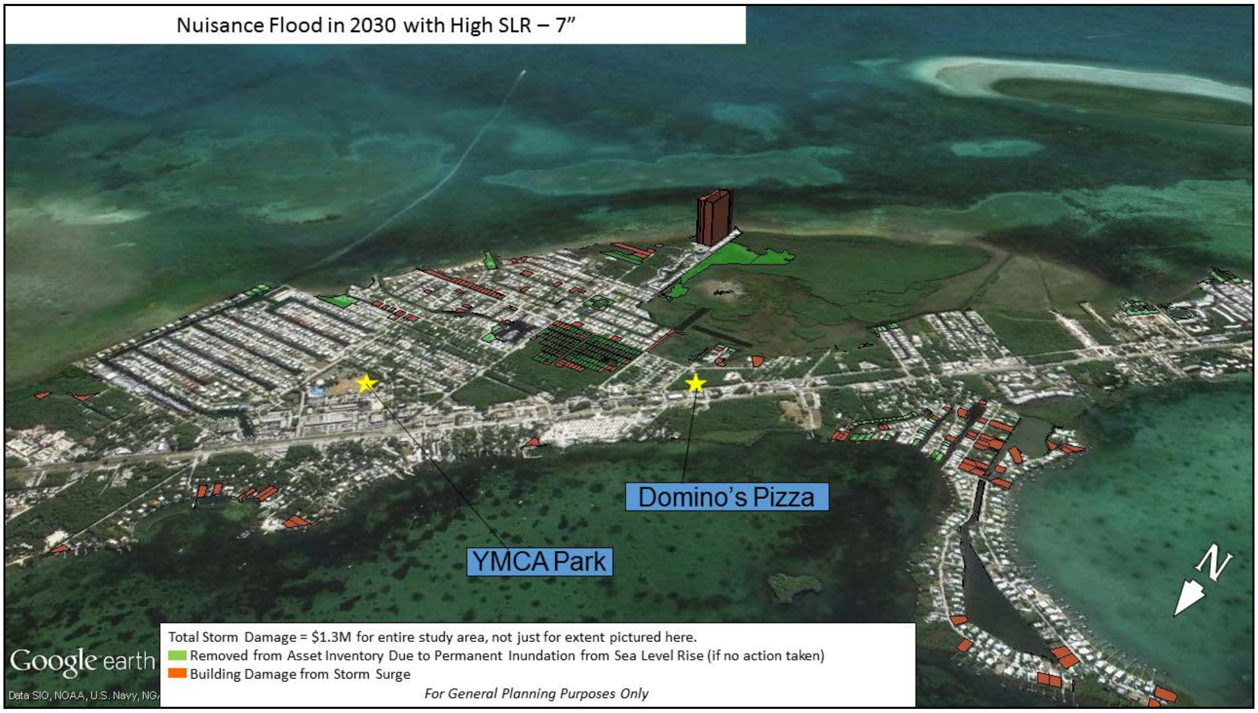

Wilma-size Flood in 2060 with Low SLR – 9"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $144.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

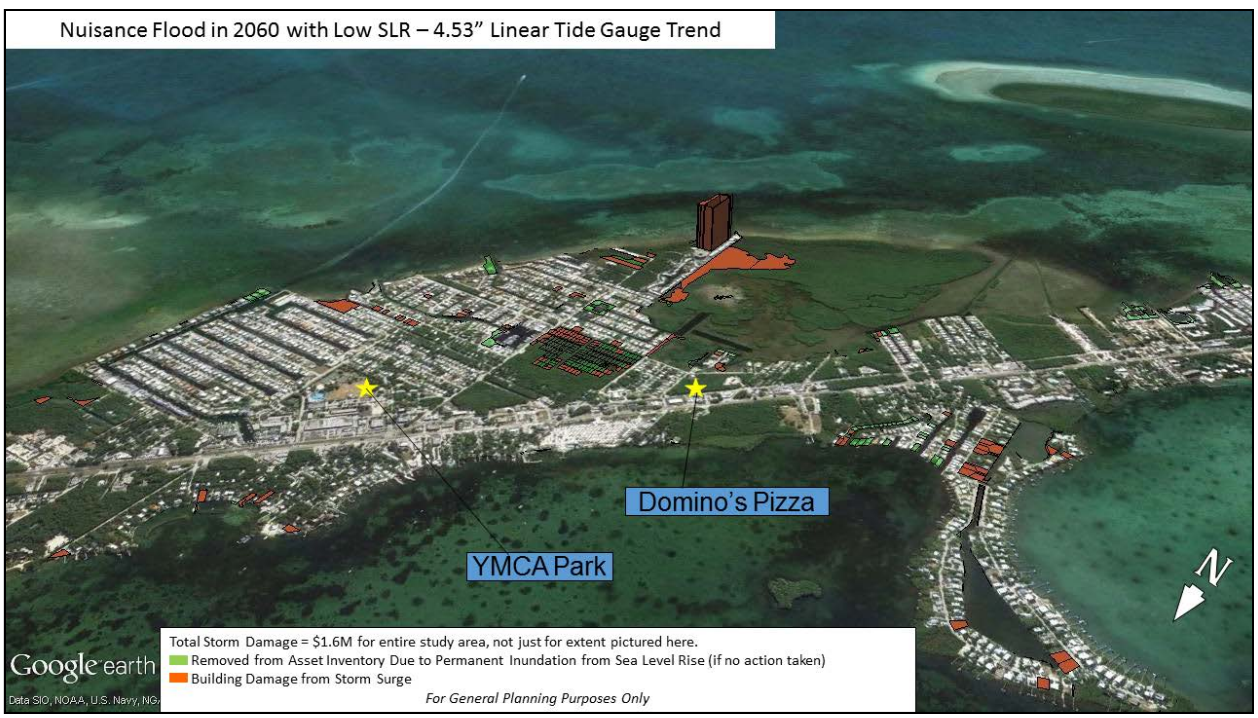

Wilma-size Flood in 2060 with High SLR – 24"
Hilton Key Largo Resort
Sunset Point
Total Storm Damage = $189.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

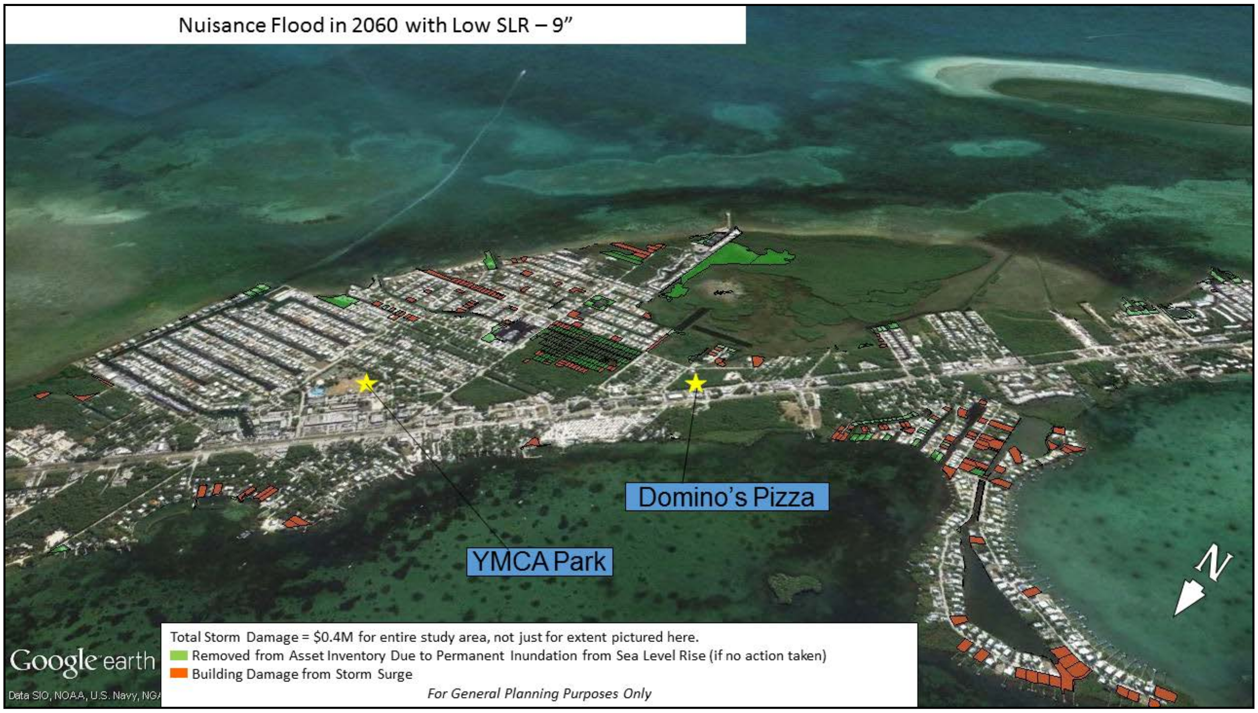

Study Area Location 3 –97900 to 100240 Overseas Highway
Domino's Pizza
YMCA Park
N
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

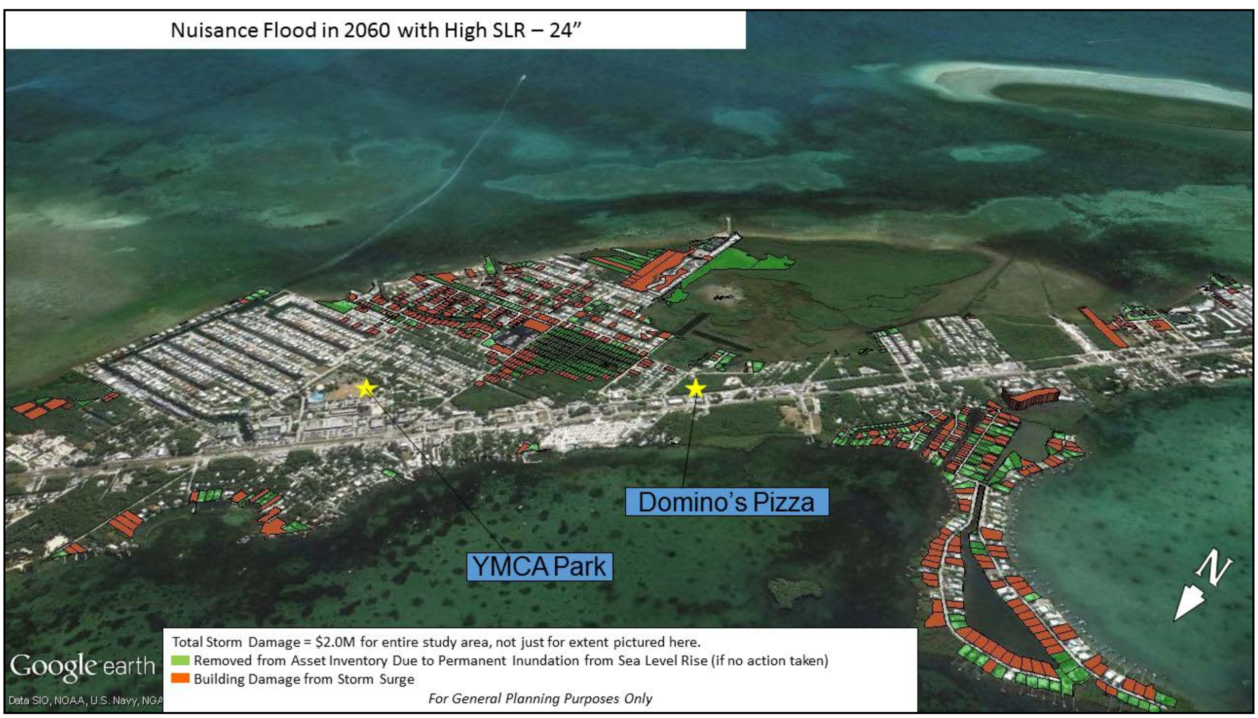

Wilma-size Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Domino's Pizza
YMCA Park
N
Total Storm Damage = $142.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

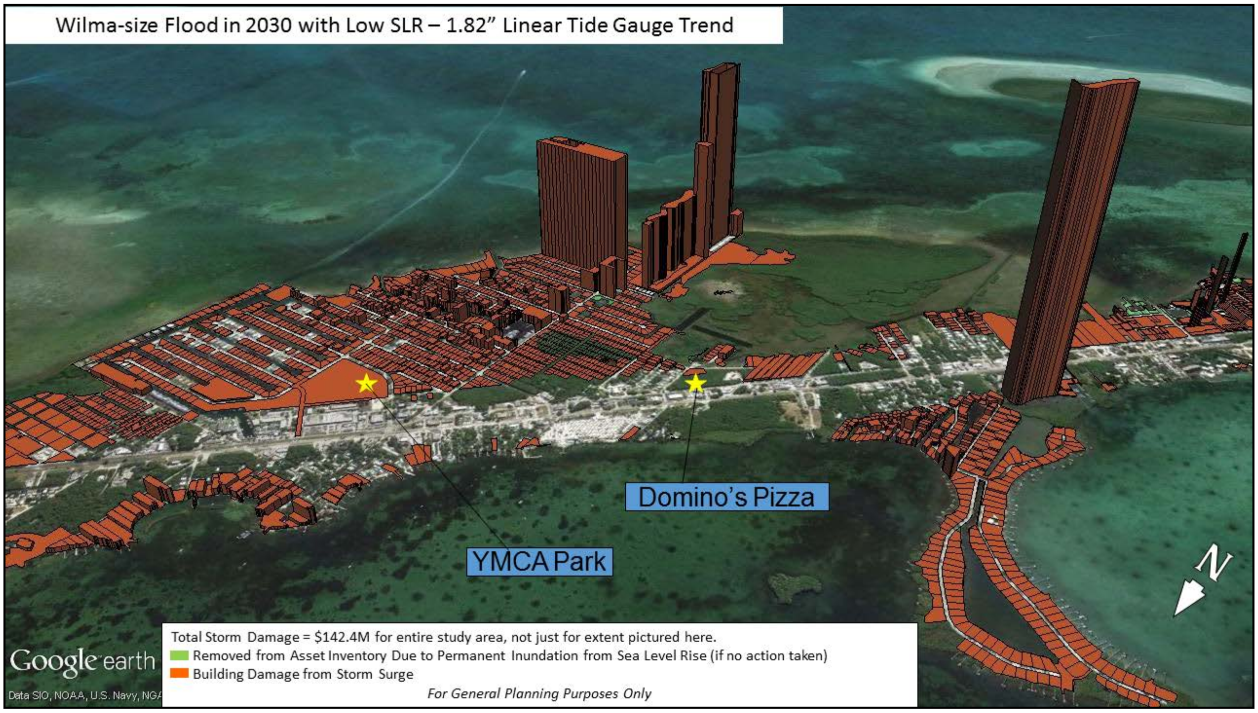

Nuisance Flood in 2030 with Low SLR – 3"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $0.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

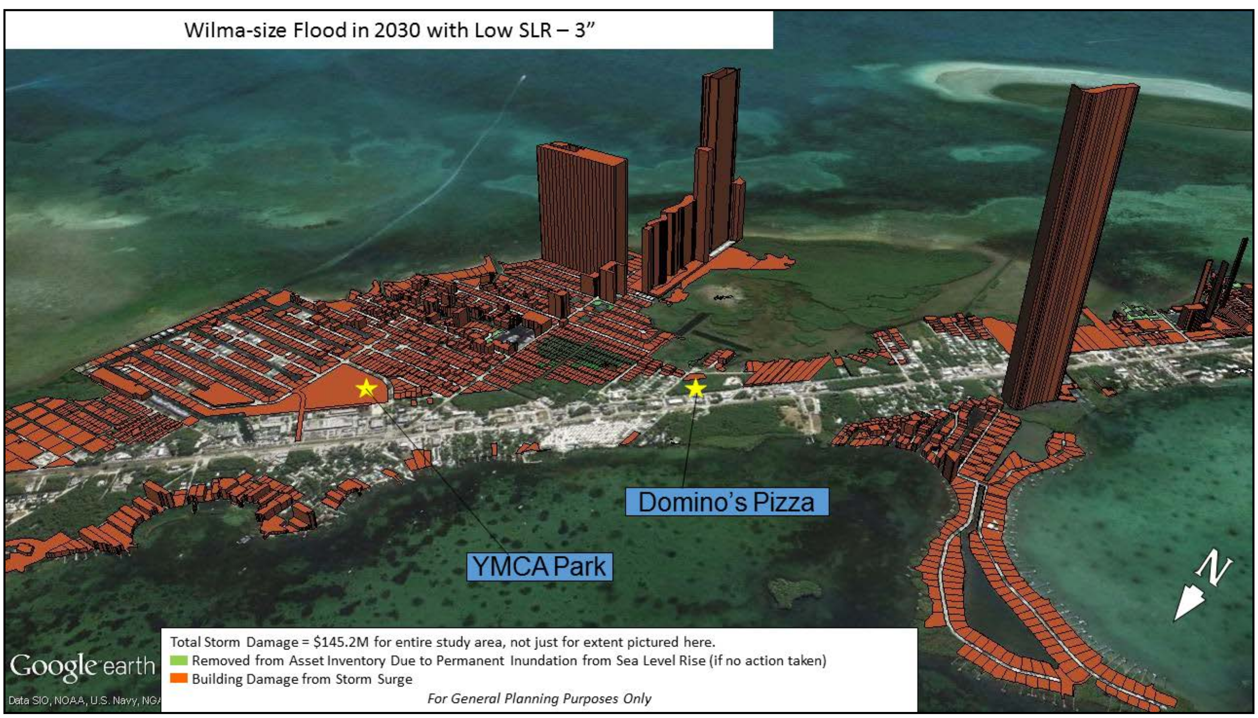

Nuisance Flood in 2030 with High SLR – 7"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $1.3M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

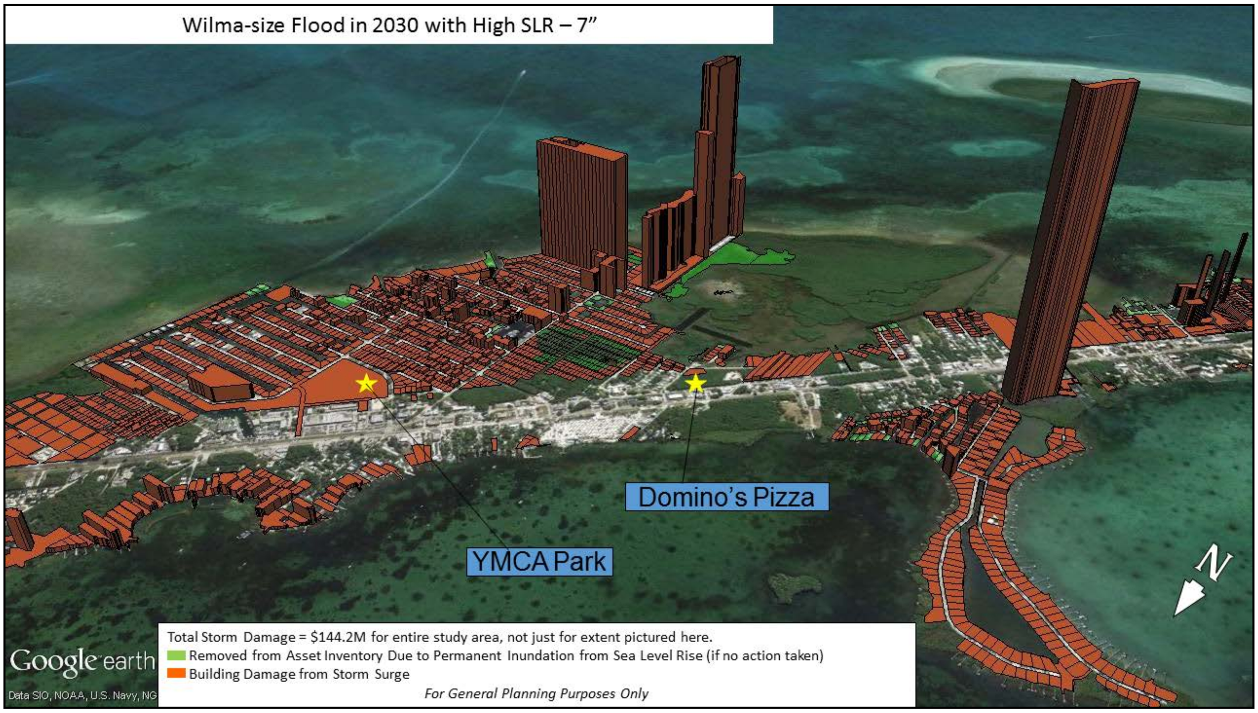

Nuisance Flood in 2060 with Low SLR – 4.53" Linear Tide Gauge Trend
Domino's Pizza
YMCA Park
N
Total Storm Damage = $1.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

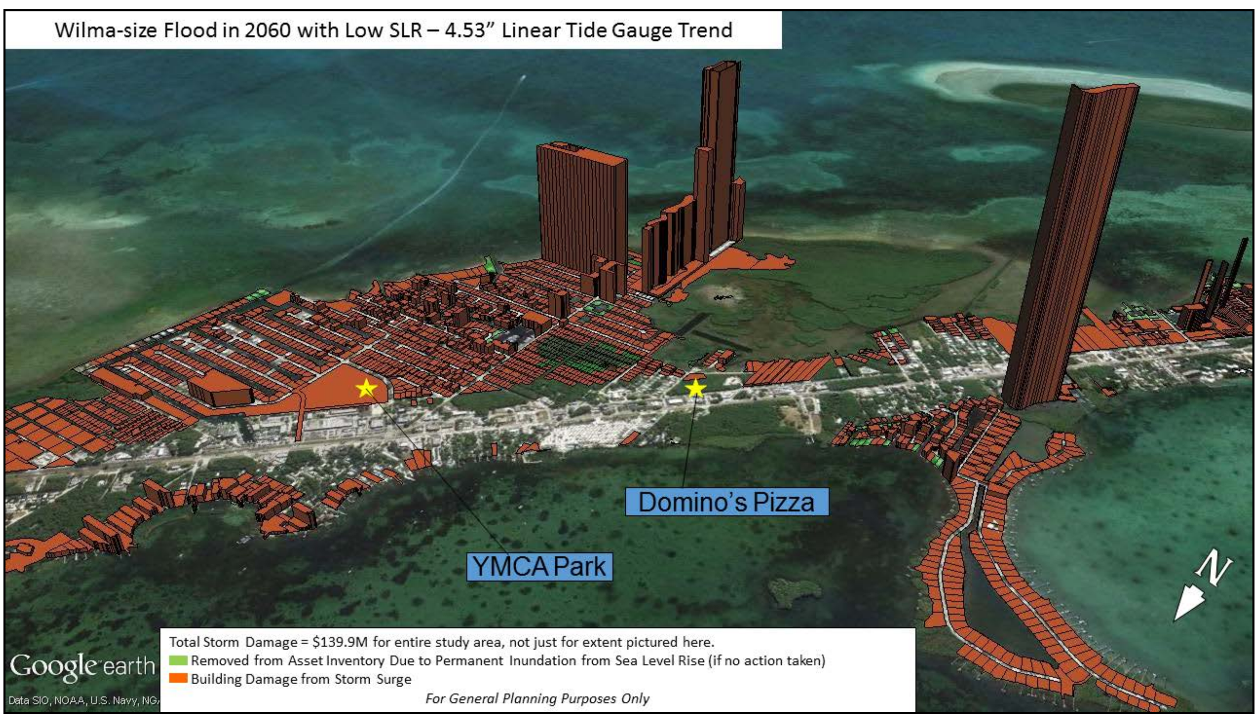

Nuisance Flood in 2060 with Low SLR – 9"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

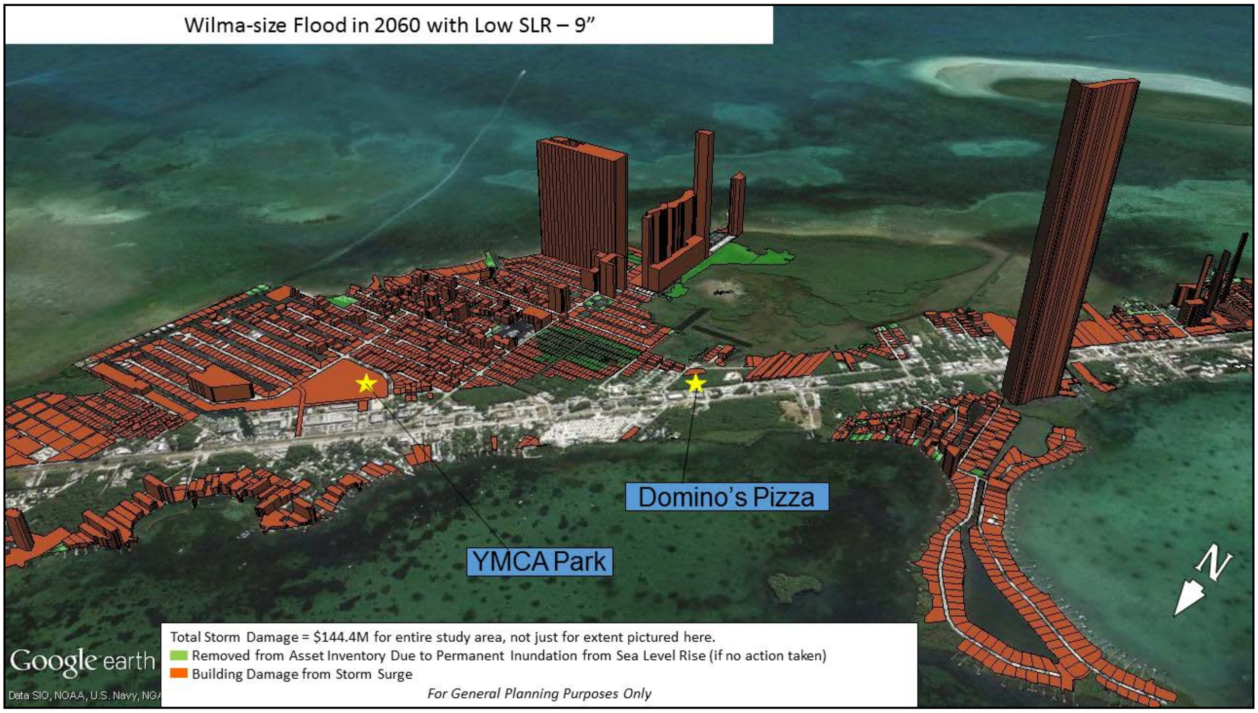

Nuisance Flood in 2060 with High SLR – 24"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $2.0M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

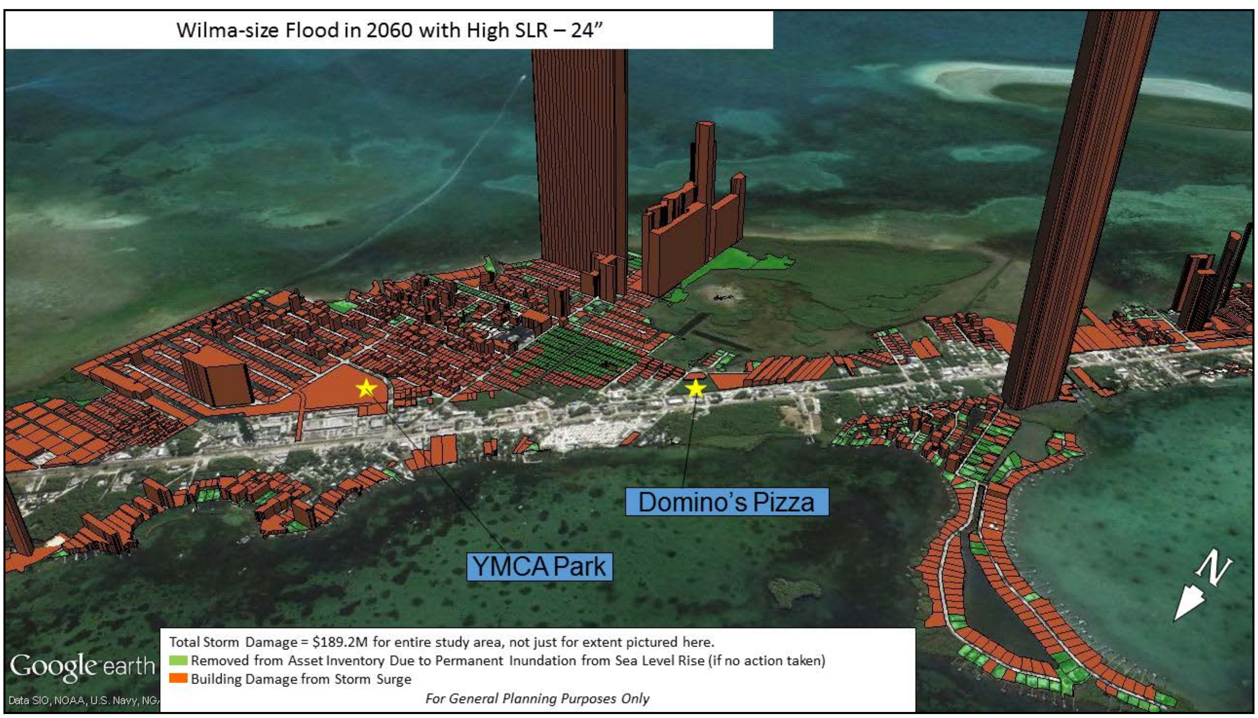

Wilma-size Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Domino's Pizza
YMCA Park
N
Total Storm Damage = $142.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

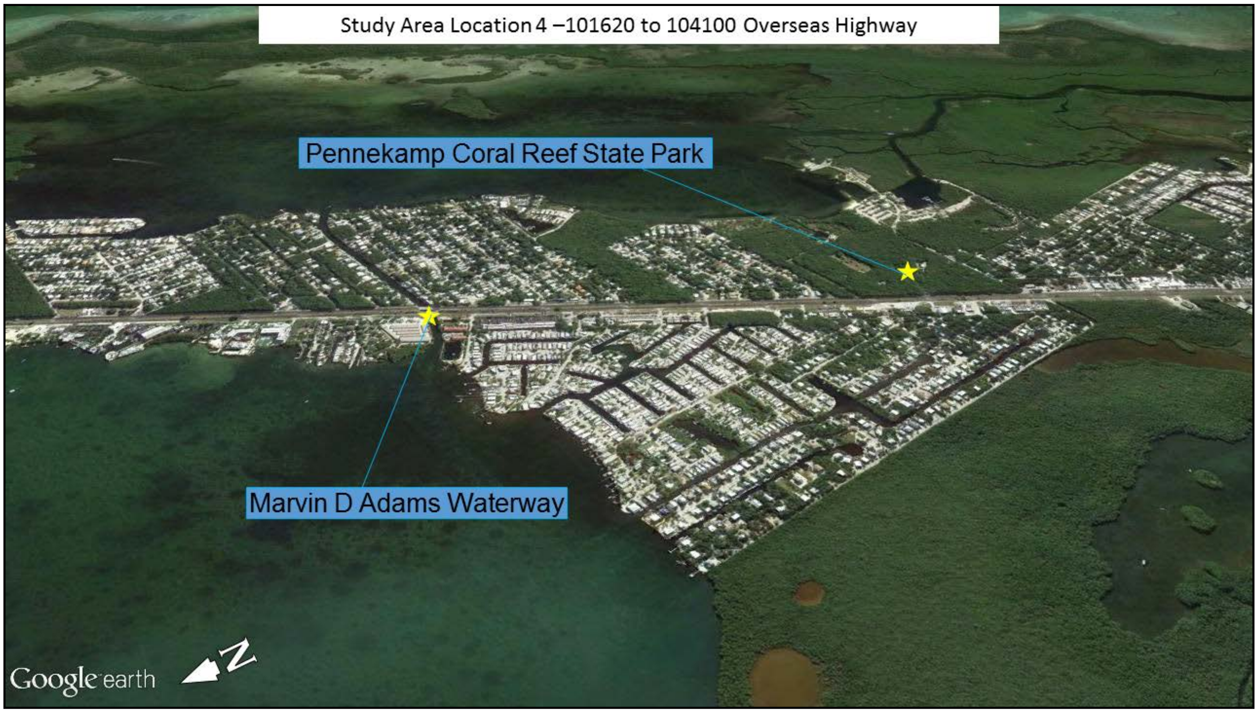

Wilma-size Flood in 2030 with Low SLR – 3"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $145.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth

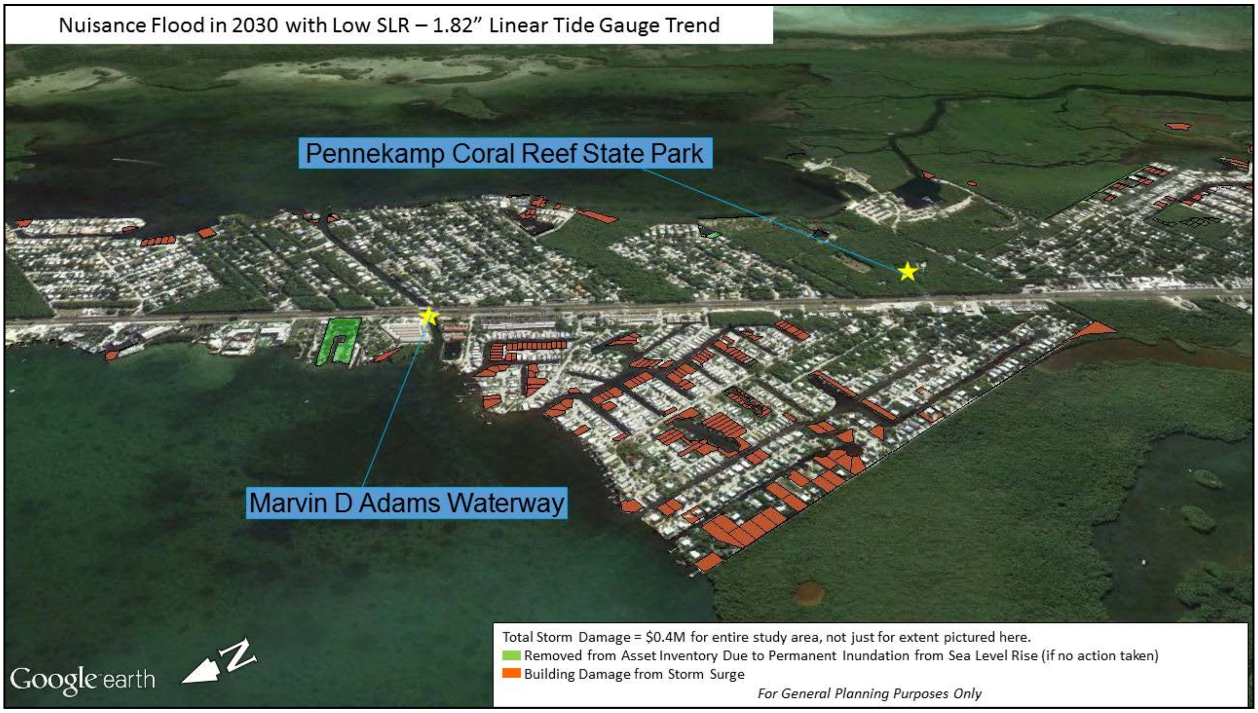

Wilma-size Flood in 2030 with High SLR – 7"
Domino's Pizza
YMCA Park
N
Total Storm Damage = $144.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
Data SIO, NOAA, U.S. Navy, NG

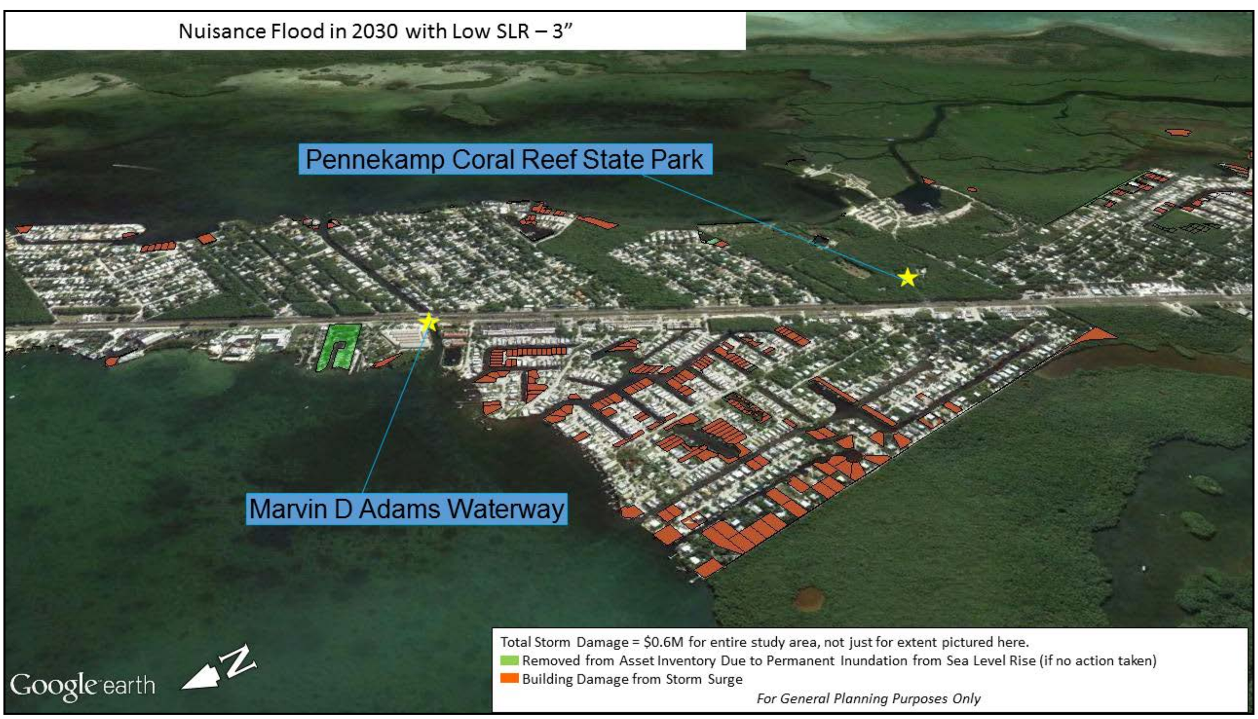

Wilma-size Flood in 2060 with Low SLR – 4.53" Linear Tide Gauge Trend
Domino's Pizza
YMCA Park
N
Total Storm Damage = $139.9M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
Data SIO, NOAA, U.S. Navy, NGA

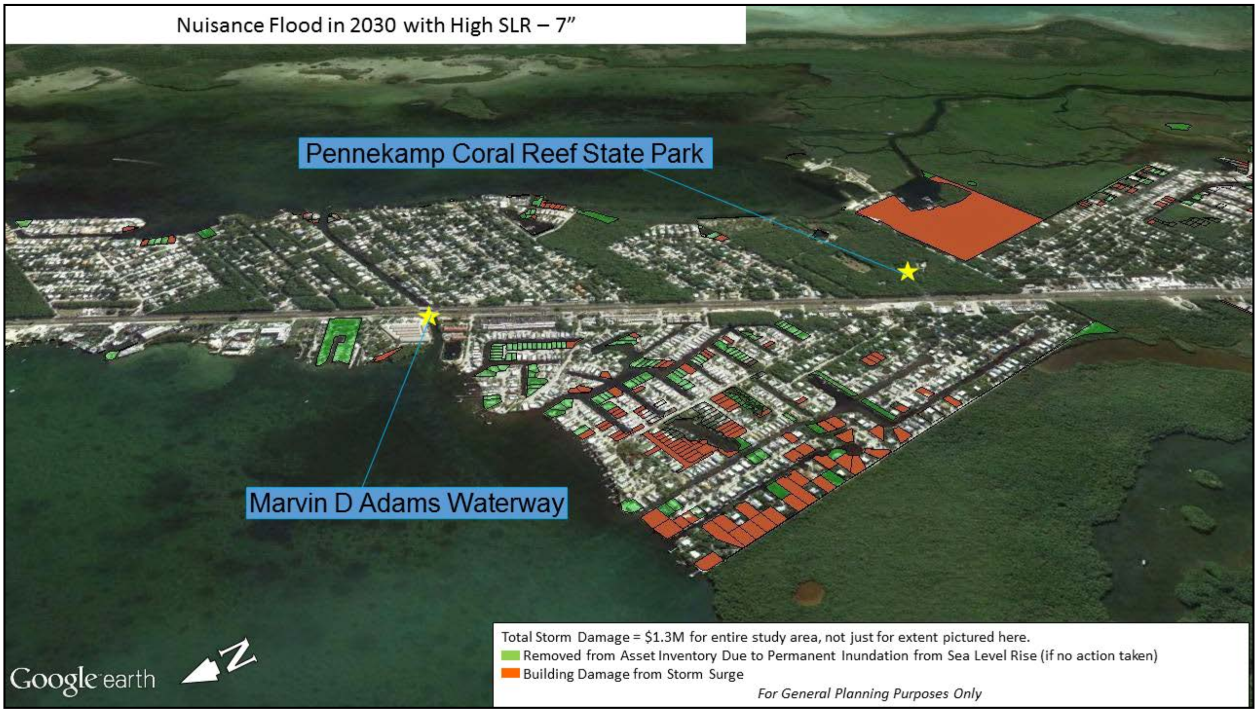

Wilma-size Flood in 2060 with Low SLR – 9”
Domino’s Pizza
YMCA Park
Total Storm Damage = $144.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

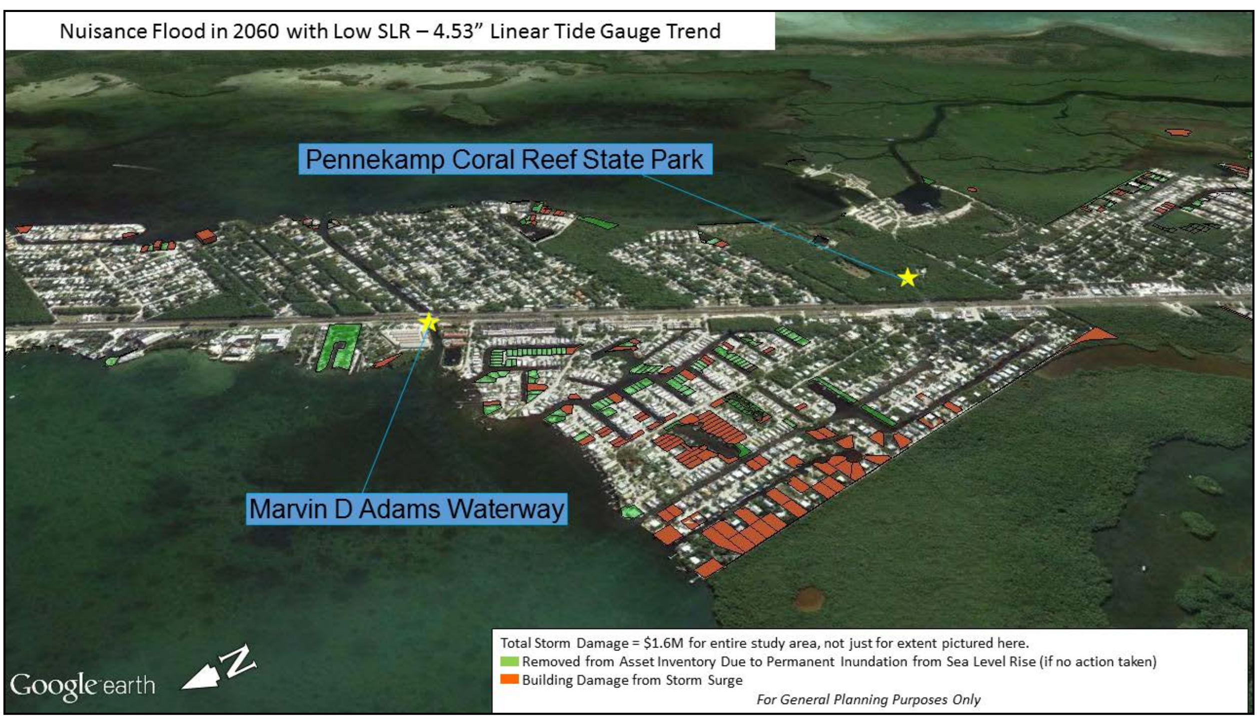

Wilma-size Flood in 2060 with High SLR – 24”
Domino’s Pizza
YMCA Park
Total Storm Damage = $189.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

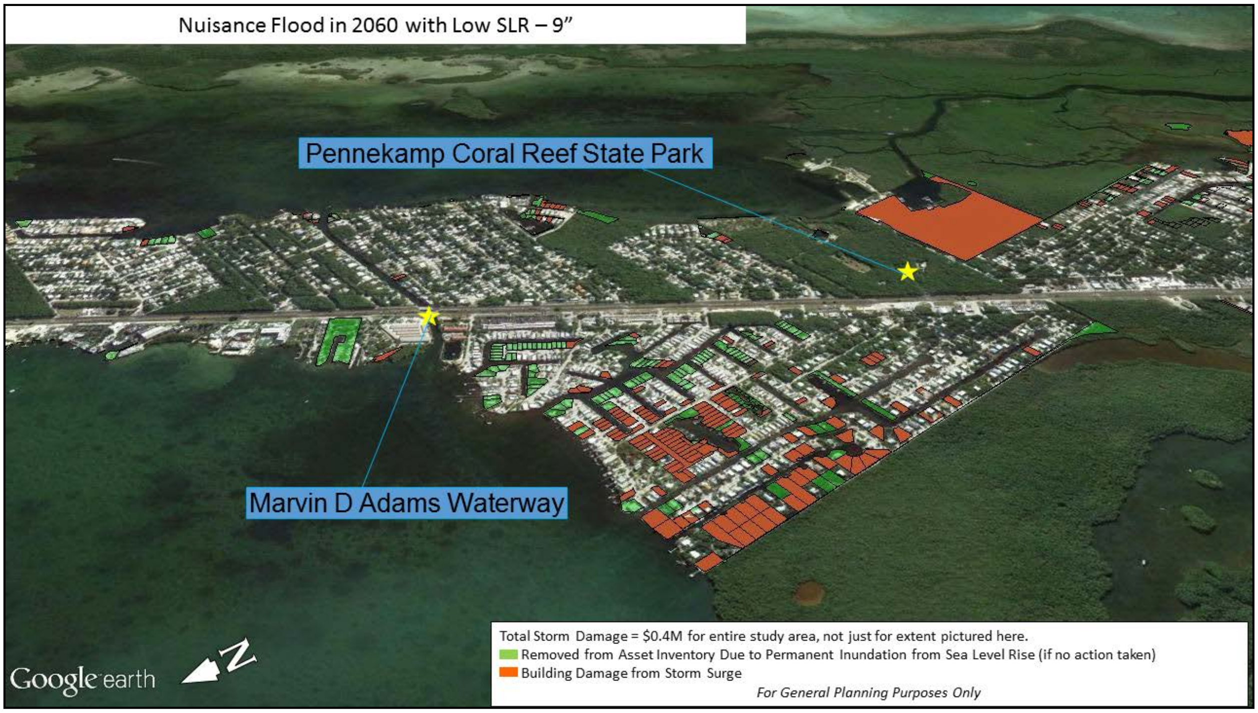

Study Area Location 4 –101620 to 104100 Overseas Highway
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
N

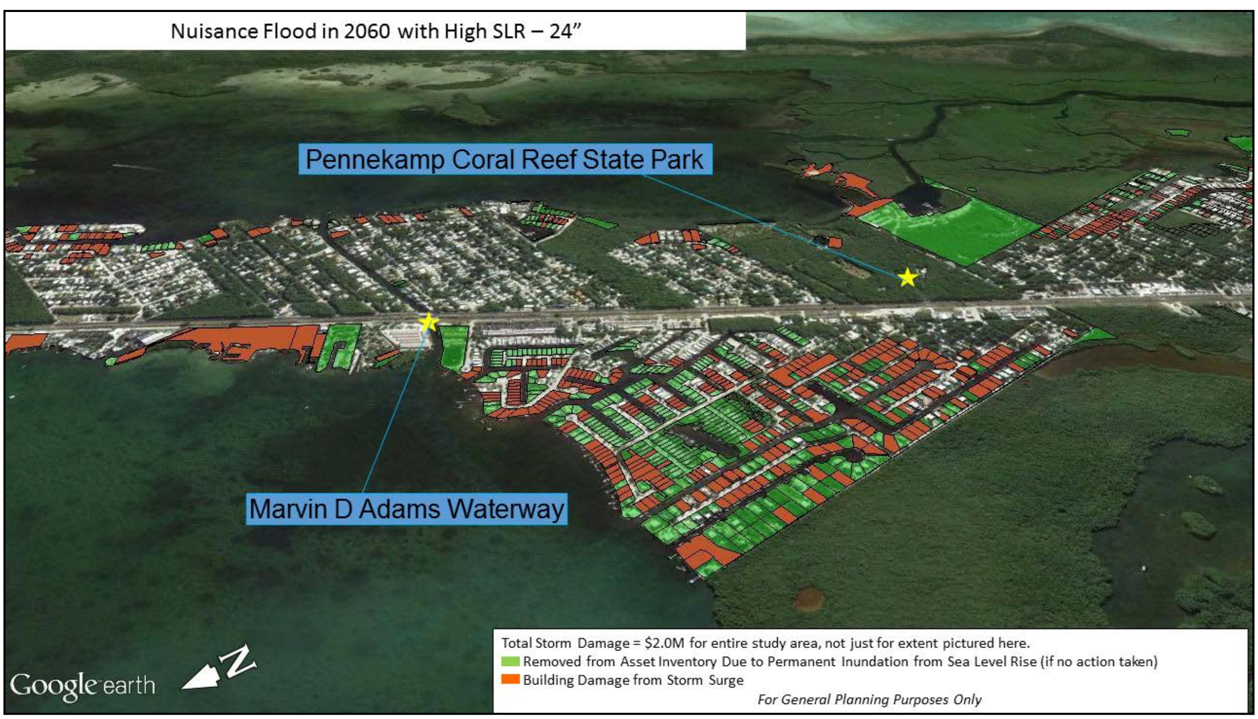

Nuisance Flood in 2030 with Low SLR – 1.82” Linear Tide Gauge Trend
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N

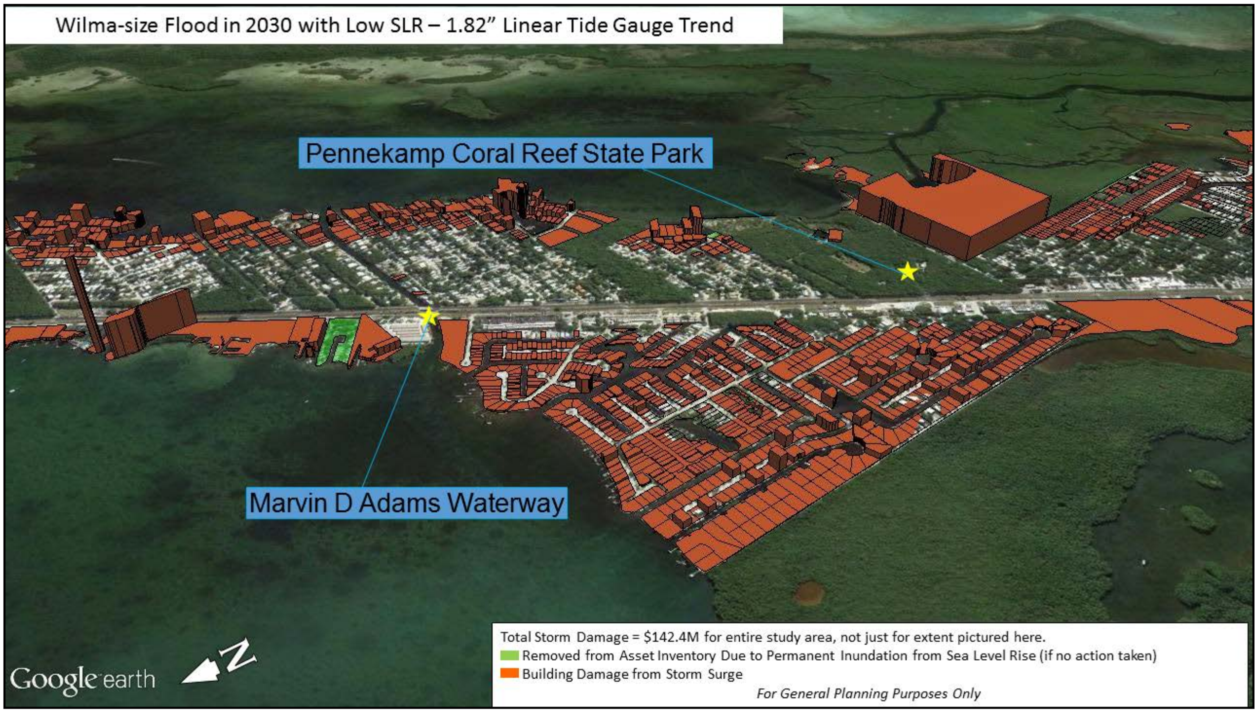

Nuisance Flood in 2030 with Low SLR – 3”
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Total Storm Damage = $0.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
N


Nuisance Flood in 2030 with High SLR – 7"
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
N
Total Storm Damage = $1.3M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only


Nuisance Flood in 2060 with Low SLR – 4.53" Linear Tide Gauge Trend
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
N
Total Storm Damage = $1.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only


Nuisance Flood in 2060 with Low SLR – 9"
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
N
Total Storm Damage = $0.4M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only


Nuisance Flood in 2060 with High SLR – 24"
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
N
Total Storm Damage = $2.0M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only


Wilma-size Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Total Storm Damage = $142.4M for entire study area, not just for extent pictured here.
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Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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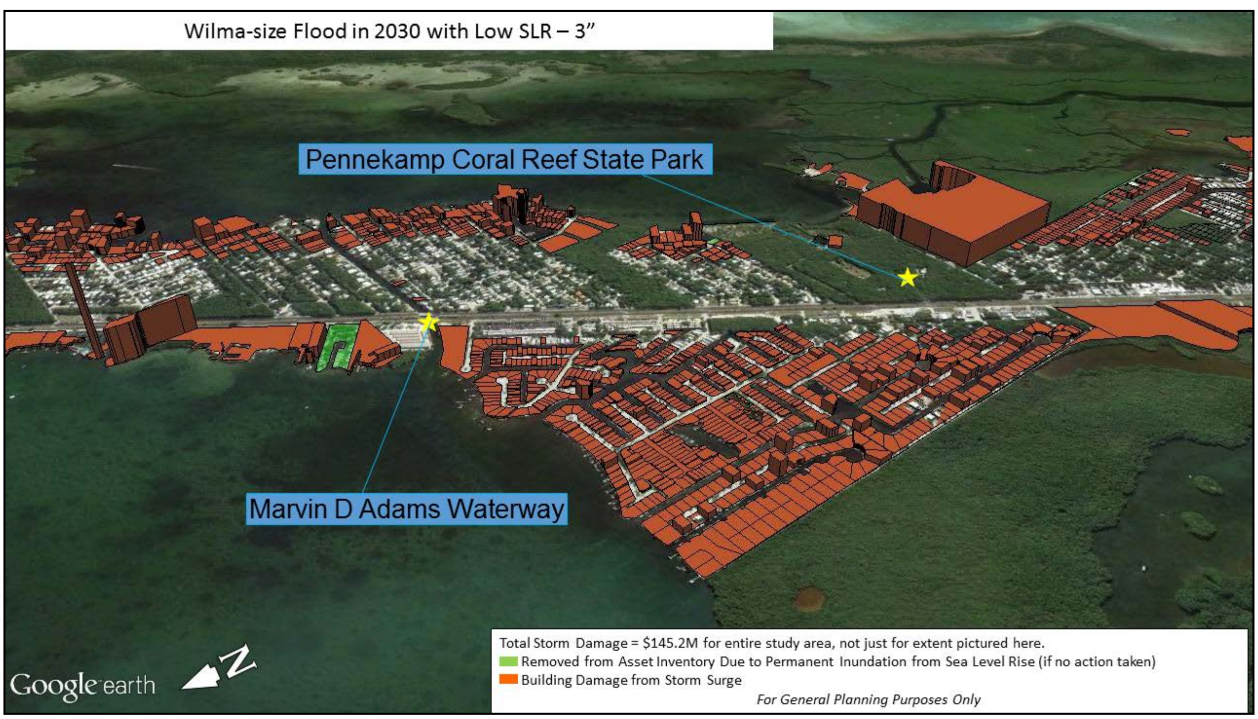
Wilma-size Flood in 2030 with Low SLR – 3"
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Total Storm Damage = $145.2M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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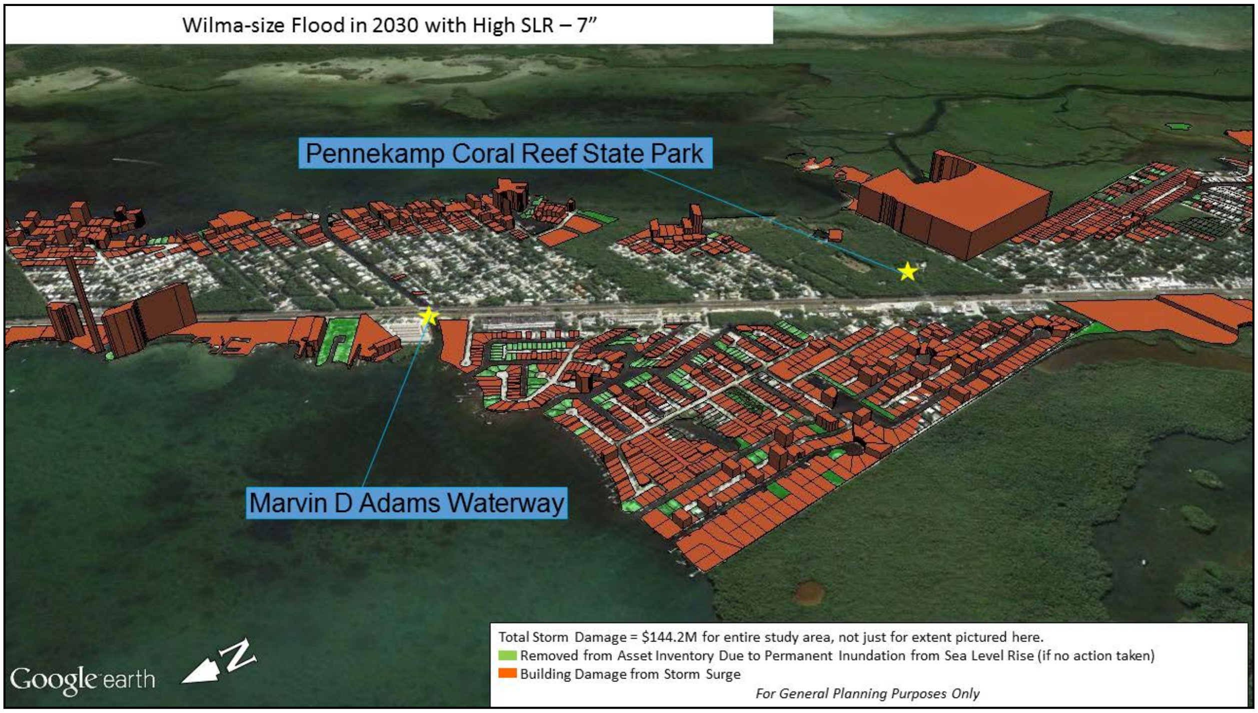

Wilma-size Flood in 2030 with High SLR – 7”
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
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Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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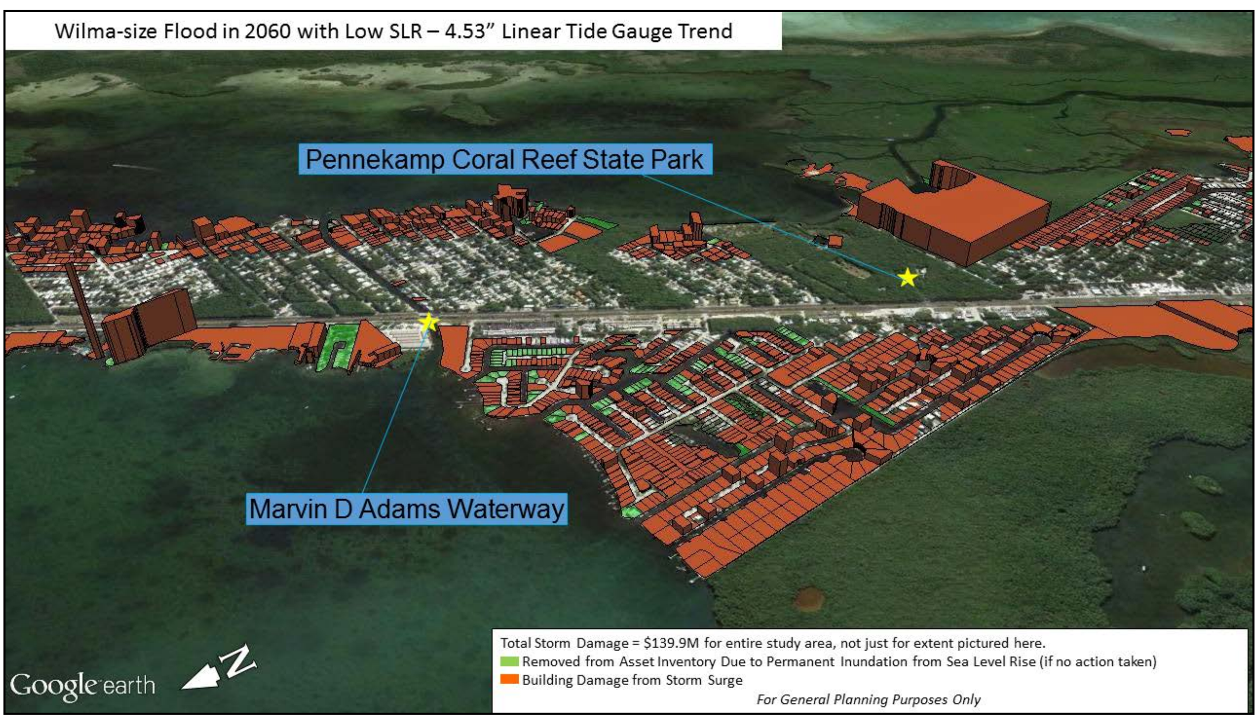

Wilma-size Flood in 2060 with Low SLR – 4.53” Linear Tide Gauge Trend
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
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Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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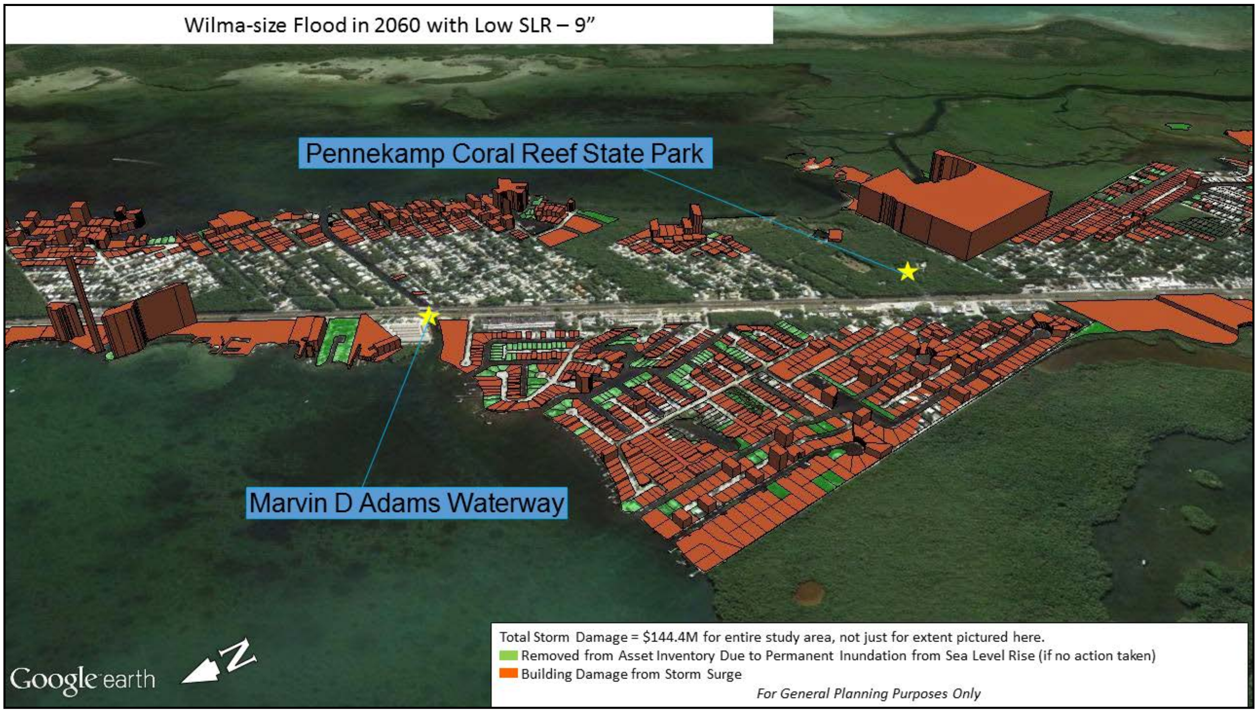
Wilma-size Flood in 2060 with Low SLR – 9”
Pennekamp Coral Reef State Park
Marvin D Adams Waterway
Google earth
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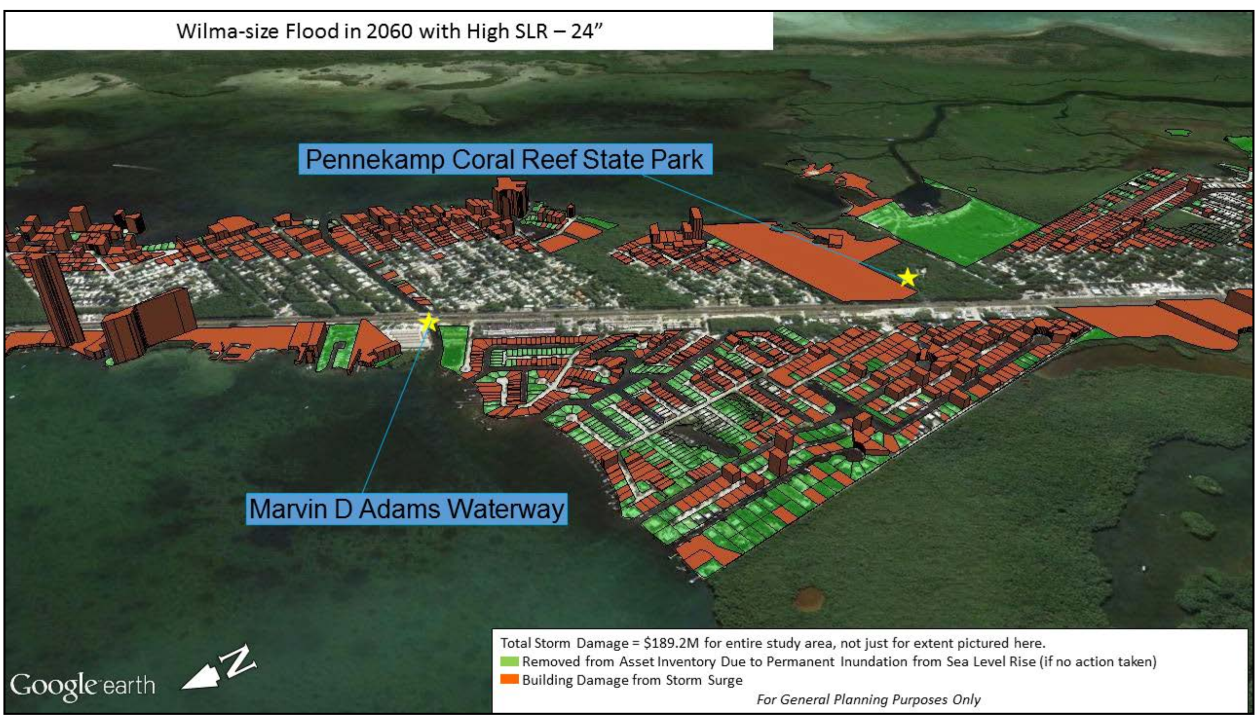
Wilma-size Flood in 2060 with High SLR – 24”
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Marvin D Adams Waterway
Google earth
N
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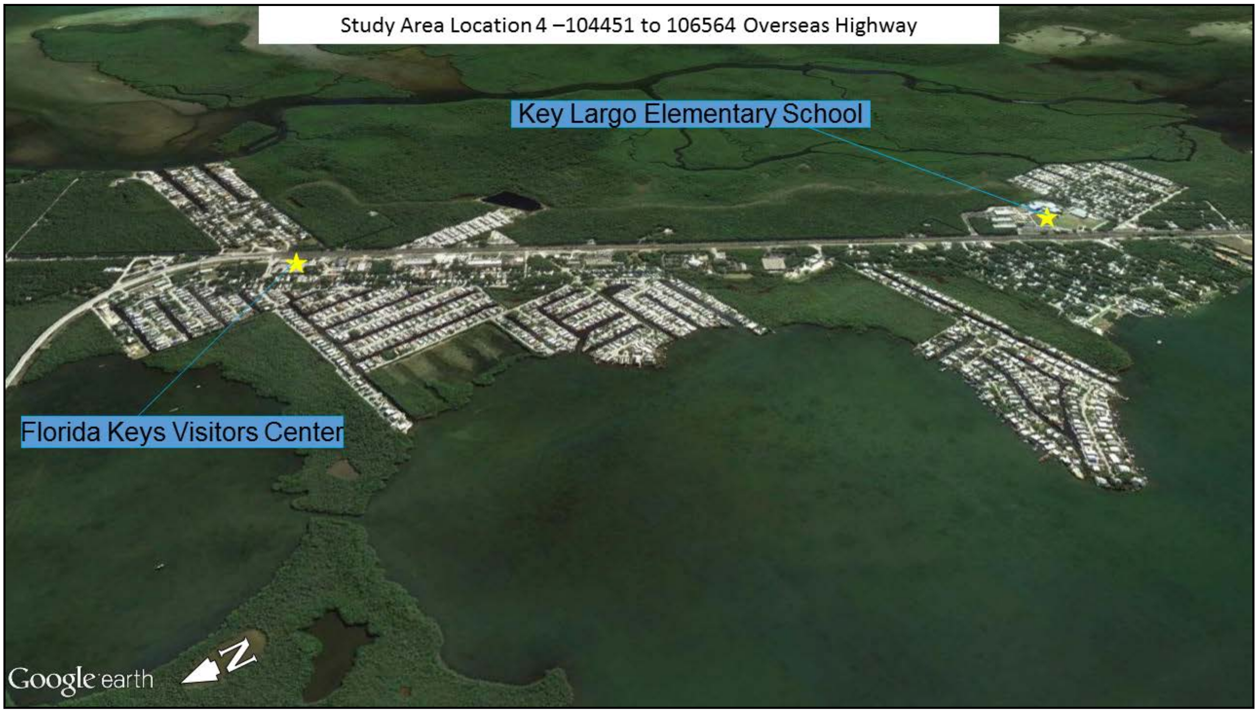
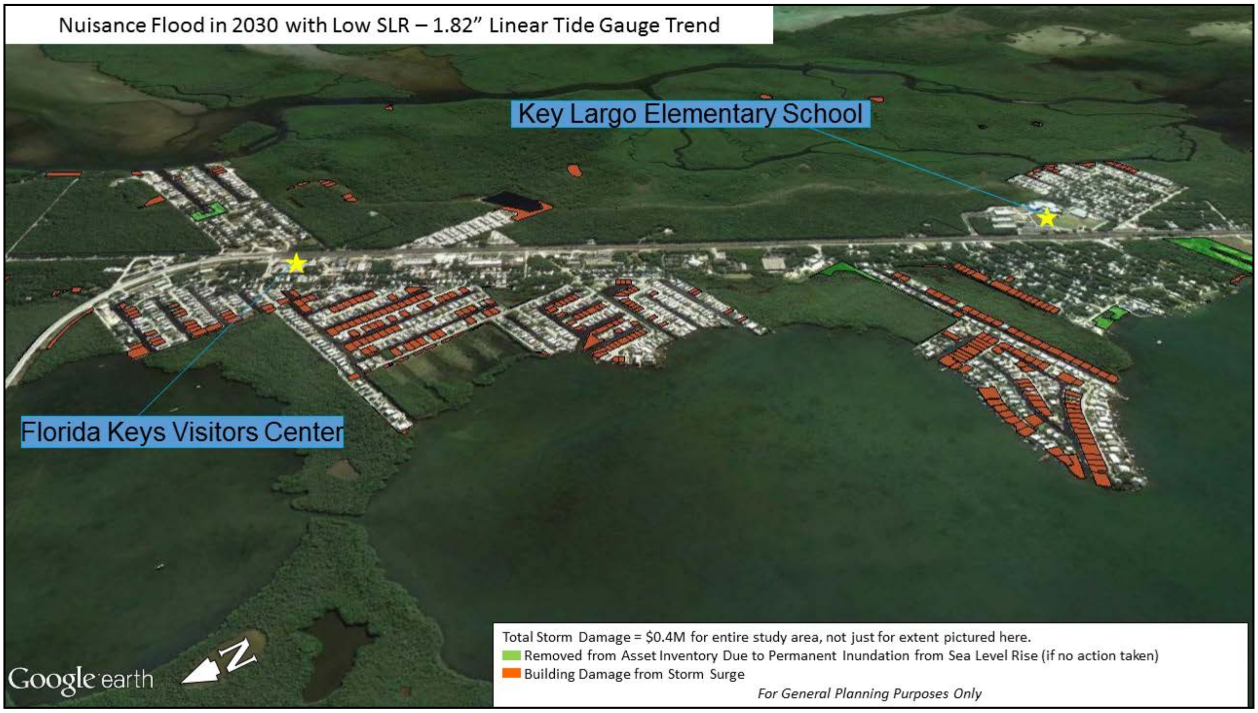
Building Damage from Storm Surge
For General Planning Purposes Only


Study Area Location 4 –104451 to 106564 Overseas Highway
Key Largo Elementary School
Florida Keys Visitors Center
Google earth
N


Nuisance Flood in 2030 with Low SLR – 1.82" Linear Tide Gauge Trend
Key Largo Elementary School
Florida Keys Visitors Center
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Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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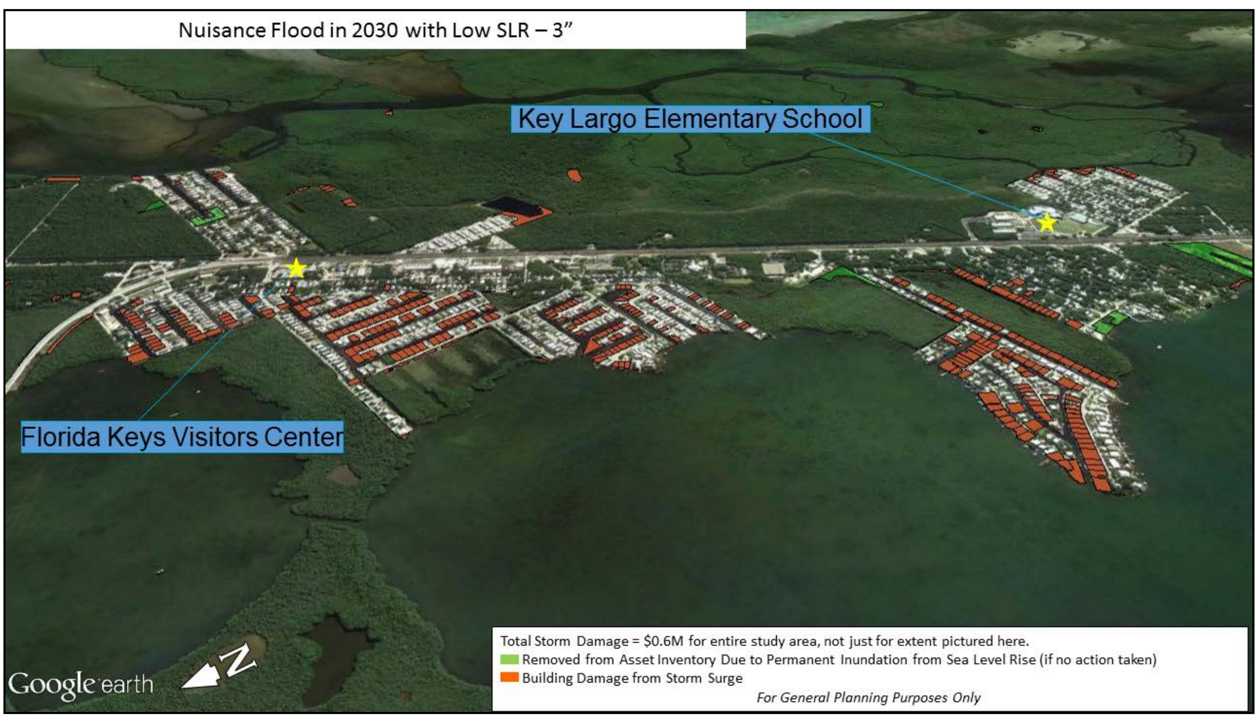
Nuisance Flood in 2030 with Low SLR – 3"
Key Largo Elementary School
Florida Keys Visitors Center
Total Storm Damage = $0.6M for entire study area, not just for extent pictured here.
Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
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Google earth
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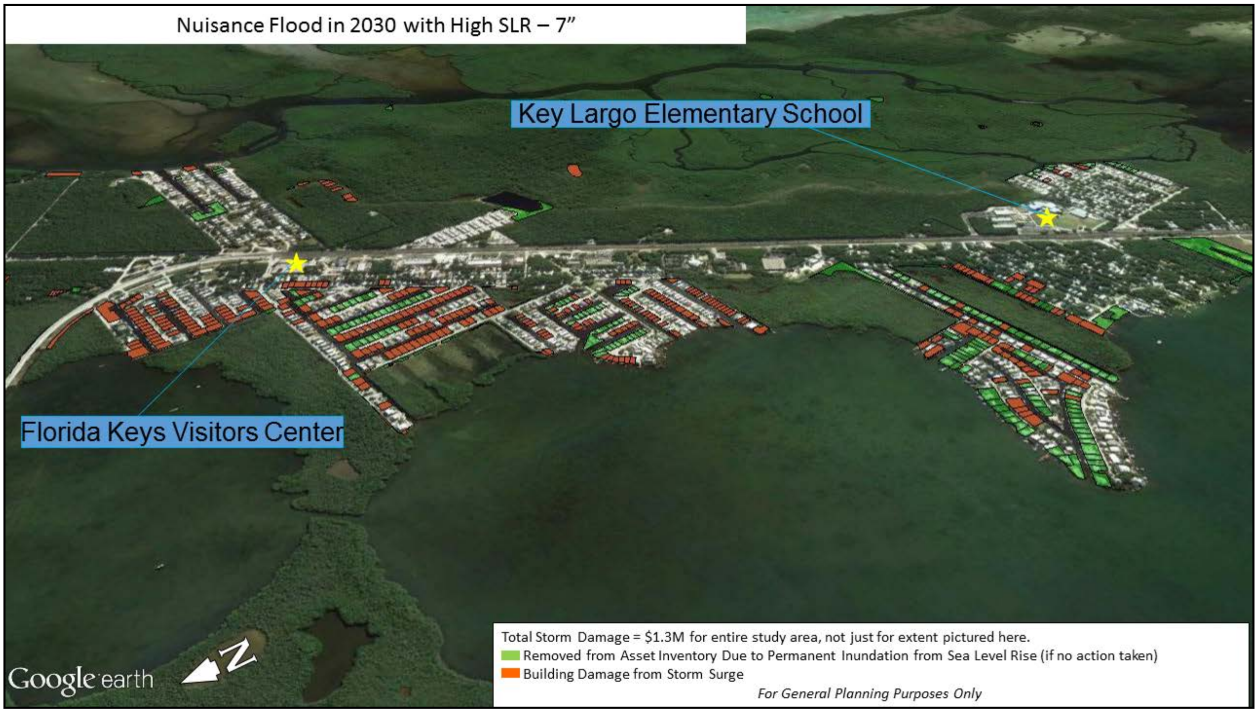
Nuisance Flood in 2030 with High SLR – 7”
Key Largo Elementary School
Florida Keys Visitors Center
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Removed from Asset Inventory Due to Permanent Inundation from Sea Level Rise (if no action taken)
Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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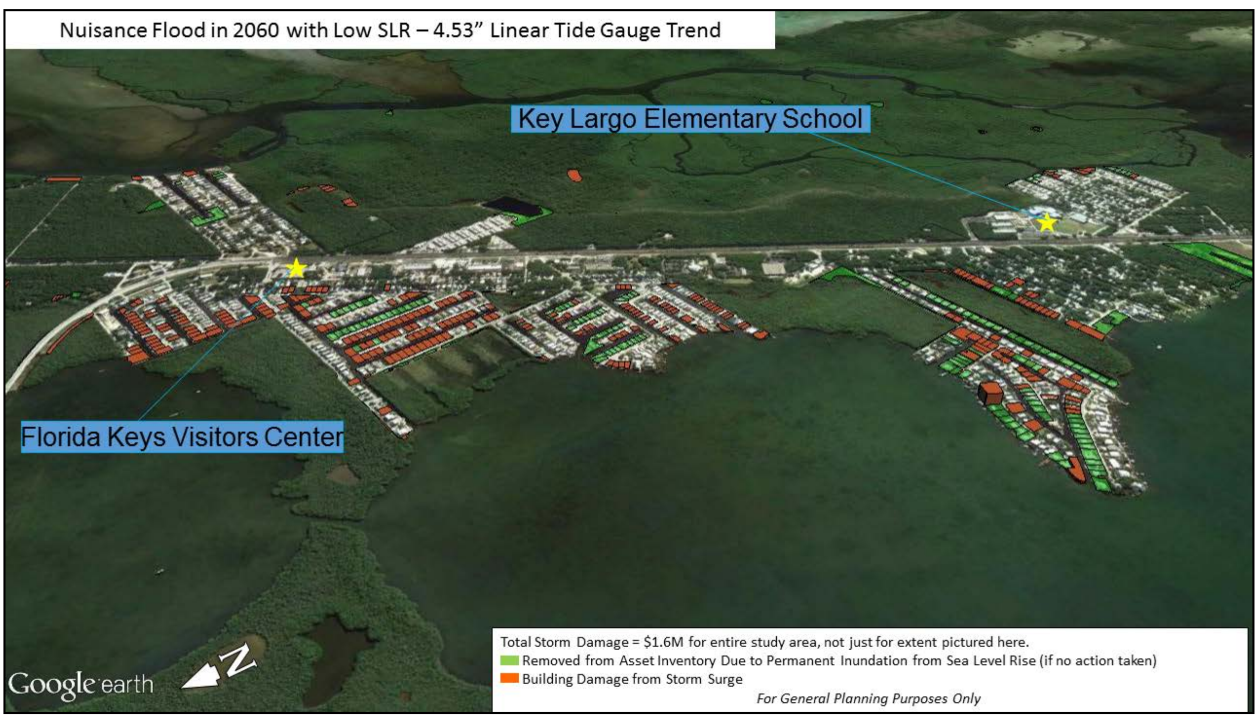
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Key Largo Elementary School
Florida Keys Visitors Center
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Building Damage from Storm Surge
For General Planning Purposes Only
Google earth
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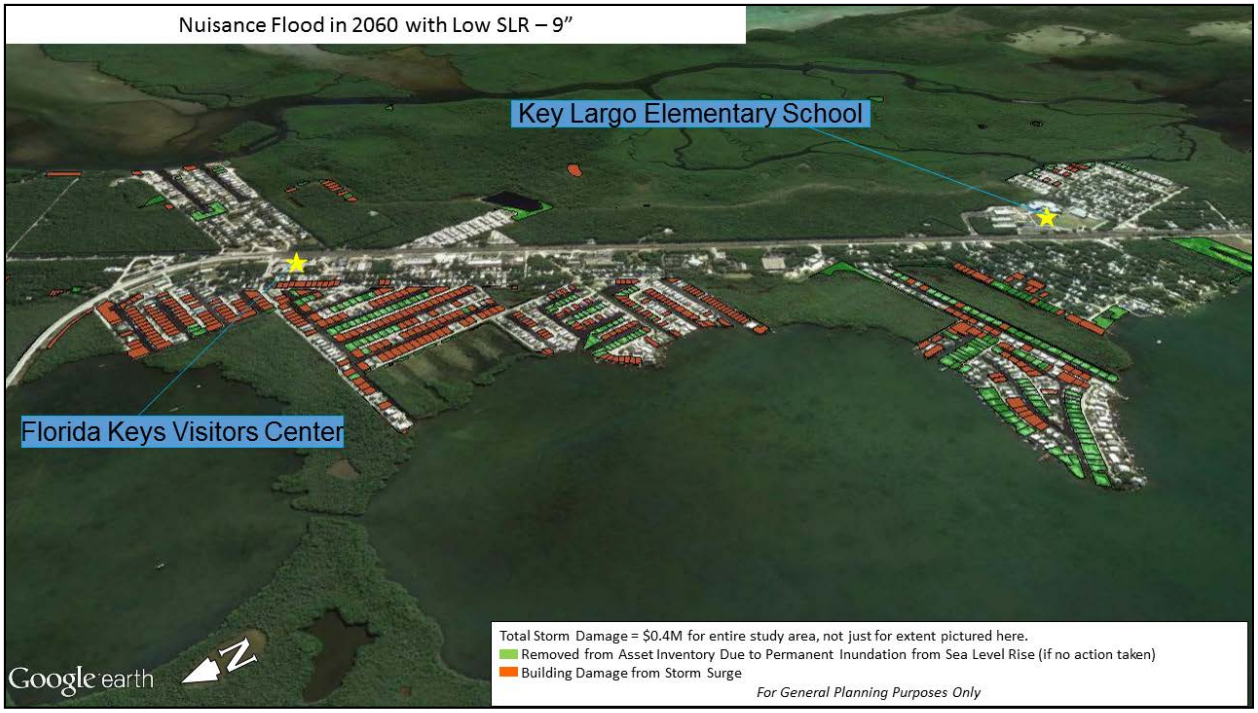
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Florida Keys Visitors Center
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Google earth
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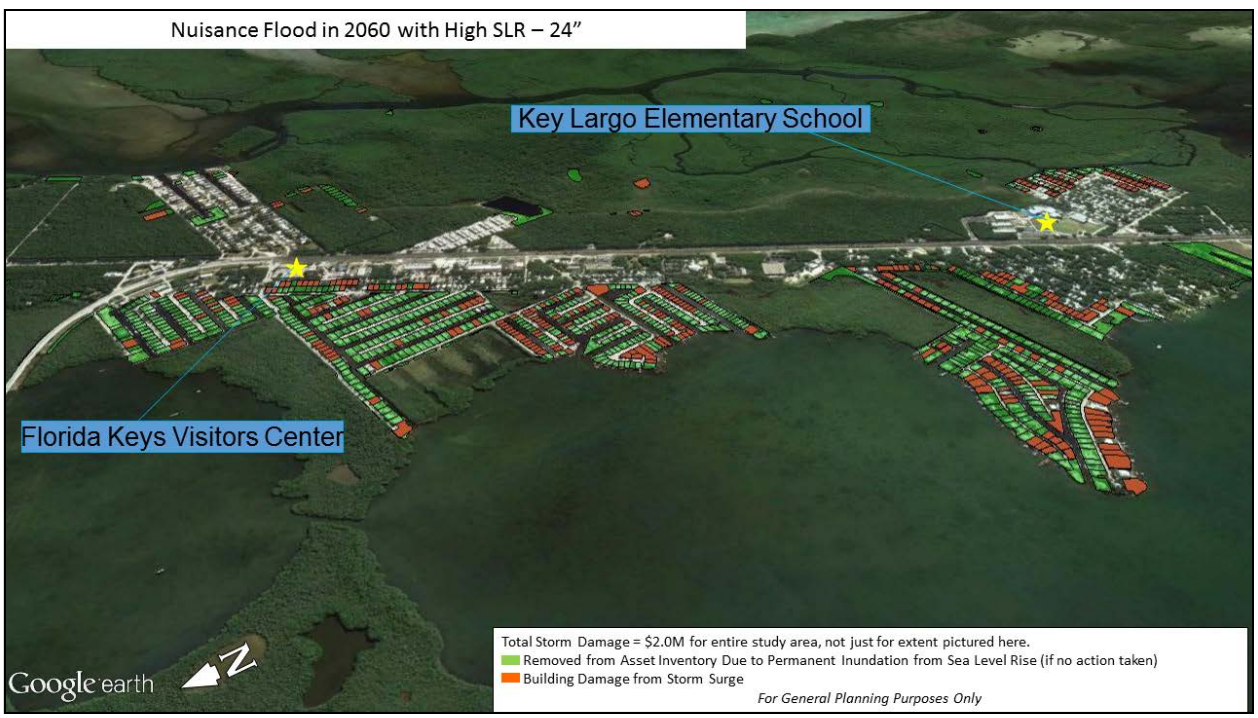
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Google earth
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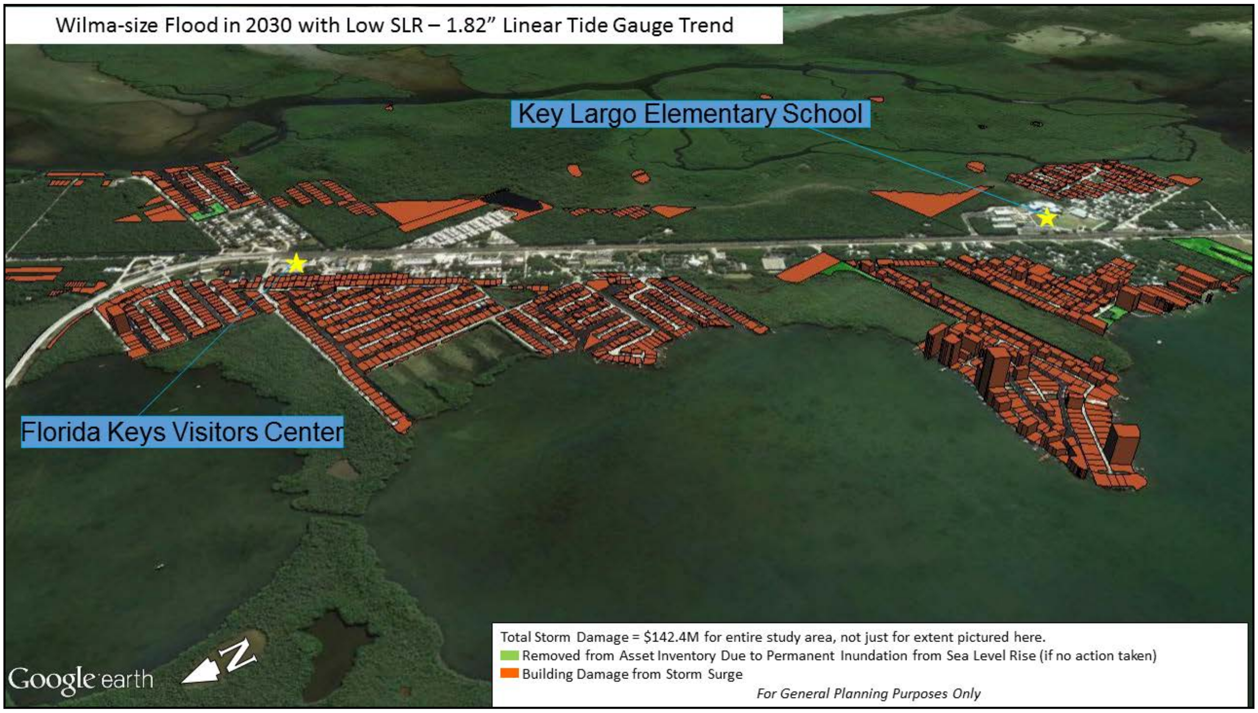
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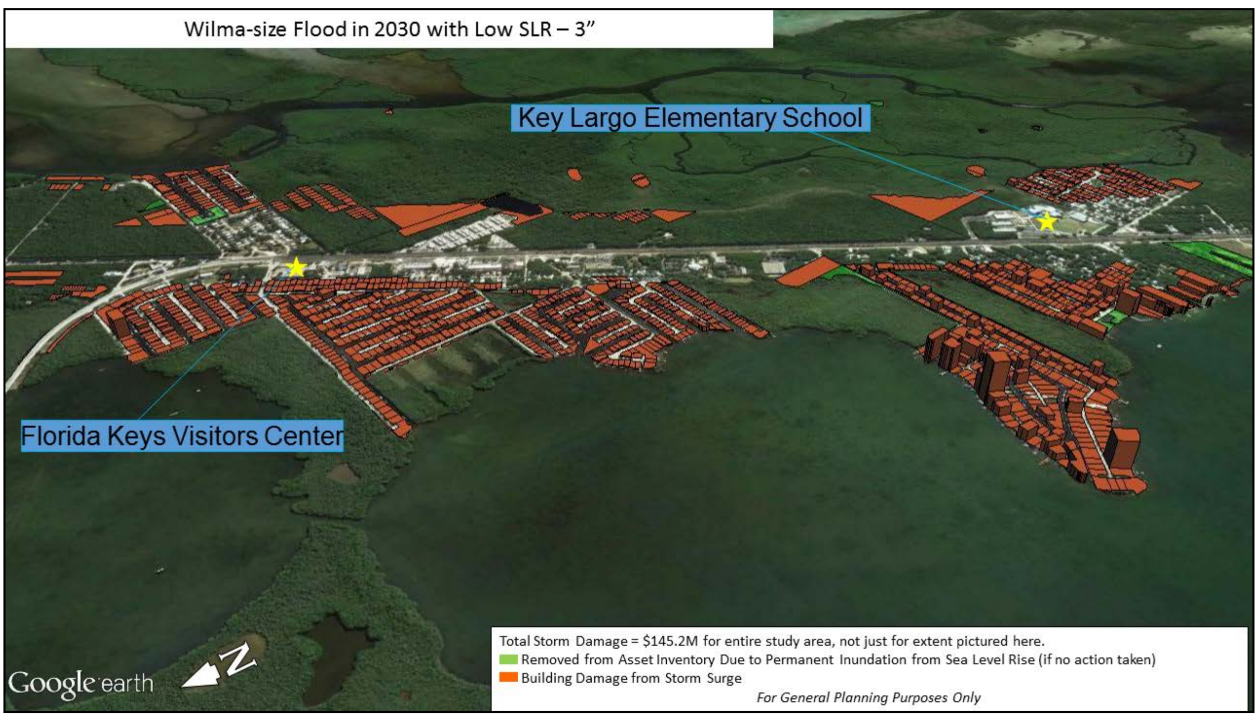
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Building Damage from Storm Surge
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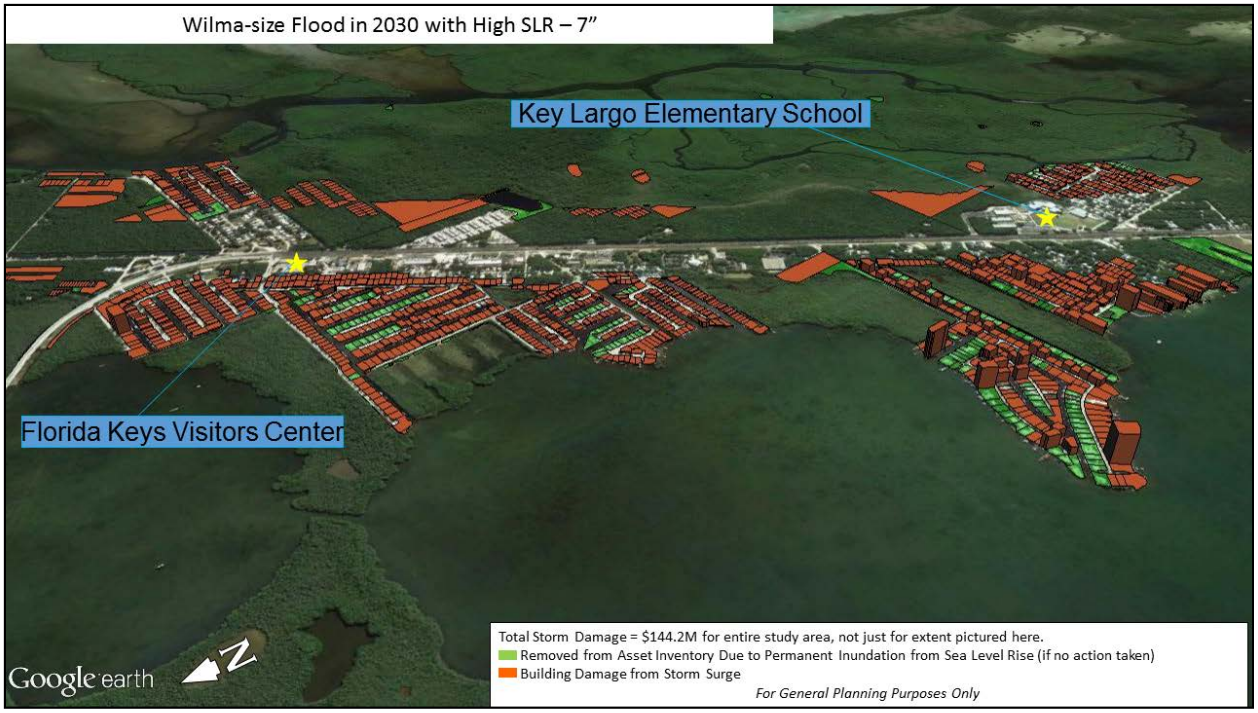
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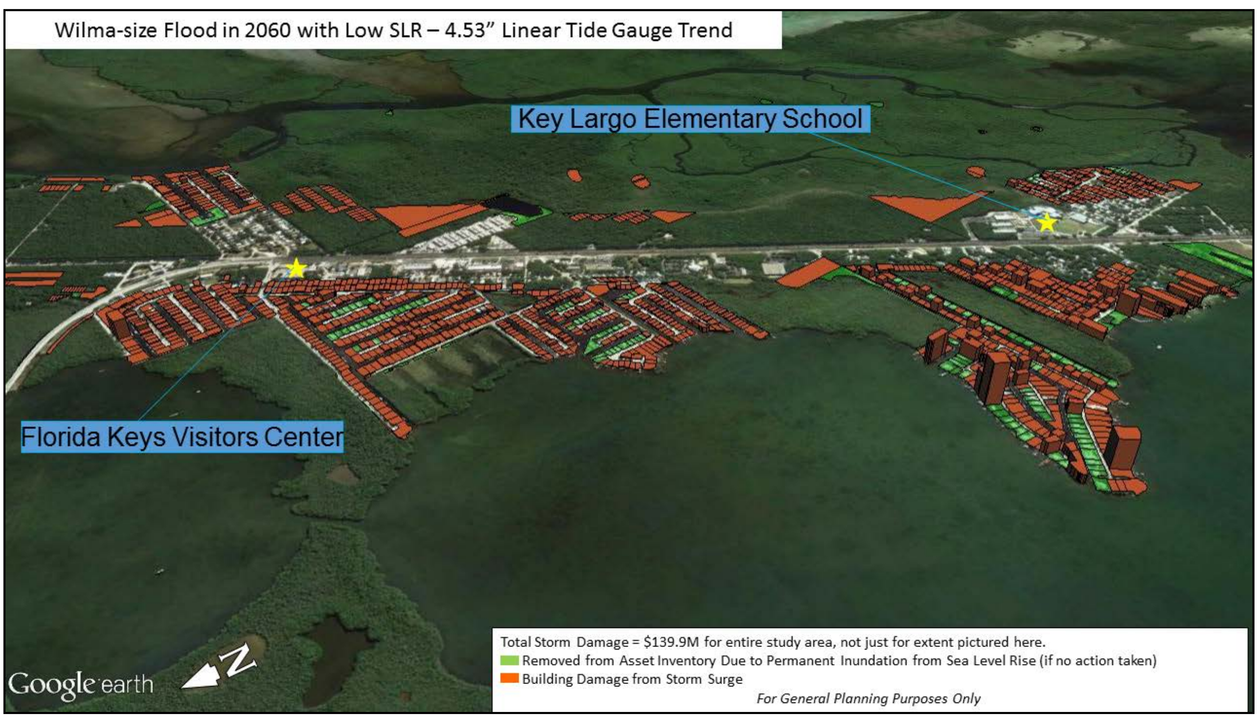
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Florida Keys Visitors Center
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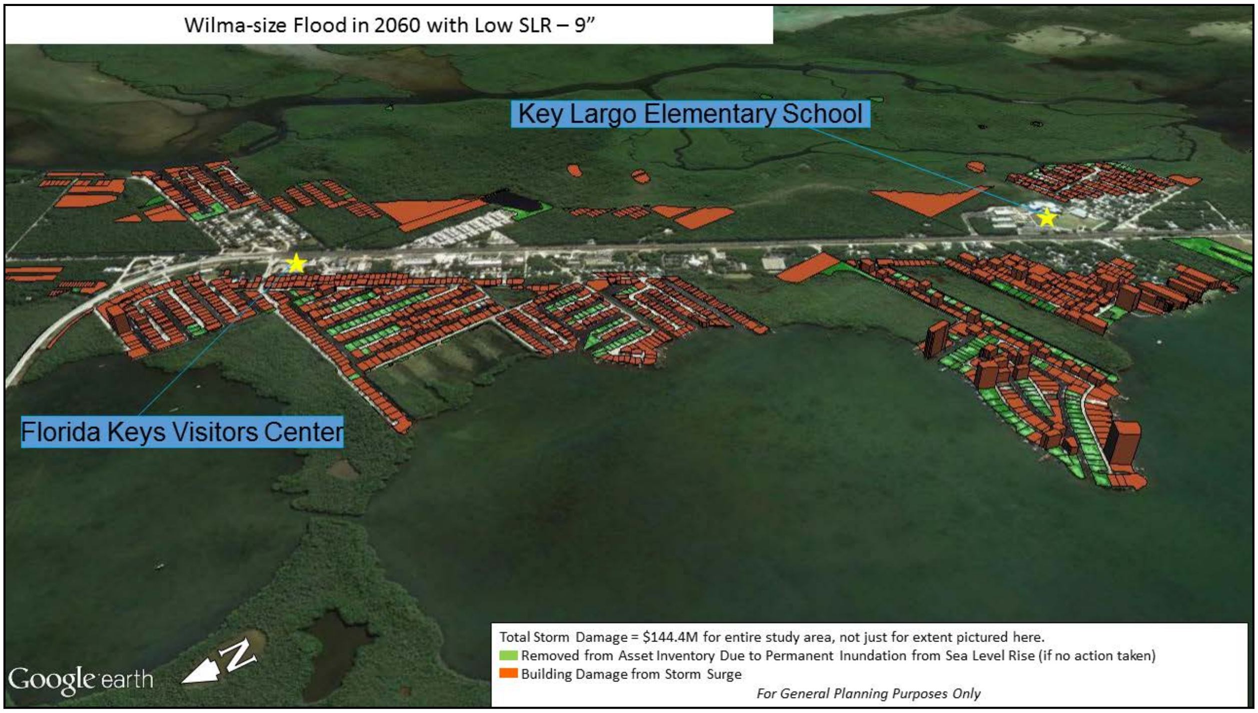

Wilma-size Flood in 2060 with Low SLR – 9”
Key Largo Elementary School
Florida Keys Visitors Center
Google earth
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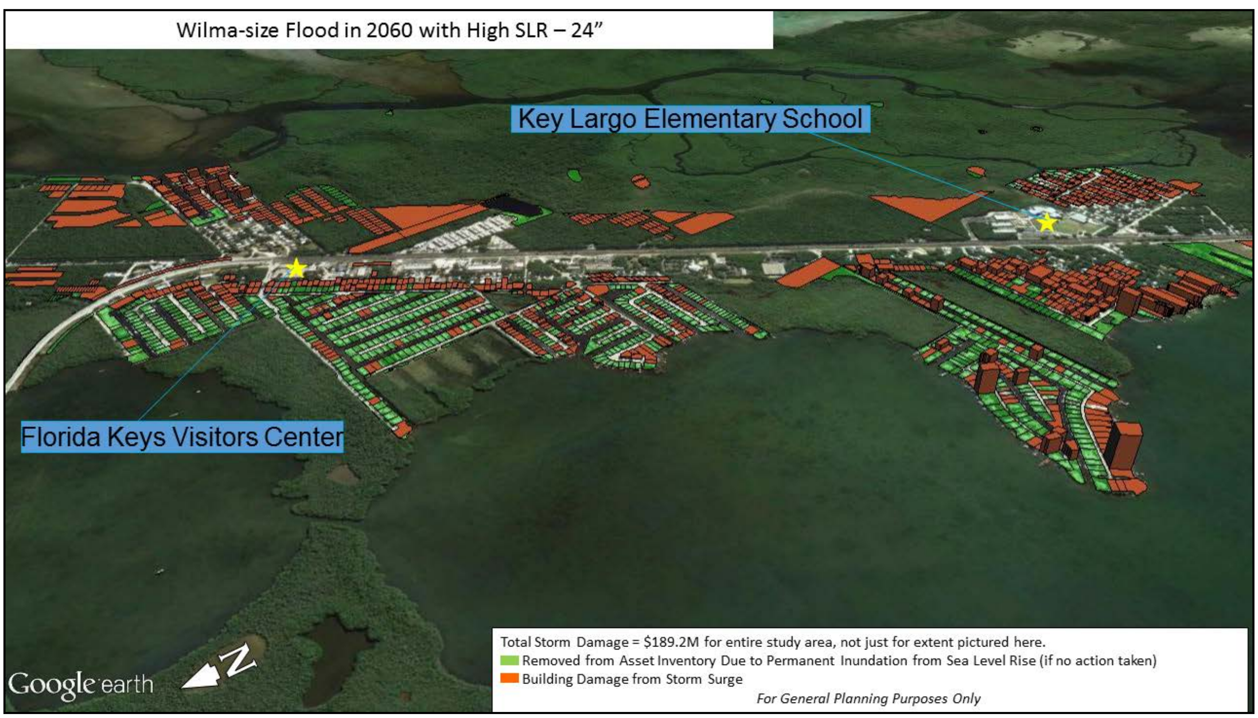

Wilma-size Flood in 2060 with High SLR – 24”
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Florida Keys Visitors Center
Google earth
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Building Damage from Storm Surge
For General Planning Purposes Only

6.3 Cost Breakdown for Adaptation Actions

6.3.1 Adaptation Action 1 – Elevate and Floodproof Buildings

	Cost Estimates for Action 1 - No Discounting, Costs paid Now				
	Number of Units Elevated in the V Zone	**Elevation Price Per Site - Low**	**Elevation Price per Site- High**	**Cost - Low**	**Cost - High**
For Elevation Component	189	$ 60,000	$ 160,000	$ 11,340,000	$30,240,000
	Total Bldg Market Value of Flood-proofed Units in A Zone	**Cost as percent of Building Structure Value - Low**	**Cost as percent of Building Structure Value - High**	**Cost - Low**	**Cost - High**
For Flood-proofing Component	$ 611,151,453	10%	20%	$ 61,115,145	$ 122,230,291
Total				**$ 72,455,145**	**$ 152,470,291**

6.3.2 Adaptation Action 2 – Constructed Barriers

	Estimated Costs Using Bid Numbers from South Cove Restoration Plan (2011) - Limestone Breakwater with Mangroves in Similar Depth - Palm Beach County ERM/Lake Worth Area					
	Qty	Unit	Unit Cost - Avg 3 Lowest Bids in 2011	Total Cost	Scale-Up Multiplier for Largo (1500 feet to 2 miles)	**Largo Cost Estimate**
Mobilization - Demobilization	1	lump sum	$ 146,533.00	$ 146,533	2	**$ 293,066**
Design Drawings	1	lump sum	$ 28,900.00	$ 28,900	3	**$ 86,700**
Fill	35000	CY	$ 20.37	$ 712,950	7.04	**$ 5,019,168**
Armor Stone	9600	Tons	$ 73.10	$ 701,760	7.04	**$ 4,940,390**
Bedding Stone	1600	Tons	$ 77.92	$ 124,672	7.04	**$ 877,691**
Total				$ 1,714,815		**$ 11,217,015**
Adjust by CPI since 2011						**$ 12,870,929**
					Low Cost Estimate	**$ 12,870,929**
				For High Cost Estimate, Add 33%		**$ 17,118,336**

6.3.3 Adaptation Action 3 – Voluntary Buyouts

	Cost Estimates for Action 3 - 100% participation in now and in 2030				
	Rolling Easement Acquisition Costs				
	Current Building Market Value	**Current Land Value - Assessed Value**	**Current Land Market Value**	**Current Total Market Value, Land + Bldg**	**Discounted to Today's Price from 2030 for reds; from 2045 for greens**
Red Parcels	$ 53,781,942	$ 80,484,581	$ 92,557,268	$ 146,339,210	$ 87,047,352
Green Parcels	$ 59,385,014	$ 84,529,363	$ 97,208,767	$ 156,593,781	$ 57,235,377
Total (Low Estimate)					**$ 144,282,728**
Total (High Estimate - High Legal Costs)					**$ 216,424,092**

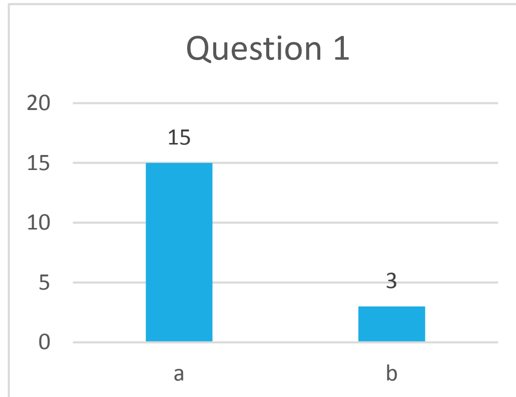
	Cost Estimates for Action 3 - 10% participation now and 100% in 2030				
	Rolling Easement Acquisition Costs				
	Current Building Market Value (100%)	**Current Land Value - Assessed Value (100%)**	**Current Land Market Value (100%)**	**Current Total Market Value, Land + Bldg (100%)**	**Discounted to Today's Price from 2030 for reds; from 2045 for greens, 10% participation now, 100% in 2030**
Red Parcels	$ 53,781,942	$ 80,484,581	$ 92,557,268	$ 146,339,210	$ 8,704,735
Green Parcels	$ 59,385,014	$ 84,529,363	$ 97,208,767	$ 156,593,781	$ 57,235,377
Total (Low Estimate)					**$ 65,940,112**
Total (High Estimate - High Legal Costs)					**$ 98,910,168**

6.4 KEYPAD POLLING RESULTS FROM COMMUNITY WORKSHOP #3

GreenKEYS! Keypad Polling Results from the COAST community modeling exercise conducted December 9 2014 at the Nelson Government Center in Key Largo, FL

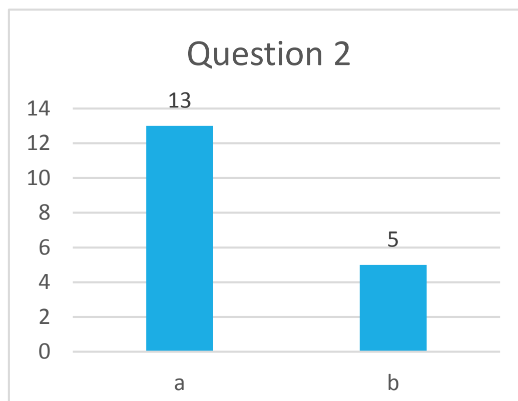
Floodproof & Elevate: 1. Given the results of the COAST model do you think this action deserves further study by the County?

1	a	**Yes**
	b	No



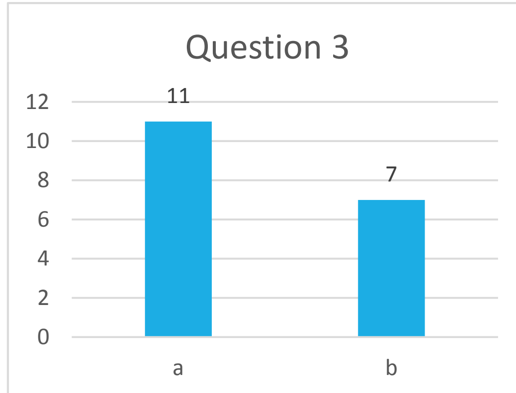
Floodproof & Elevate: 2. Do you think the County should require elevations of structures in Key Largo after they are damaged by more than 50% by a storm surge event, to a higher level than the current code requires? (Such as the 100 year flood height plus 2 or 3 feet, versus just the 100 year flood height, as required today?)

2	a	**Yes**
	b	No



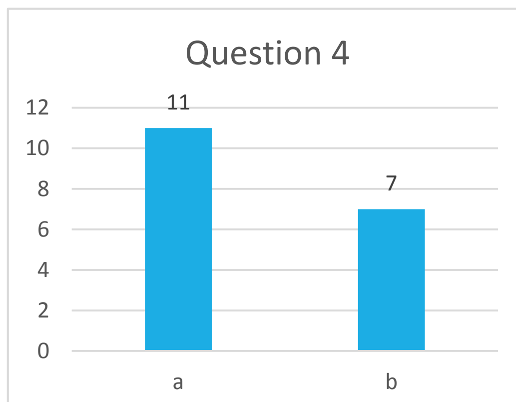
Floodproof & Elevate: 3. Do you think the County should pursue sources of funding to help private property owners elevate properties located in the FEMA V-zone, as a way to prevent storm surge damage?

3	a	**Yes**
	b	No



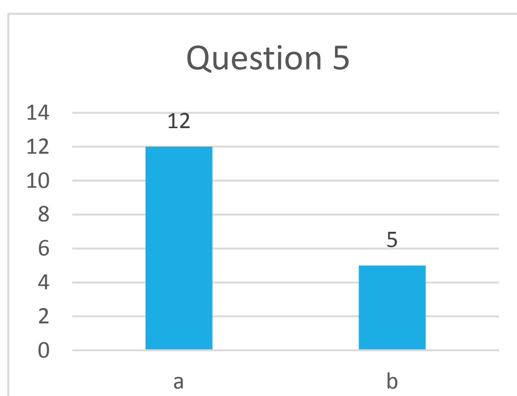
Floodproof & Elevate: 4. Do you think the County should pursue sources of funding to help private property owners flood-proof their properties located in the FEMA A zone, as a way to prevent storm surge damage?

4	a	**Yes**
	b	No



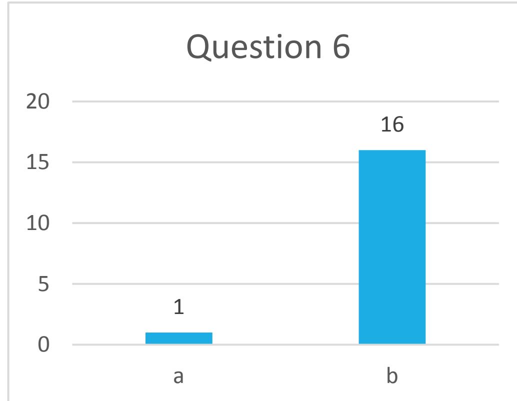
Floodproof & Elevate: 5. After looking at the model results, and participating in the group discussions of the three (3) actions modeled, do you like this one the best?

5	a	**Yes**
	b	No



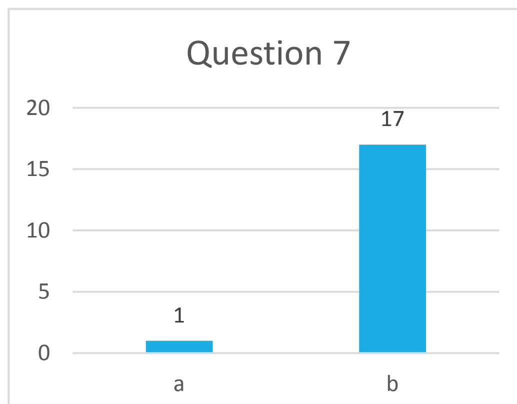
Construct Breakwater: 6. Given the results of the COAST model, do you think this action deserves further study by the County?

6	a	Yes
	b	**No**



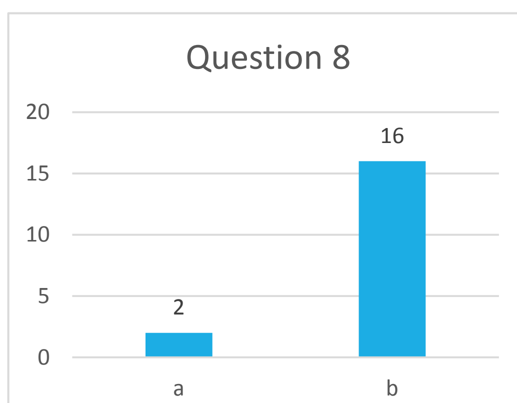
Construct Breakwater: 7. Given that there may be local, state and/or federal regulations constraining such breakwaters from being constructed in the areas shown, do you think the County should spend any effort to change laws or rules to facilitate such projects?

7	a	Yes
	b	**No**



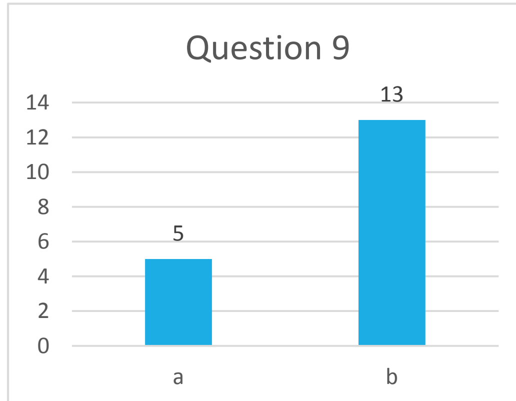
Construct Breakwater: 8. Do you think the County should pursue sources of funding to construct limestone/mangrove breakwaters to protect homes from storms?

8	a	Yes
	b	**No**



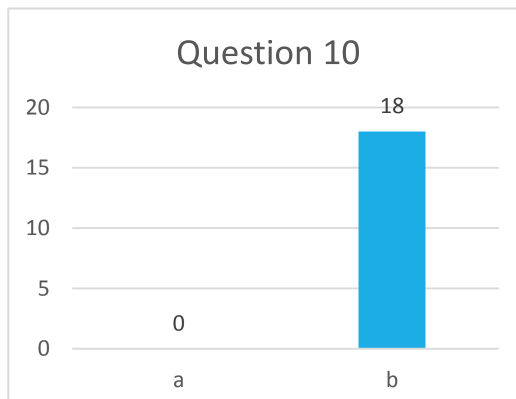
Construct Breakwater: 9. Do you think the County should pursue identification of resources at risk from storm damage for which breakwaters might have a favorable benefit-cost ratio?

9	a	Yes
	b	**No**



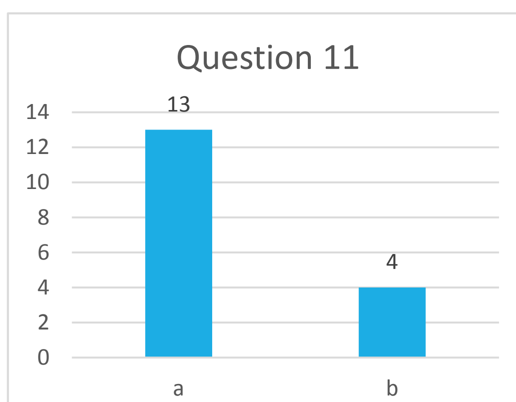
Construct Breakwater: 10. After looking at the model results, and participating in the group discussions of the three (3) actions modeled, do you like this one the best?

10	a	Yes
	b	**No**



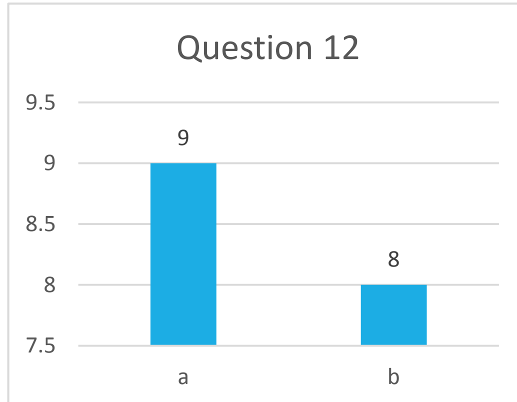
Relocate Over Time: 11. Given the results of the COAST model, do you think this action deserves further study by the County?

11	a	**Yes**
	b	No



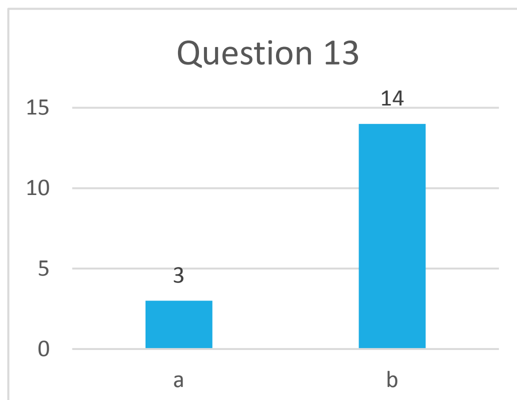
Relocate Over Time: 12. Do you think the County should pursue sources of funding to support a voluntary rolling easement purchase program, similar to what was modeled in this study?

12 a **Yes**
b No



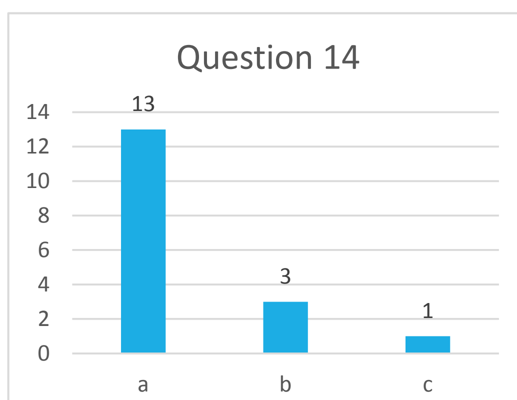
Relocate Over Time: 13. After looking at the model results, and participating in the group discussions of the three (3) actions modeled, do you like this one the best?

13 a Yes
b **No**



14. Should the County host this series of community workshops in the Middle and Lower Keys?

14 a Yes
b No
c Maybe



6.5 Community Presentation and Workshop Minutes

6.5.1 GreenKeys! Community Workshop #1 – October 9, 2014

Workshop started 5:41pm

1. **Rhonda Haag Introduction** started 5:43pm
    - Turned over to Erin Deady 5:44pm

2. **Erin Deady Overview** – started 5:44pm
    - brief introduction
    - attendee introductions
    - Greenkeys! project overview
    - Turned over to Jason Evans 5:52pm

3. **Jason Evans Presentation** – started 5:52pm
    - Audience member asked what the photos are on nuisance flooding slide– is that from Key Largo? She then questioned whether that nuisance flooding is really even happening in Key Largo or the Keys generally
        - Mayor addressed her and told her that there really is flooding occurring here and throughout Keys
        - Someone else questioned why just run the four models – unhappy that the Southeast Florida Regional Climate Change Compact (SEFRCC) data sets being used; lots of comments from audience questioning the validity of the data sets and why the blue line representing what has happened in the past 100 years is not part of a model run
        - Mayor Murphy defended by reiterating that this is the entire purpose of this process – to see what will happen and develop solutions beforehand to protect infrastructure
    - Jason Evans posed **Question 1**: Do the panelists or audience have any stories to share about the King Tides within the past 24 hours?
        - Audience answers – flooding seen on Drurry Road, Capel Road and other roads that frequently flood
        - Panelist Mayor Sylvia Murphy – indicated that she gets emails and calls about bad flooding areas routinely
            - Area of Shaw Drive – used to be mangroves, cut down/chopped and built over
        - Panelist Stephanie Scuderi – said Lower Matecumbe stretch that is covered with water; says variable elevations so very hard to say; says we could have started this process much sooner but good that we are doing now; recommends looking to Key West as model for what is to come here
            - Audience member argued that Key West should be taking care of their own problem – not the County; Stephanie Scuderi said we would be remiss not to consider what is going on in other parts of the Keys
        - Panelist Dr. Jerry Lorenz – said he hasn't gotten through all the data for this King Tides period; but can talk about what he has seen in his neighborhood – his HOA dock you had to wade through water to get to dock during King Tides; now happening with regularity; with development what will happen? – eliminated 50% of mangroves lost for construction or development – those will be the first places impacted by rising sea

levels; in his neighborhood natural slough from the 1940s which was just above sea level, now the slough has been filled in and he gets standing water on his street routinely

- Panelist Richard Barreto – said water higher in past than during this past week, sees in Harris Park nuisance floods a lot; says important to quantify as a percent how much of this area will be impacted in the Keys – how much will be impacted; says we need to be careful to not over exaggerate for all what some people will see as a result of a bad choice in purchasing property below sea level; then he wants to model the 9 inches that have been seen in the past 100 years – not the other levels because those are not proven; then asked what opening the Everglades – how will that impact water levels in the Keys?
- Audience Question – addressed Shaw Drive and says he lives in last house on Shaw Draw – private road and not part of County, road is 12-15" higher than the County road; area where the road goes up a foot has water in it regularly
- Audience Question – says he did the model for 9" and saw that it went from a pine forest to mangrove and buttonwood forest in 100 years; means change of entire landscape and way people live down here
- Audience Question – if there was a direct hit from Wilma, with salt intrusion, it isn't about the 9 inches that might come it is about the 2 inches that will happen with storms

- Jason Evans turned presentation over to JT Lockman at 6:28pm

4. **JT Presentation** began 6:28pm
   - Brief introduction and then posed second question
   - **Question 2:** Do you have the sense that people in Key Largo are interested in seeing their local, regional, and state governments initiate efforts to elevate or flood proof roads business and residences in the community?
     - Panelist Mayor Sylvia Murphy – thinks everyone with flooding in their areas are interested in seeing the roads elevated; $28 million committed in this County for road projects over the next 5 years, some of which is elevation and storm drainage; another reason to consider is that the cost of building and rebuilding is extremely expensive today – don't want to waste money on having these underwater in just a few years; also making arrangements for growth management with new flood maps coming out – allowing houses with higher elevations
       - Audience member asked if you have to raise 2 feet – Mayor Murphy said no that is just what the County is going to allow; audience member said she is confused because Miami-Dade County and Broward County are making their zoning requirements less stringent – Jason Evans said that the elevation data and flood maps are much better quality with LiDAR so there are more people moved into the X zone (making it seem less stringent but not a policy move, more the result of much better elevation data)
     - Panelist Stephanie Scuderi – has seen the momentum of the discussion coming from these types of workshops; gave example of coworker who told her to get her head out of the sand – she thinks all is very connected; gut reaction is to be personal about it but from a community perspective we are driven by tourism where tourists want to be right on the water – if that goes away, what will the impact to the industry/economy be – huge expenses; reiterates that this

economy is nothing without tourism; brought up rising flood insurance rates and the fact that even without sea level rise there will be major economic consequences.

- D.A. Aldridge (audience member) comment – in her neighborhood people are not interested in sea level rising; there are extremes – people either care about the issue a lot or totally don't care
  - Panelist Stephanie Scuderi commented that it isn't just about current generation; there are future generations that will be impacted by this

- Audience member questioned what COAST is, who created it, why should we trust it?
  - JT Lockman answered that his partner Dr. Merrill created it, unique product, proprietary – told woman he could talk to her offline about the product in greater detail if she so desired
- JT Lockman got back into the presentation 6:45pm
  - Audience Question – models are good but only as good as the data – what type of data was used – JT Lockman explained that elevation data is good to within 2-3 inches; audience member asked if the model would determine what percentage of land is impacted by 24 inch sea level rise? JT Lockman said that it could
  - Panelist Richard Barreto – does model assume that all buildings are created equal – wood vs concrete? JT Lockman explained that it does account for difference in construction – different tables for residential, commercial, elevated – not painting everything with the same brush – assigns different depth damage ratios to account for that
    - Another audience comment – government does a lot now; this area is an area of critical state concern so much land here cannot be filled – so can't pile more dirt on top of the area
  - Audience Question – asked if this modeling is the same as what property casualty insurance companies are doing? JT Lockman said yes but for a different reason, we are trying to find solutions for a community, not deny coverage to homeowners

- **Question 3:** After learning about the Piermont, NY community input process, are there any similarities and differences you see with regard to impacts and strategies the community developed? If so, what? If not, what do you suggest?
  - Panelist Dr. Jerry Lorenz – most striking difference is the substrate – we live on limestone that is porous, eliminates a lot of options on how we can solve the sea level rise problem - including barriers; similarities – Truman Annex in Key West is very similar so we can look at that area to see what will happen in Key Largo; a lot of dredge and fill areas here and will be very different than that in Piermont
  - Panelist Mayor Sylvia Murphy – asked if we are in touch with FIRM? Erin Deady says yes that all things are being factored with buildings; audience member asked - when we talk about Key West is it Keys wide or something else? Mayor Murphy responded that every city is doing separate things, different budgets, different goals; explained that Erin Deady was selected and is providing services for Monroe County and Islamorada but we can't look at them separately; in terms of impacts etc. Mayor Murphy says we need help, what to do and what we should be focusing on – but indicated that there are priorities

        - Audience Question – what is the flexibility of the model and can we add drivers to the model? Audience member commented that it is different here and not water moving up river, more storm surge and more storms will be happening here – JT Lockman answered that probability studies are not forward looking – they wait 15 years and run study to see what happened – his model is conservative, there is no way to make the storms closer together, speed them up – there is not that type of information available
- JT Lockman got back to presentation and what Piermont people wanted to do – 7:12pm
    - Panelist Richard Barreto asked does model take into account duration of flood water? – said here the water doesn't stay here, it goes from one side to the other – JT Lockman explained that Hudson River does act more like an ocean, flooding dissipates quickly there too, within a day
    - Audience comment - Maybe it makes more sense to say we have x number of dollars to spend on this? – then work within the budget – give people reassurance that this process won't become unaffordable
    - Audience comment – how much did all of this cost in Piermont? JT Lockman provided rough numbers and indicated that state grant partially funded project – audience member ranted that there is a $17 trillion dollar deficit and we need to stop the trend of environmentalists seeing the sky is the limit with all these unnecessary projects
        - Panelist Stephanie Scuderi commented by asking what is the risk, to model and price out potential damage and then come up with a solution – that's very low risk
        - Audience comment – is there anyone from the mortgage industry here? – what if houses in 2050 are worthless, doesn't need to look that far if they are already going to be worthless in 2020
            - Another audience member commented that she knows someone who can't sell their house because no one wants to buy it – no microphone so ultimate point unclear
        - Audience comment – how much money is spent on after storm repairs? spending upfront could be way less than after storm costs we are already seeing – wanted to see more data for storm costs to see how this upfront work compares with disaster funding that is inevitable

- **Question 4:** What unique characteristics about Key Largo should we take into account as a group when we develop adaptation actions in the next workshop?
    - Panelist Dr. Jerry Lorenz already said wall won't work because of porosity of land here in the Keys
    - Panelist Mayor Sylvia Murphy – wanted to answer two question first
        - How much has the county spent on storm damage? Recent two Category 2 and two Category 3 storms – FEMA foots most of the bill, County has slush fund just for that purpose, many millions because County has to pay upfront and FEMA reimburses
        - Why do this kind of program? Because when in a crowd on any subject, there are question about whey we aren't doing this or that, because we don't have the billions of dollars to do it all. Groups like this are great because we can see what we can afford and what is pie in the sky

        - Mayor then addressed porosity issue – said much on stilts, much on the ridge – doesn't know what we should do, wants feedback from the audience on that
    - Panelist Richard Barreto – was asked if they have discussed in HOA? Said no
        - Reality is if there is a major storm, there will be major damage
        - Florida Building Code requires certain fortification so he isn't concerned about his house, just his yard - more concerned about what are the critical functions and what will be absolutely critical – will those be up and running after big storm? – look at that rather than broad view of stopping water from running over the entire Keys
            - Mayor Murphy commented that sea level rise will sneak up on us – not be one dramatic event
            - D.A. Aldridge (audience member) comment – says unique characteristic is that we are the entry and exit to all the rest of the Keys, this must be considered when talking about adaptation actions
                - One County bridge and one state bridge – need to focus on the state bridge and ensure that it is available when needed
            - Panelist Stephanie Scuderi says also ties into the rebuild of this area – lot of fill that went into that – many elements went into the fill - there are unique infrastructure constraints here
            - Panelist Dr. Jerry Lorenz commented on 905 at Card Sound Road dispatch need to be elevated 5-6", better to build causeway but what can we afford here
            - Audience comment – Miami resident comes down here, unique characteristic is the tourism industry – if the houses that once were here are someday gone, tourists would not be as likely to come back if it looked so different from what they are accustomed to historically
                - Mayor Murphy seconded that and Erin Deady brought back to Panelist Stephanie Scuderi comment that waterfront is the most important thing
            - Panelist Richard Barreto – commented that underground utilities are needed here so that power doesn't go out so frequently after storms
            - Audience comment – don't focus on storm events, focus on the everyday impacts that are being seen now and what we need to do to maintain the current lifestyle
                - Mayor Murphy says political climate doesn't support sea level rise or climate change – Florida Department of Transportation (FDOT) doesn't either and they are the ones redoing the roads, they are at the mercy of the politicians in Tallahassee – crime that they are not even thinking about this
                - Audience comment – made point that even the most rural farmers in the Midwest believe in climate change
- Back to JT Lockman at 7:47pm for ingredients of the model

- Audience member questioned using the SEFRCC projected levels – and made point that the County is endorsing these levels and that endorsement will have significant impacts on property values
    - They want to see the nothing will happen blue line modeled too
    - Erin Deady brought it back to where the project data came from, the SEFRCC – they created the Unified Sea Level Rise projections which represent the scientific consensus on expected rise
    - D.A. Aldridge (audience member) comment – would rather look at what the scientist are telling her rather than looking at anything else
    - Panelist Richard Barreto – agreed with question poser – that we should use actual experience rather than scientific projections – wants blue line modeled too
    - Michael Blondin (audience member) comment – says stuff in Keys coming from different directions, flood decisions impacting them now – his rental property flood insurance rates just went up 25%; says we need to be cautious about throwing the 24 inch numbers out – we have insurance issues and flooding issue, we can't let the tail wag the dog; wants the sea level rise sessions but is very concerned about the messaging
    - Audience member comment – wants the historical model run, no reason to just include the other ranges
    - Audience member comment – look at historical data we have and base the future on that; doing otherwise would have extreme results on the Keys
        - Same audience members continued pressing for blue line model run
        - Panelist Richard Barreto also indicated he wants to use the blue line in the model
        - Erin Deady asked audience about what runs they want the model to run?
            - Audience again concerned about what the insurance industry is doing and what they can do with whatever our model results generate
            - Audience member questioned whether we can add a model run have it privately funded – Mayor Murphy says no, this is a County contract and no portion can be privately funded
            - Audience question – will the model run percentages of acreages of land that will be affected – JT Lockman says yes – audience member says that it is very important and we need to know
            - Audience question – says you need to take the historical perspective but also the opinions of cities
                - Are you reinventing the wheel? – there are Europeans that are building dams around cities, so they must be getting ready for sea level rise

        - Is there any way to figure what the Europeans are doing and see what the data they have say? Erin Deady and Jason Evans answered that the data being used as part of SEFRCC does incorporate European data (IPCC etc.)
      - Erin Deady asked for vote on what model runs people want used:
        - **Keep 3-7 inches and 9-24 inches – votes 17**
        - **Keep 7 and 24 inches and drop 3 inch number to blue line and 9 inches down to blue line – votes 10**
          - Suggestion on how to do better – audience member says use other countries data, other than SEFRR
            - FIU audience member said that SEFRCC data are conservative as compared to the international models – lower than the IPCC corrections – these are the downscaled models already – this is based on Europe and Netherlands and Holland –
          - Rhonda Haag comments – says she will see if we can do an additional model run to accommodate blue line
    - JT Lockman moved onto to the next model ingredient
      - Use assessed values or use a multiplier to reflect market value?
        - Audience member comment – doesn't matter what values are used because we don't know what will happen in future – all relative in the end
        - Audience member comment – says Monroe County uses market value and assessed value –
        - Audience member comments that we need to be conservative and use 15% add on - use market rate
        - Alicia Betancourt (audience member) says use the multiplier because will make a difference in CBA – need to get as close as possible to actual numbers
        - Panelist Richard Barreto – says use assessed value and convert later – JT Lockman says cannot do that because there is future discounting

- Michael Blondin (audience member) comment – used to run real estate values – never had properties sell for tax assessed value – can't use that, always market value – need to use fair market value and put 15% on there from the get go
- **Public Vote:**
  - **Assessed value – 0 votes**
  - **15% above that (more reflective of actual value) – all others in favor**

- JT Lockman moved to next ingredient 8:23pm – digital parcel data
  - When talking about projections:
    - Audience question - are you assuming that these surges are happening at low high tide? – JT Lockman answered that model starts at high tide?
    - Audience member corrected error in slide – 2030 vs. 2060 designations
  - When talking about tide gage data
    - Panelist Richard Barreto - Why using tide data from station 50 miles away? – JT Lockman answered that it the only one with Wilma stage numbers and mean higher high water (MHHW) data
  - FEMA flood data
  - LiDAR data
  - Any comments/issues with data as proposed?
    - D.A. Aldridge (audience member) question – is the entire island of Key Largo being considered or some other boundary? JT Lockman responded that he needed to review precise boundary for limits
      - Census would be MM94 north

- Audience polled - would people be willing to start next section earlier? –
  - People work and cannot get here until 5:30pm
  - Second person said 5:30pm is earliest
  - Audience member asked if the additional blue line was going to cost more – Rhonda Haag responded yes – audience member further commented that she doesn't want to pay any more money than what is already being spent

5. **Workshop ended** 8:38pm

6.5.2 GreenKeys! Community Workshop #2 – November 5, 2014

Workshop started at 5:37 P.M.

1. **Rhonda Haag Introduction** – started 5:37 P.M.
   - Discussed purpose of video camera in the room.
   - Greenkeys.info page has previous video and will post future videos
   - Turned over to Erin Deady 5:39 P.M.

2. **Erin Deady Overview** – started 5:39 P.M.
   - Welcome introductions and agenda
     - Review of Workshop 1 – what went into the model
     - Results from the no-action model
     - Discuss adaptation strategies
     - Decisions of what to do for modeling based on audience input
   - Project overview
   - Turned it over to J.T. Lockman 5:42 P.M.

3. **J.T. Lockman Presentation** – started 5:42 P.M.
   - Revisited the Coastal Adaptation to Sea Level Rise Tool (COAST)
     - One-damage from future events
     - Cumulative damage over time, from many different size storms
     - Parcels of land that are lost to sea level rise
   - Went over the inputs for modeling the "No-Action Scenario"
     - High and Low sea level rise estimates for the Four-County Compact
       - 3 and 7 inches by 2030; and 9 and 24 inches by 2060
     - Straight Line Extension of historic sea level rise from tide gauge for the last 100 years
       - 1.82 inches by 2030 and 4.53 inches by 2060
     - Surge heights for 10-, 50- and 100-year storms
     - Also factored "Nuisance Flood" at 1.08 feet and "Wilma-sized Flood" of 6 feet
     - Building values from tax assessors model (noting buildings which were already elevated and protected from storm surge and sea level rise)
     - LiDAR was used for topography
     - US Army Corps of Engineers depth damage functions for percentage of building damage from various flood heights
   - Went over "One Time Damages" from Nuisance Floods and a Wilma-Sized 6 foot surge arriving in 2030 and 2060.
   - Went over "No-action Scenario" cumulative building damages from storms:
     -

Timescale	SLR Scenario	Cumulative Damage to Buildings
2014-2030	Low – 1.82"	$575.7 million
2014-2030	Low – 3"	$583.3 million

2014-2030	High – 7”	$609.2 million
2031-2060	Low – 4.53”	$1.097 billion
2031-2060	Low – 9”	$1.195 billion
2031-2060	High – 24”	$1.521 billion
2014-2060	Low – 4.53”	$1.673 billion
2014-2060	Low – 9”	$1.778 billion
2014-2060	High – 24”	$2.130 billion

- Went over “No-action Scenario” buildings and land lost to sea level rise:

Timescale	SLR Scenario	Buildings and Land
2014-2030	Low – 1.82”	$48.1 million
2014-2030	Low – 3”	$131.2 million
2014-2030	High – 7”	$255.6 million
2031-2060	Low – 4.53”	$158.8 million
2031-2060	Low – 9”	$372.5 million
2031-2060	High – 24”	$450.0 million
2014-2060	Low – 4.53”	$206.9 million
2014-2060	Low – 9”	$503.8 million
2014-2060	High – 24”	$705.6 million

- Erin Deady asked for audience questions at 6:01 P.M.
  - Audience member asked about gross dollar damages – thought J.T. may have mentioned it but she couldn’t write as fast as J.T. was speaking. She wanted to know gross value of all properties
  - J.T. answered with $4.243 billion in buildings and land
  - Audience member asked if Army Corps of Engineers depth damage functions take into account Florida’s stringent building codes
  - J.T. answered yes because data was available which noted buildings that were elevated
  - Audience member asked for clarification on cumulative damage and assumptions about rebuilding
  - J.T. answered that assumptions were based on rebuilding if the parcel was not lost to sea level rise, but was damaged after a storm
- J.T. went over one-time storm damage visuals
  - Various locations around Key Largo
  - Examples of government buildings and property
- Went over the next steps for Workshop #2
- Erin Deady asked for audience questions at 6:22 P.M.
  - Audience member asked about taxable properties in unincorporated Monroe County
  - J.T. answered by describing the study area of Key Largo (Tavernier Creek to where Rt. 1 bends up towards the Everglades)
  - Mr. Caplain asked about how much Catalysis is charging the County

- Erin Deady answered approximately $30,000 – to do the workshops and data analysis, and adaptation strategy development
- Audience member asked if J.T. had data on sea levels that goes back further than 100 years
- J.T. answered with no
- Audience member asked why the study area included non-county owned properties (single family homes). She said those people should be buying flood insurance.
- Erin Deady answered by saying that looking at parcels will help to get a discussion going about solutions. Audience member replied by saying that is what flood insurance is for. J.T. said that communities are starting to take a look at solutions as an entire community.
- Audience member asked about damage dollars. Are they today's dollars?
- J.T. answered that the analysis is done in today's dollars because it can get confusing otherwise. The next workshop will be using future discounted dollars for comparing solutions.
- Mr. Moe mentioned that the population could decrease if issues arise. Asked if we can look at levels of population and assess the damage figures in population decreases or increases.
- J.T. answered that we could in the future, but for this purpose we assume things stay the same.
- Audience member asked about adaptation solutions and wanted to know where things were going.
- J.T. answered by telling the audience about the next steps for the workshop
- Audience member asked why we used increasing property prices if in the future areas will be flooded. Shouldn't the price then decrease?
- J.T. acknowledged this point, but said the group decided in the last workshop to use 15% increase in property values
- Sarah Bellmund asked if there's a written report on the model and calibration.
- J.T. answered – not yet, but there's information on the model on the Catalysis website. J.T. mentioned that Sam Merrill could explain the model and its calibration since he devised the software.
- Erin turned it over to Sam Merrill at 6:39 P.M.

4. **Sam Merrill Presentation** started at 6:39 P.M.
   - Background on adaptation options
     - Do nothing
     - Fortify
     - Accommodate
     - Relocate
   - Examples of adaptation actions – pros and cons
   - Sam turned it over to Chris Burgh to discuss natural barriers for the sake of this project at 6:58 P.M.

5. **Chris Bergh Presentation** started at 6:58 P.M.

- Discussed natural barriers in Florida Keys
  - Reefs
  - Mangroves
  - Beeches/dunes
  - Pine forests
  - Co-benefits (ecosystem)
  - Snook Island Living Shoreline example
- Should the barrier be submerging, at water level or emerging out of the water?
- Should the barrier be off-shore, near-shore or on-shore?
- Chris Burgh turns it over to Sam Merrill at 7:14 P.M.

6. **Sam Merrill Presentation** continues at 7:14 P.M.

- Went over candidate solutions
  - Solution 1: Elevate and Floodproof
  - Solution 2: Construct Breakwater (natural barriers)
  - Solution 3: Relocate Over Time
  - They are non-committal
- Erin Deady calls on Alisia to raise her issue at 7:24 P.M.
  - Alisia asked about needing electricity, fresh water, sewers and roads.
  - Erin responds by talking about the other aspects of the project, not related to the work of Catalysis: county assets, infrastructure, habitat, etc. that were presented to the county commission on September 3.
  - Sam responds by saying that the purpose of modeling is to start the conversation not determine a solution right away.
- Sam takes questions at 7:29 P.M.
  - Audience member asks why certain areas between red- and green-colored parcels are not colored. Are they higher elevation?
  - Sam responds by saying the parcels flooded are determined by the way in which water flows.
  - Audience member comments that many solutions wouldn't work in south Florida because it is made up of porous rock.
  - Sam acknowledges the audience member and sited an earlier part of the presentation where he stated the "sponge-like" issue of south Florida.
  - Audience member asks how qualified the public is to make these decisions. They may not be qualified to take a popularity questions about adaptation possibilities.
  - Sam responds by saying that you don't have to be an expert to answer these questions since Catalysis is providing the technical knowledge. The public is answering whether or not they think people will approve various adaptation proposals.
  - J.T. jumps in at 7:35 P.M. to say that the group wanted Catalysis to look at a different sea level rise scenario. J.T. wants people to feel like the study isn't something that been delivered to you, more that you've had a say in what aspects of the scenarios are modeled.
- Sam goes over polling questions

- Mentions the difference between positions and interests
- Mayor Sylvia Murphy – mentioned that people are hearing information they have never heard before. In the future, you will hear subjects come up that are dealing with these scenarios, which is why she wants people to remember what is being discussed with respect to this project.

7. **Erin Deady Ends Presentation** at 7:40 P.M and instructs audience to move to table stations for round table discussions.

8. **Roundtable discussions at Three Stations for Three Candidate Solutions** were held from 7:40 to 9:00 P.M.
   - Three discussion stations were set up in the Nelson Center Lobby.
   - The audience was divided into three groups, and each group rotated around the three discussion stations, spending about 25 minutes at each.
   - At each station each of the three candidate solutions was discussed thoroughly.

9. **Polling on Desired Modifications to Three Candidate Modeling Solutions** started at 9:05 P.M.
   - Electronic voting was attempted by keypad polling but technology failed
   - Participants voted with their paper ballots after pencils were distributed.
   - Voting ended approximately 9:15 P.M.
   - Sam Merrill announced and described voting results after they were tallied at approximately 9:25 P.M.
   - Participants were promised an email with the polling results as soon as possible.

10. **Workshop ended** at approximately 9:40 P.M.

6.5.3 GreenKeys! Community Workshop #3 – December 9, 2014

Workshop started at 5:36 P.M.

1. **Rhonda Haag Introduction** – started 5:36 P.M.
   - Welcome and introduction
   - Turned over it to Erin Deady 5:37 P.M.

2. **Erin Deady Introduction** – started at 5:37 P.M.
   - Agenda for meeting
   - Recap of previous workshops and GreenKeys! project
   - Turns it over to JT Lockman for COAST results and recap at 5:42 P.M.

3. **JT Lockman Introduction** – started at 5:42 P.M.
   - Reviewed COAST software tool
     - Specific sea level rise scenarios used in the model
     - Surge heights from FEMA Flood Insurance Study, astronomical high tides and the Hurricane Wilma flood
     - One-time and cumulative damage over time from many different sized storms
     - Parcels of land lost to sea level rise
   - Reviewed results from "No-Action Scenario"
     - Low (4.53") Sea Level Rise by 2060 – $1.673 billion in cumulative damage to buildings – $206.9 million and 717 parcels lost to sea level rise
     - Low County Compact (9") Sea Level Rise by 2060 – $1.778 billion in cumulative damages to buildings – $503.8 million and 1250 parcels lost to sea level rise
     - High (24"") Sea Level Rise by 2060 - $2.130 billion in cumulative damages to buildings – $705.6 million and 2344 parcels lost to sea level rise
   - Reviewed adaptation strategy models
     - Elevate and floodproof
     - Construct a limestone breakwater with mangroves
     - Voluntary relocation for payment
   - JT took questions at 5:49 P.M.
     - Audience member asked why damage went from $1.7 billion in one slide to $200 million in the next.
     - JT responded by saying the first slide showed the cumulative damages over time while the second slide showed the assessed value of buildings and land that would be lost to sea level rise alone
     - Audience member asked about the sea level rise assumptions since there hasn't been any global warming in 17 years
     - Jason Evans responded by saying that the blue line was a linear regression from the NOAA tide gauge
     - Audience asked whether the linear regression could differentiate between the ocean side and bay side
     - JT responded by saying the differences were negligible

- JT continued his presentation at 5:57 P.M.
    - Reviewed the specific inputs for adaptation scenarios
    - Jason Evans clarified that building a barrier ring around the keys would not prevent sea level rise because the limestone in the keys is porous and would still come up through the ground
    - JT reviewed the voluntary rolling easement process
    - Audience member asked who would pay for the rolling easements
    - JT responded by saying that the strategies were simply thought experiments and that the “who would pay” question hasn’t been answered yet, but that most likely the community would seek outside sources for funding assistance
    - Reviewed the specific polling results for adaptation models and the costs for each strategy (both low and high cost estimates)
        - Elevate and Floodproof - $72.5 million (low) and $152.5 million (high)
        - Construct Breakwater - $12.9 million (low) and $17.1 million (high)
        - Voluntary Relocation - $144.3 million (low) and $216.4 million (high)
- JT took questions at 6:11 P.M.
    - Audience member asked about houses collapsing under sea level rise
    - JT responded by saying that those homes floodproofed were in the A-Zone and those homes aren’t at risk from water velocity damage
    - Chris Burge also commented that those homes floodproofed would only get wet during storms, not sea level rise alone
    - Audience member asked about 3.3% discount rate whether that is a yearly interest rate
    - JT responded by saying that was correct
    - Audience member questioned the costs for elevation because homes in the Florida Keys are built on concrete slabs and are more costly to lift.
    - JT acknowledged the audience member and said there was a method for anyone to substitute their own assumptions for construction costs and get their own benefit-cost ratios
    - The same audience member also asked if construction costs included materials that builders might want to use instead of what is currently being used
    - JT said that those issues were not considered or modeled, but Erin Deady said that further analyses of that could be studied in the future
    - Audience member asked if the organization has spoken with other communities facing similar but more drastic issues, like: Holland, Venice or New Orleans.
    - JT responded by saying the last meeting included pictures of solutions those communities have used but that unfortunately the limestone ground in the keys makes many of those solutions ineffective.
- JT then went over the results of avoided damages for the three adaptation solutions and the benefit-cost ratios
        - Elevating and floodproofing had the best benefit-cost ratio
- JT took questions from the audience at 6:22 P.M.
    - Audience member asked if the benefit-cost ratios were based on discounted future dollars.

  - JT responded by saying that was correct
  - JT also showed how the benefit-cost ratios changed when the high cost estimates were used instead of the low cost estimates.
  - Audience member asked if the numbers being reported were damages from sea level rise and storm surge
  - JT responded by saying that was correct
  - The same audience member than asked if the damages included houses that were inundated from sea level rise
  - JT explained the two numbers that were presented earlier: those buildings that were damaged during storms, and those buildings that were permanently lost to sea level rise because daily high tides flood the parcels
- JT continued his presentation
  - Elevating and floodproofing came out the best
- Erin Deady opened the floor for discussion at 6:31 P.M
  - Audience member asked about house-boat community photographs she saw at the last meeting. What permitting would be needed to do that?
  - Erin Deady responded by saying that additional solutions could be raised in the final report as something for the County to look further in to studying
  - Audience member asked if the properties in the red zone would be gone by 2030.
  - JT responded by saying that the houses in the red zone were barely above high tide, and that adding even a foot of sea level rise would jeopardize the parcel.
  - The audience member then asked about bring in fill and making the ground higher
  - JT responded by saying that the porous nature of limestone underneath the ground might make adding fill not as effective of a solution
  - Audience member responded to the audience member that asked about house-boat communities by saying that Dade County doesn't allow those types of communities because the increase in shade over the water kills sea grass and other benthic organisms
  - Audience member asked about the consequence of people retreating after the first storm and not coming back to repopulate the area (the study isn't addressing this human behavior aspect)
  - JT responded by saying that the three workshops were really just a first step at the greater problem and that more study is needed to further develop the strategies and assumptions that go with them
  - Audience member than asked what the county would do with abandoned houses or houses that have stilts but you need a boat to get to them. The numbers are nice but what do they mean to us?
  - Audience member commented that New Orleans probably isn't the best case study to follow since many of the houses in the lower 9th ward have been abandoned and the city isn't doing anything with them
  - Audience member asked if habitat change was being looked into, so that when houses are abandoned nature has a way of taking those areas back
  - Erin Deady responded that habitat change is being modeled by Jason Evans and the county is looking at the changes internally

    - Mr. Roberts spoke at 6:43 P.M. and said that the county is looking into their land acquisition matrix and hope to bring to the county commission a new prioritization land acquisition program; not to pick the parcels they want to purchase, but for instances when someone wants to sell their land and if the county should consider purchasing it from the seller
    - Audience member asked Mr. Roberts to clarify if the county would buy land that was going to be inundated
    - Mr. Roberts said the board has not yet decided whether they would buy a parcel that is not usable. There are arguments for both sides of that debate, but there is not an official policy adopted yet.
    - Audience member commented that the figures presented thus far are for individual parcels and not the community infrastructure (sewer, water, roads) which he believes would increase the loses by twice as much
- Erin Deady ended the presentation at 6:46 P.M.

4. **Presentation concluded** – at 6:46 P.M.

5. **JT began the key pad polling** – at 7:51 P.M.
    - Given the results, do you think floodproofing and elevation should be further studied by the county?
        - 15 yes, 3 no
    - Do you think the county should mandate that after a house is destroyed by more than 50% from storm surge that it be replaced with a structure that is higher than the current code?
        - 13 yes, 5 no
    - Do you think the county should pursue sources of funding to help residents elevate homes that are in the V-Zone?
        - 11 yes, 7 no
    - Do you think the county should pursue sources of funding to help residents floodproof homes in the A-Zone?
        - 11 yes, 7 no
    - Of the three actions modeled, is elevating and floodproofing you favorite?
        - 12 yes, 5 no
    - Given the results, do you think constructing a breakwater should be further studied by the county?
        - 1 yes, 16 no
    - Given there might be (state and/or federal) regulations against building a breakwater do you think the county should spend resources to change those regulations to approve those projects?
        - 17 no
    - Do you think the county should spend money to build breakwaters with mangroves?
        - 16 no
    - Do you think the county should further study vulnerable areas for which a breakwater might help?
        - 13 no, 5 yes

- Given the results and group discussion, do you like this action the best?
  - 18 no
- Given the results, do you think the topic of rolling easements and voluntary buyouts should be further studied by the county?
  - 13 yes, 4 no
- Do you think the county should pursue sources of funding to support a voluntary buyout program similar to what was modeled in this study?
  - 9 yes, 8 no
- Given the results and group discussion, do you like this action best?
  - 3 yes, 14 no
- Do you think the lower keys would benefit from these workshops?
  - 13 yes

6. **Erin Deady opens up the floor for comments about the workshops** – at 8:07 P.M.
   - Audience member said she wanted the presentations to be available online
   - Audience member asked if having a breakwater onshore with mangroves would help with storm surge
     - Chris Burgh said that mangroves do help but they need a source of sediment to grow with sea level rise
   - Erin asked for feedback from the audience to improve results and communication of them
     - Audience member asked if a final report will be created in response to the meetings and presented to the county (recommendations)
     - Erin responded that the results are part of a larger project that is being created for the county
     - Audience member commented that she doesn't approve of adaptation programs that are paid for with tax dollars since the federal government is in debt
     - Audience member asked if height restrictions would be removed by the county if people have to raise the first floor of their houses
     - Erin responded by saying that they are also looking into giving more time to allow for more public comment; but that recently Key West approved a referendum that would allow people to exceed the height restrictions for each foot they raise their house above flood level
     - Audience member commented that the more engagements and presentations on the subject, the better.
     - Audience member suggested using Keys TV to promote and present information.

7. **Erin Deady ended the workshop** – at 8:21 P.M.

6.6 Analysis of Damages from Storm Surge and Sea Level Rise for Stock Island using the COastal Adaptation to Sea level rise Tool (COAST)

6.6.1 Executive Summary

Several months after completing work on the Key Largo geographic area, Catalysis was contracted by Erin L. Deady, P.A. to use COAST to perform a vulnerability assessment of homes and commercial building structures and to model one adaptation scenario within Stock Island, FL.

The "asset" selected for analysis was the value of residential and commercial buildings, obtained from Monroe County tax records. The methodology was essentially the same as that employed for the Key Largo geographic area. Sea Level Rise assumptions were based upon the Unified Sea Level Rise Projection for Southeast Florida[6]. Those projections included a low and high estimate of sea level rise in 2030 of 3" and 7" respectively, as well as a low and high estimate of sea level rise in 2060 of 9" and 24" respectively. As requested by Erin L. Deady, P.A. Catalysis also analyzed a lower sea level rise projection based on the historic rate of sea level rise monitored at the Key West tide gauge and projected in a linear relationship with time. This "tide gauge" trend was reported as having a rise of 2" by 2030 and 4" by 2060. Surge values from various sized storms were obtained from the most recent FEMA Flood Insurance Study.

Key damage estimates from the vulnerability assessment for different sized one-time storm events occurring in the year 2060, with sea level impacts added, ranged from $1.1 Million from a nuisance flood on top of 4 inches of sea level rise (tide gauge trend), to $83.8 Million from a Hurricane Wilma-size flood on top of 24 inches of sea level rise (high scenario). Estimates of cumulative damages over time from the combined impacts of storms of various sizes between today and 2060, ranged from $243.4 Million with 24 inches of sea level rise (high scenario) to $302.4 Million in damages with 4" of sea level rise (tide gauge trend). The model predicted lower cumulative damages by 2060 with a higher, faster sea level rise scenario, because under such conditions, many properties would be completely and permanently flooded by that time, and therefore not subject to storm damage from events occurring several decades from now. 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. Estimates of the value of properties (buildings and land) permanently inundated by sea level rise alone by 2060 (from daily flooding at high tide) ranged from $287.4 Million (tide gauge trend – 4") to $582.5 Million (high scenario – 24").

The potential adaptation action modeled was to elevate and floodproof all structures that were currently not elevated or floodproofed. Costs were determined by the Project Team and incorporated low and high estimates. Building elevation heights used the same modeling parameters as those used in the geographic region of Key Largo. Catalysis then used the COAST model again with these potential adaptation actions in place to quantify the predicted reduction in damages over the same time period as the vulnerability assessment.

These results were converted into benefit-cost ratios. Ratios greater than 1 represented actions that reduced more in damages in the future than it cost to implement them. Ratios less than 1 represented

[6] Southeast Florida Regional Climate Change Compact Counties, Sea Level Rise Ad Hoc Technical Working Group (April 2011).

actions that would cost more than the amount of reduced damages in the future (i.e., not cost effective). Elevating and floodproofing buildings (that were not already elevated or floodproofed) resulted in benefit-cost ratios that ranged from 5.42 (high cost estimate elevating and floodproofing buildings and high sea level rise scenario) to 14.25 (low cost estimate for elevating and floodproofing buildings and low sea level rise scenario). All scenarios were thus considered cost effective, regardless of the costs and sea level rise scenario used in the model. However, these results do not mean that the County should begin implementing a program to elevate and floodproof residential and commercial buildings. Catalysis recommends that the County use this information to:

- Further discuss sea level rise vulnerability with County residents and the importance of having a method to weigh different adaptation actions against one another (benefit-cost analysis)
- Develop a framework for using new knowledge to engage with residents so that consensus on an eventual adaptation action is data- and stakeholder-driven
- Share this information with neighboring communities so that more regional communication can take place and strengthen any local momentum towards adaptation
- Document any progress or failures towards adaptation so that other communities around the country have lessons from which they can learn

6.6.2 Methodology and Assumptions used for COAST Model Analysis

The methods used for analysis in Stock Island were the same as those used in the geographic region of Key Largo. The only difference was that the height of the linear tide gauge trend in Stock Island was 2” by 2030 (not 1.82”) and 4” by 2060 (not 4.53”), because of its position in the Lower Keys.

6.6.3 Vulnerability Assessment

One-time flood damage estimates for Stock Island were generated for a “nuisance flood” or “king tide” arriving in the years 2030 or 2060 as if no adaptation action had been taken. A nuisance flood or king tide is defined as the highest tide of the year which occurs when the moon is full and is at perigee (the closest distance to the earth in its orbital path). One-time damage estimates were also generated for a Hurricane Wilma-sized storm surge (6 feet in 2005), made worse over time by sea level rise. COAST created visualizations of the pattern of these predicted damages (Figures 1-4). Parcels in coral represent those flooded from storm surge, with the height of each coral bar showing relative dollar damage. Parcels in green represent those permanently inundated from sea level rise. All images for all major sections of Stock Island are located in the last appendix section (6.6.7). Cumulative building damage over time was also calculated, through the years 2030 and 2060. Results are summarized in tables below.

Key Findings of Vulnerability Assessment – If no action is taken

- By 2030 a nuisance flood would cause $2.2 Million in damages to buildings even if the rate of sea level rise stayed constant from the past 100 years (linear tide gauge trend, Table 1).
- By 2060 a nuisance flood would cause $700,000 in damages to buildings under a high (24”) sea level rise scenario (Table 1).
- By 2030 a Wilma-sized flood would cause $77.5 Million in damages to buildings under a low (3”) sea level rise scenario (Table 2).
- By 2060 a Wilma-sized flood would cause $83.8 Million in damages to buildings under a high (24”) sea level rise scenario (Table 2).
- By 2060, cumulative damages from all possible storms (Table 3) would result in damages ranging from $243.3 Million (high scenario) to $302.14 Million (tide gauge trend scenario).
- By 2060, the total value of all buildings and land that are no longer inhabitable as a result of sea level rise (Table 5) would be between $187.4 Million (linear tide gauge trend) and $582.5 Million (high sea level rise scenario).
- This represents a loss of 27.5% to 55.7% in the taxable assessed value of Stock Island.

Table 1. One-time damage estimates from nuisance floods in Stock Island in 2030 and 2060 with high, low and linear tide gauge trend sea level rise.

Event: 1.08 ft. Surge Nuisance Flood	SLR Scenario *Linear Tide Gauge Trend **Four County Compact Sea Level Rise Projections	One-Time Damage to Building Values
Year 2030	*Tide - 2.00"	$ 2.2 Million
Year 2030	**Low - 3.00"	$ 1.1 Million
Year 2030	**High - 7.00"	$ 0.02 Million
Year 2060	*Tide - 4.00"	$ 1.1 Million
Year 2060	**Low - 9.00"	$ 0.1 Million
Year 2060	**High - 24.00"	$ 0.7 Million

Table 3. One-time damage estimates from Hurricane Wilma-size floods in Stock Island in 2030 and 2060 with high, low and linear tide gauge trend sea level rise.

Event: 6.00 ft. Surge Wilma-Size Flood	SLR Scenario *Linear Tide Gauge Trend **Four County Compact Sea Level Rise Projections	One-Time Damage to Building Values
Year 2030	*Tide - 2.00"	$ 82.0 Million
Year 2030	**Low - 3.00"	$ 77.5 Million
Year 2030	**High - 7.00"	$ 75.0 Million
Year 2060	*Tide - 4.00"	$ 77.7 Million
Year 2060	**Low - 9.00"	$ 80.8 Million
Year 2060	**High - 24.00"	$ 83.8 Million

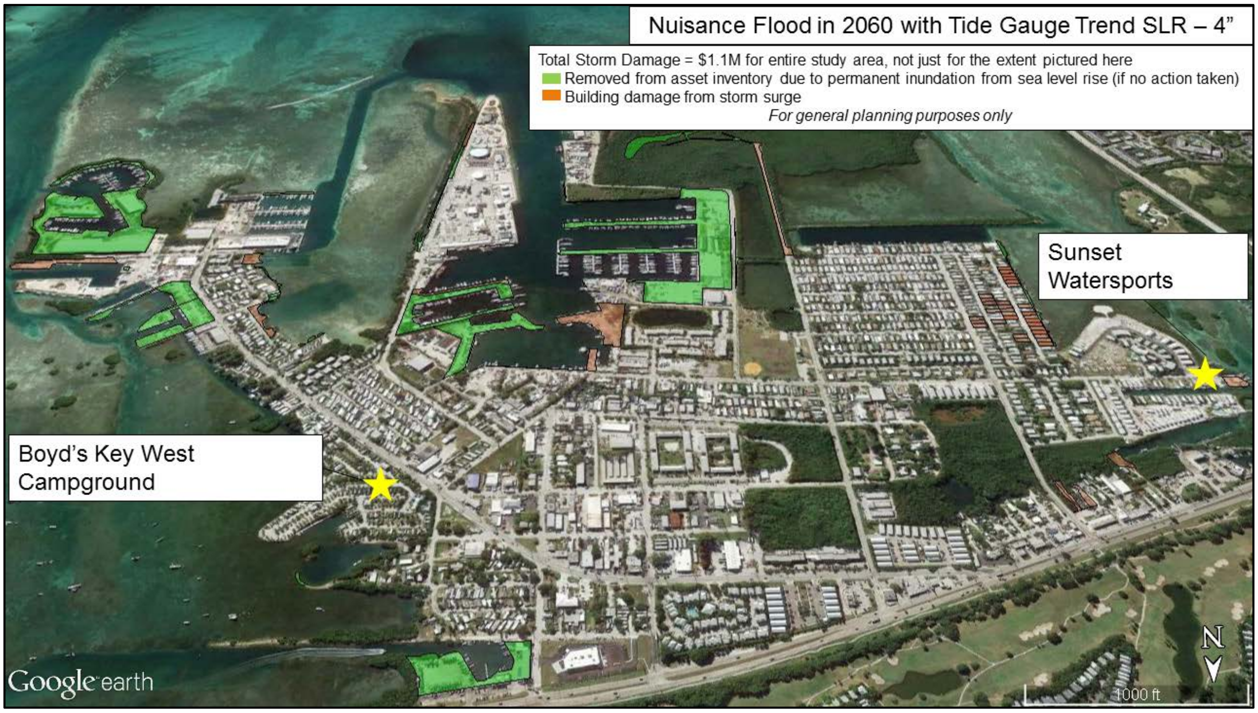


Figure 1. Google Earth image of potential flooding damages from a nuisance flood (linear tide gauge trend) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts. Parcels in green indicate those permanently inundated from sea level rise.

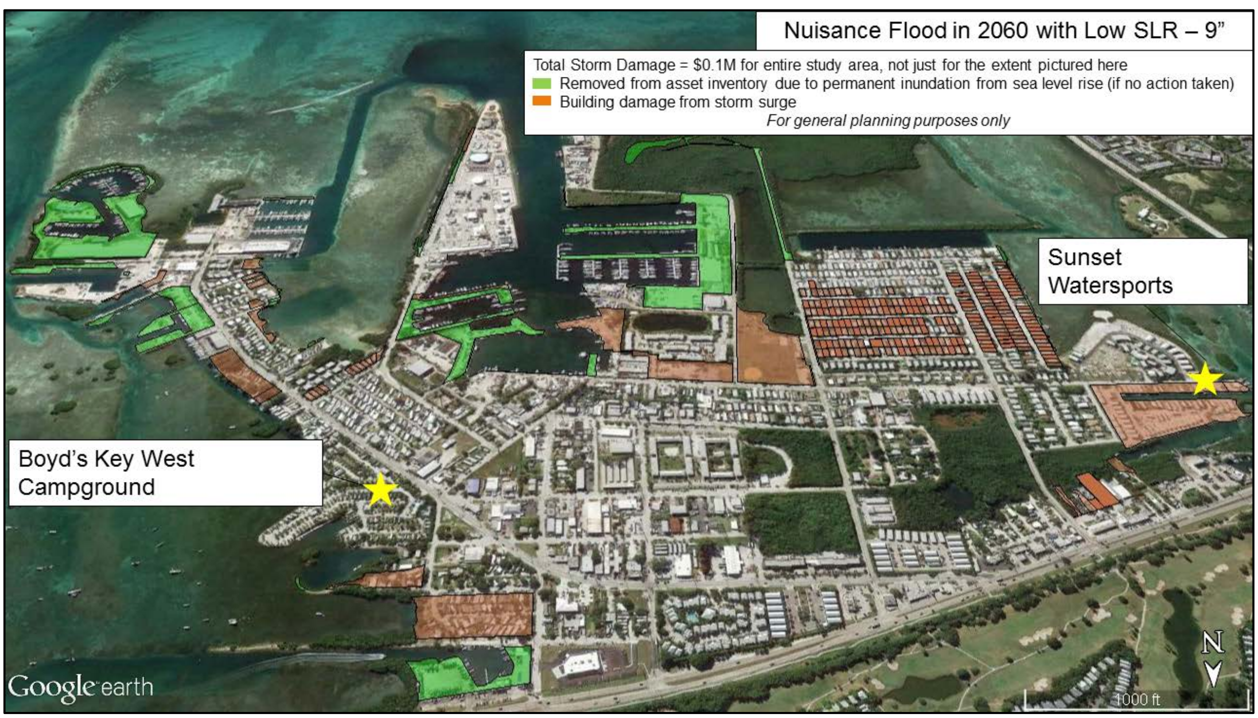


Figure 2. Google Earth image of potential flooding damages from a nuisance flood (low sea level rise scenario) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts.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

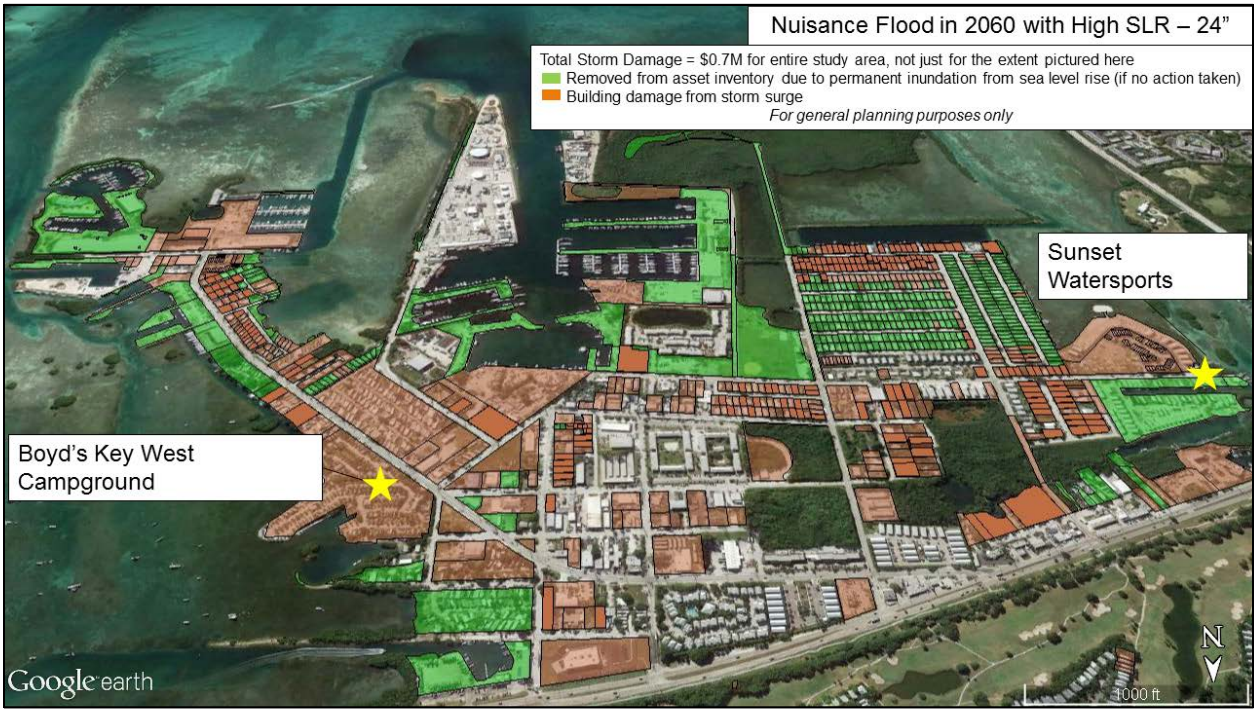


Figure 3. Google Earth image of potential flooding damages from a nuisance flood (high sea level rise scenario) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts. Parcels in green indicate those permanently inundated from sea level rise.

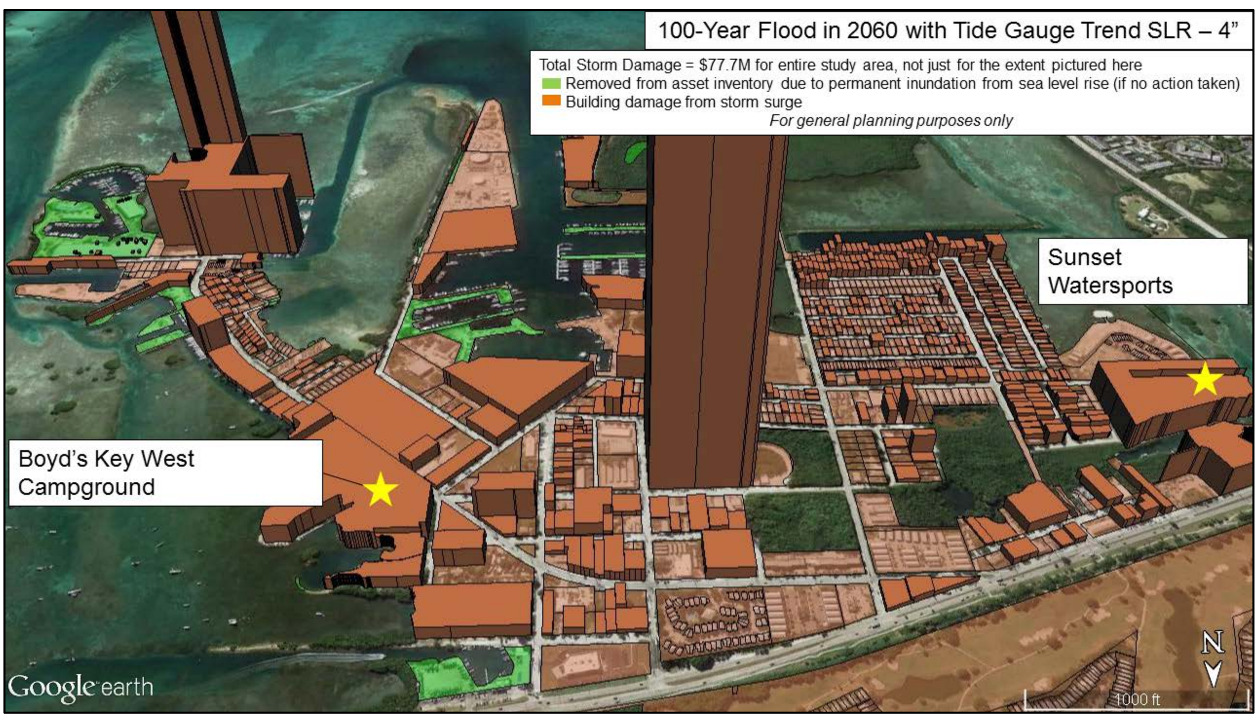


Figure 4. Google Earth image of potential flooding damages from a Hurricane Wilma-size flood (linear tide gauge trend) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts. Parcels in green indicate those permanently inundated from sea level rise.

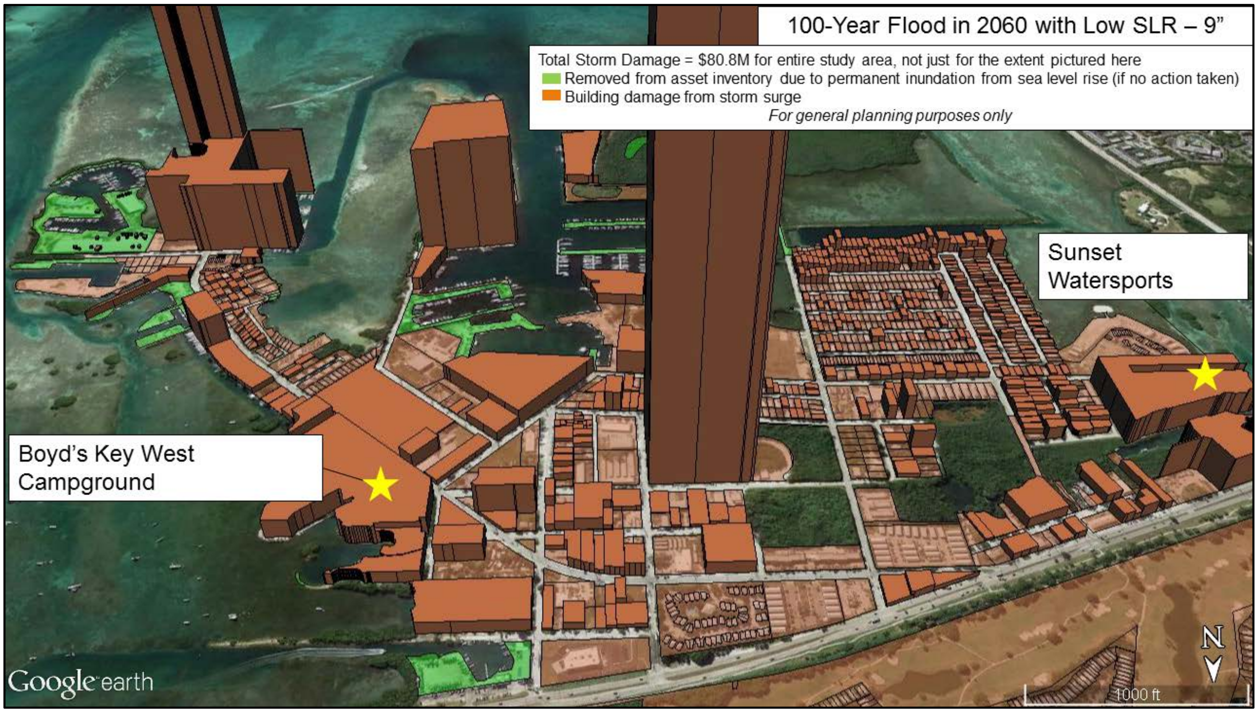


Figure 5. Google Earth image of potential flooding damages from a Hurricane Wilma-size flood (low sea level rise scenario) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage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

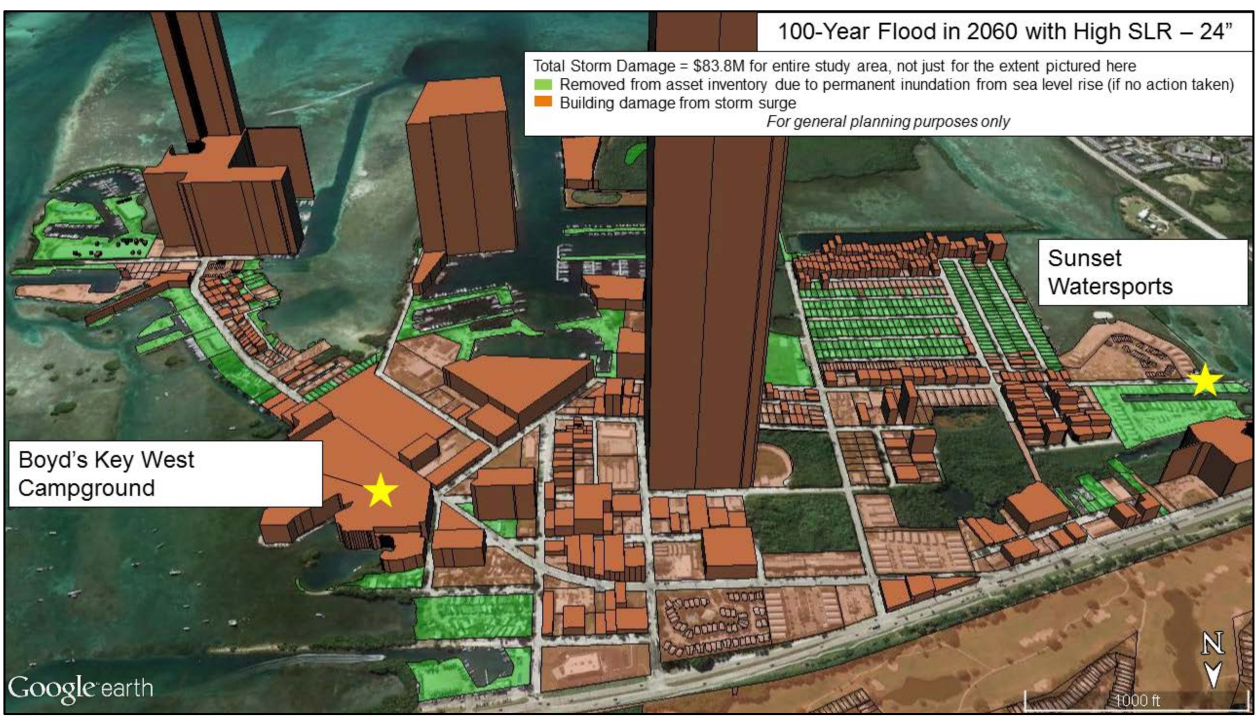


Figure 6. Google Earth image of potential flooding damages from a Hurricane Wilma-size flood (high sea level rise scenario) in 2060 for a section of Stock Island, Monroe County, FL. Coral parcels indicate those flooded from storm surge, with the height of the coral extrusions representing relative damage amounts. Parcels in green indicate those permanently inundated from sea level rise.

Timescale	SLR Scenario *Linear Tide Gauge Trend **Four County Compact Sea Level Rise Projections	Cumulative Damage to Buildings by Scenario Date
2015-2030	*Tide - 2.00"	$ 152.6 Million
2015-2030	**Low - 3.00"	$ 144.0 Million
2015-2030	**High - 7.00"	$ 113.2 Million
2031-2060	*Tide - 4.00"	$ 149.8 Million
2031-2060	**Low - 9.00"	$ 103.6 Million
2031-2060	**High - 24.00"	$ 130.2 Million
2015-2060	*Tide - 4.00"	$ 302.4 Million
2015-2060	**Low - 9.00"	$ 247.6 Million
2015-2060	**High - 24.00"	$ 243.4 Million

Table 4. Cumulative damage estimates from all possible storms during a given time period with high, low and linear tide gauge trend sea level rise.

SLR Scenario *Linear Tide Gauge Trend **Four County Compact Sea Level Rise Projections	Value of Buildings Lost to SLR	Value of Land Lost to SLR	No. of Parcels Lost to SLR	Total Value of Builds and Land Lost to SLR	Percent of Total Taxable Assessed Value
*Tide - 4.00"	$ 119.3 Million	$ 168.1 Million	53	$ 287.4 Million	27.5%
**Low - 9.00"	$ 131.7 Million	$ 246.6 Million	68	$ 378.3 Million	36.2%
**High - 24.00"	$ 176.8 Million	$ 405.7 Million	452	$ 582.5 Million	55.7%

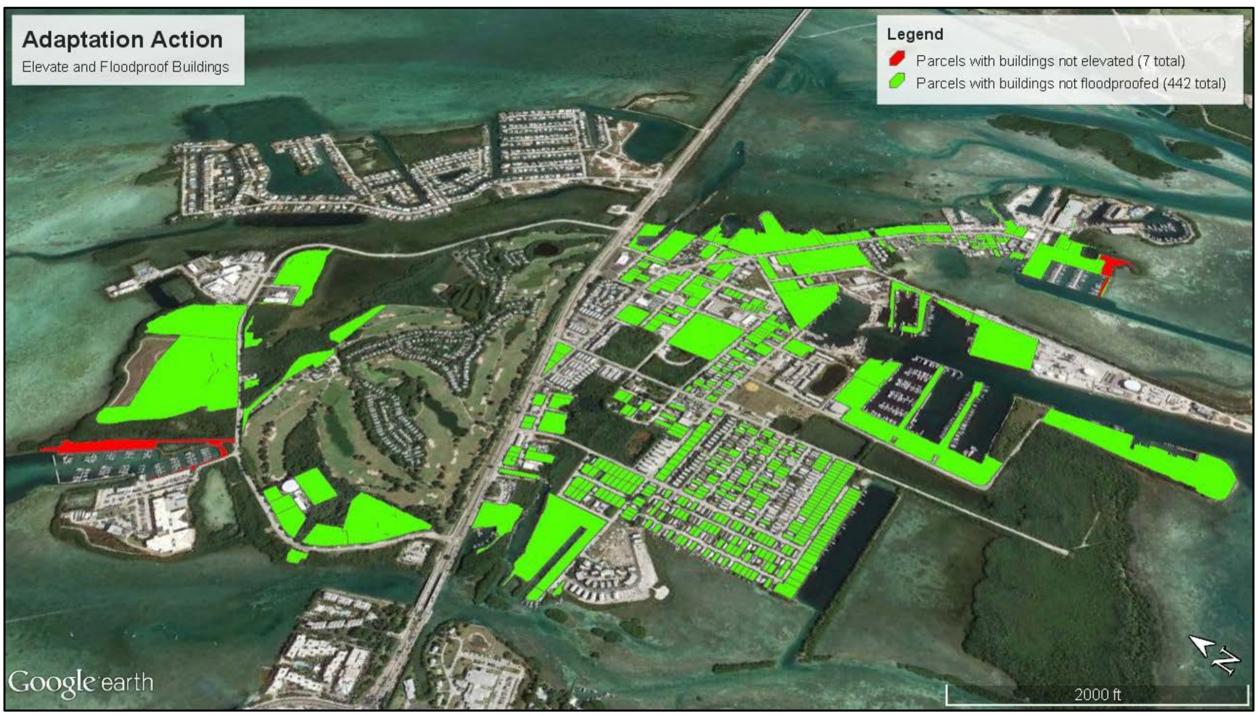
Table 5. Buildings and land permanently inundated from sea level rise during scenario years 2015-2060 with high, low and linear tide gauge trend sea level rise.

6.6.4 Description of Proposed Adaptation Strategy Scenario

The Elevate and Floodproof strategy included elevating all buildings not currently elevated in the FEMA-designated V-Zones and floodproofing all buildings not currently floodproofed in the FEMA-designated A-Zones. It was determined that seven (7) properties had buildings that were not elevated and four hundred forty-two (442) properties had buildings that were not floodproofed. Those buildings being modeled as elevated were raised to the current code plus three (3) feet and buildings that were floodproofed remained undamaged until a height of eight (8) feet.

Elevate and Floodproof (Fig. 7)

- 100% of properties in FEMA V-Zones elevated to current code plus three (3) feet
- 100% of properties in FEMA A-Zones floodproofed to eight (8) feet



Figures 7. Elevate and Floodproof Scenario: Images of Stock Island area. Parcels in red indicate those that are located in a FEMA V-Zone and had their buildings elevated (7 total). Parcels in green indicate those that are located in a FEMA A-Zone and had their buildings floodproofed (442 total).

6.6.5 Results for Modeling the Elevate and Floodproof Adaptation Action

Table 6 below shows the results for the Elevate and Floodproof Adaptation Action. Avoided damages by the year 2060 ranged from $149.6 Million (high sea level rise) to $193.8 Million (linear tide gauge trend sea level rise). Estimated costs to elevate a building ranged from $60,000 to $160,000[7], and costs to floodproof a building ranged from $29,920 to $59,841[8] respectively. Complete pricing information is available in Section 6.6.8. Avoided damage estimates by the year 2060 for three sea level rise scenarios (high, low and a linear tide gauge trend), and with both high and low cost estimates, resulted in six (6) benefit-cost ratios. These ranged from 5.42 (high sea level rise with high cost estimates) to 14.25 (linear tide gauge trend sea level rise with low cost estimates). These ratios represent long-term savings in the form of damage reduction for every dollar spent today. For example, under the best benefit-cost ratio, for every $1 spent today to elevate and floodproof buildings, $14.25 would be saved by 2060.

Table 6 - Elevate and Floodproof Buildings		
Avoided Damages Tide Gauge Trend – (4.00")	**Avoided Damages Low SLR – (9.00")**	**Avoided Damages High SLR – (24.00")**
($ Millions)	($ Millions)	($ Millions)
193.8	169.1	149.6
Low Cost Estimate	**High Cost Estimate**	
$13.6 Million - Total	$27.6 Million - Total	
Avg. Price Per Unit - Elevation	Avg. Price Per Unit - Elevation	
$60,000	$160,000	
Avg. Price Per Unit - Floodproofing	Avg. Price Per Unit - Floodproofing	
$29,920	$59,841	
Benefit/Cost Ratios - Using Low Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
14.25	12.43	11.00
Benefit/Cost Ratios - Using High Cost Estimate		
Tide Gauge Trend	Low SLR	High SLR
7.02	6.13	5.42

Table 6. Results from COAST model of Adaptation Action: Elevate and Floodproof buildings. 100% of buildings in FEMA V-Zones were elevated and 100% of buildings in FEMA A-Zones were floodproofed.

[7] Estimated elevation cost ranges were provided by local engineers.

[8] Estimated floodproofing cost ranges were calculated by taking 10% (low) and 20% (high) of the building values and dividing by the number of buildings to be floodproofed. The high and low percentages (10% and 20%) were provided by local engineers.

6.6.6 Discussion and Conclusions

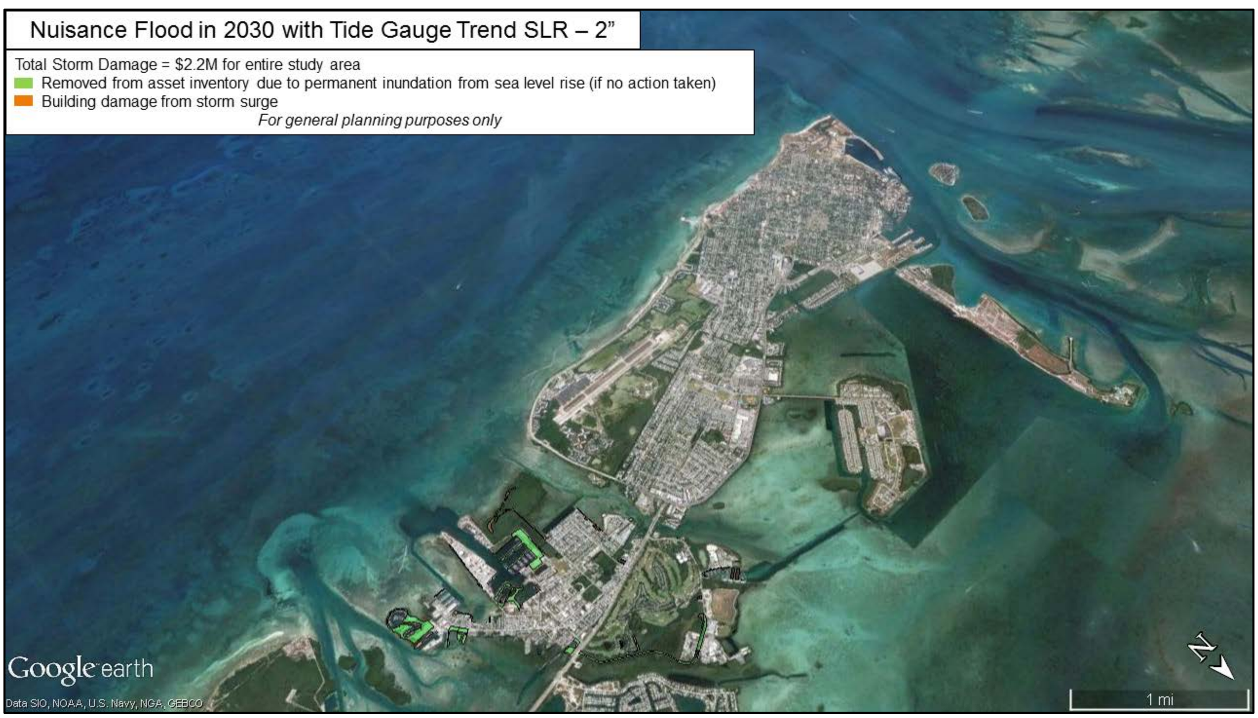
It may seem counter-intuitive that elevating and floodproofing buildings had less of an impact in a high sea level rise scenario than in a low or tide gauge trend sea level rise scenario. The main reason there was more damage (and thus more avoided damages) under a smaller sea level rise scenario is that Stock Island is a very low lying, and flat area. Under a high sea level rise scenario more buildings were being lost to sea level rise than in the smaller sea level rise scenarios, and as a result, those buildings were no longer damaged during the modeling period from storm surge. The high sea level rise scenario permanently flooded so many buildings that there were few buildings for which elevating and floodproofing could have a positive impact. In addition, elevating and floodproofing is not an adaptation used for addressing sea level rise – only storm surge. In other words, the same number of buildings are permanently inundated from sea level rise in both the no-action and elevate and floodproof scenarios.

While this adaptation action might not seem like a good solution to address both storm surge and sea level rise, elevating and floodproofing did have benefit-cost ratios that were all financially efficient. This means that this action is actually a good investment despite the fact that it doesn't protect against sea level rise. There have been many cases around the world, such as in Australia and the United States where large storm surge events (stemming from hurricanes) damage a community to the point where people decide to move away rather than rebuild. In these situations the communities not only experience the initial shock of the storm event itself, but are quickly shocked again when residents leave and take with them their portion of tax revenue on which those communities rely.

The situation described above can happen when communities aren't prepared for the risks of large storm surge events, and elevating and floodproofing buildings is one way to address those risks. However, decision-makers also need to be conscious of the fact that sometimes certain adaptation strategies can have the same effect. For example, if a voluntary buyout program is implemented which incentivizes many people to leave without a process for addressing lost tax revenue, those that don't have the ability to move (perhaps due to personal financial or health reasons) may experience the shock of a dissolved community and fewer social services.

Adapting to both storm surges and sea level rise is a complicated problem, and no one solution is the best solution everywhere. Communities need to understand both their short- and long-term risks, develop and test many different strategies to address those risks while being conscious about unintended consequences. The best approach for achieving these goals is to engage with residents so that consensus on an eventual adaptation action is both data- and stakeholder-driven.

6.6.7 Maps of Potential One-time Flooding in Stock Island, FL



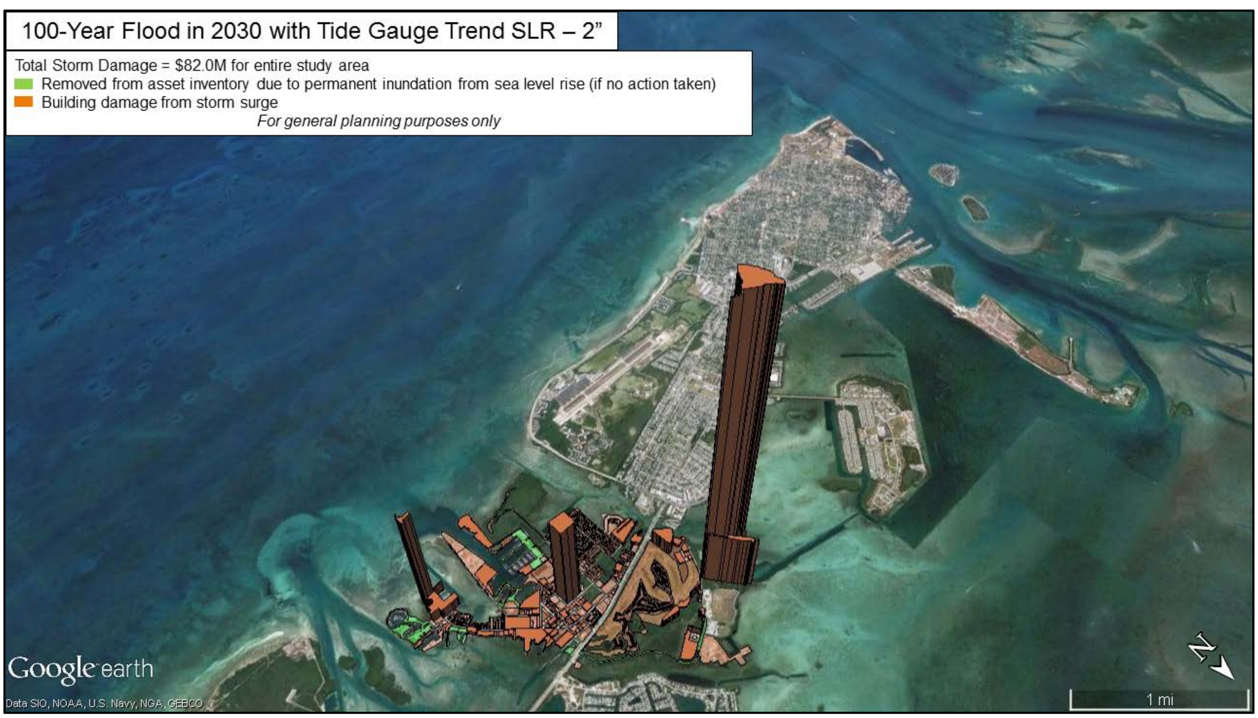

Nuisance Flood in 2030 with Low SLR – 3”
Total Storm Damage = $1.1M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi


Nuisance Flood in 2030 with High SLR – 7”
Total Storm Damage = $0.02M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi


Nuisance Flood in 2060 with Tide Gauge Trend SLR – 4"
Total Storm Damage = $1.1M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi


Nuisance Flood in 2060 with Low SLR – 9"
Total Storm Damage = $0.1M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi

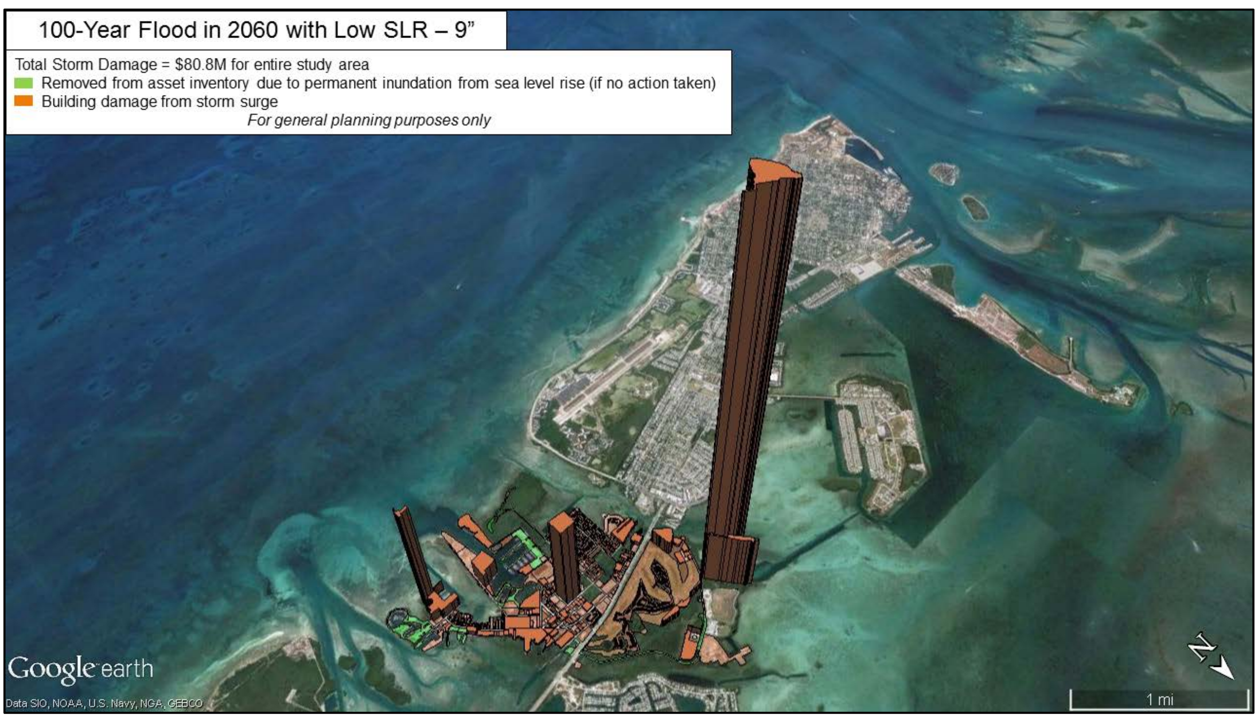

Nuisance Flood in 2060 with High SLR – 24”
Total Storm Damage = $0.7M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
1 mi


100-Year Flood in 2030 with Tide Gauge Trend SLR – 2”
Total Storm Damage = $82.0M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
1 mi

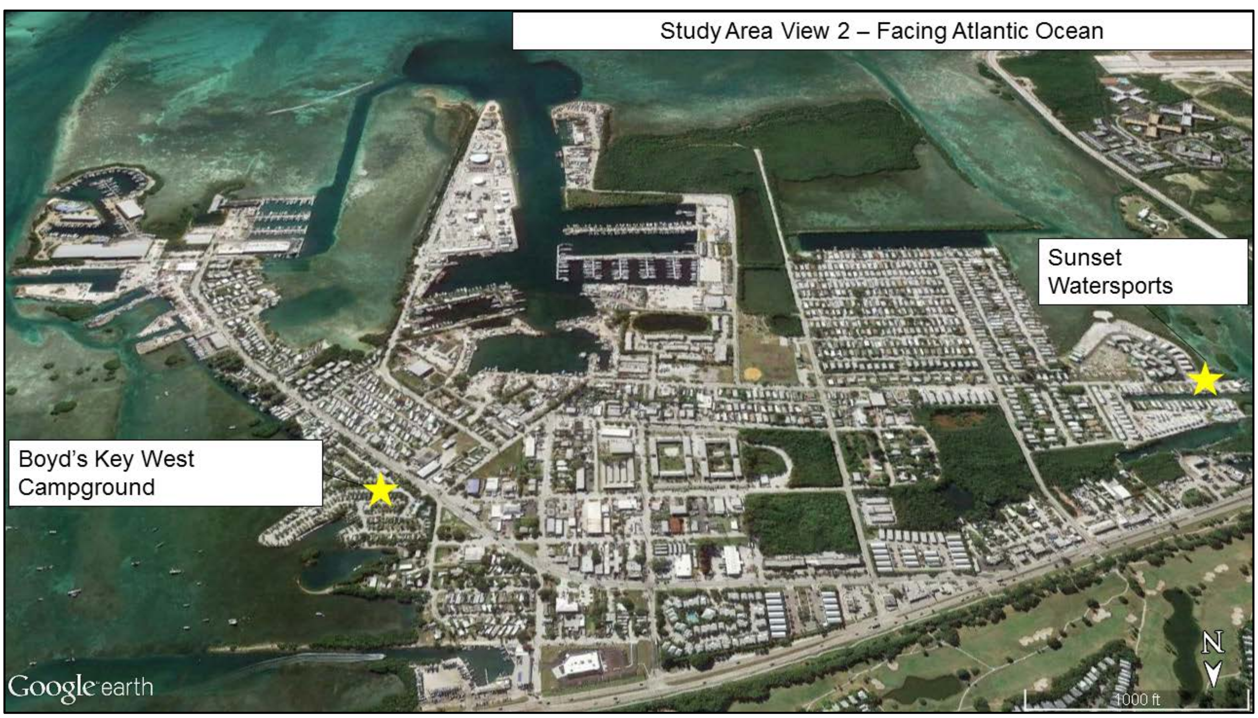

100-Year Flood in 2030 with Low SLR – 3”
Total Storm Damage = $77.5M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
1 mi

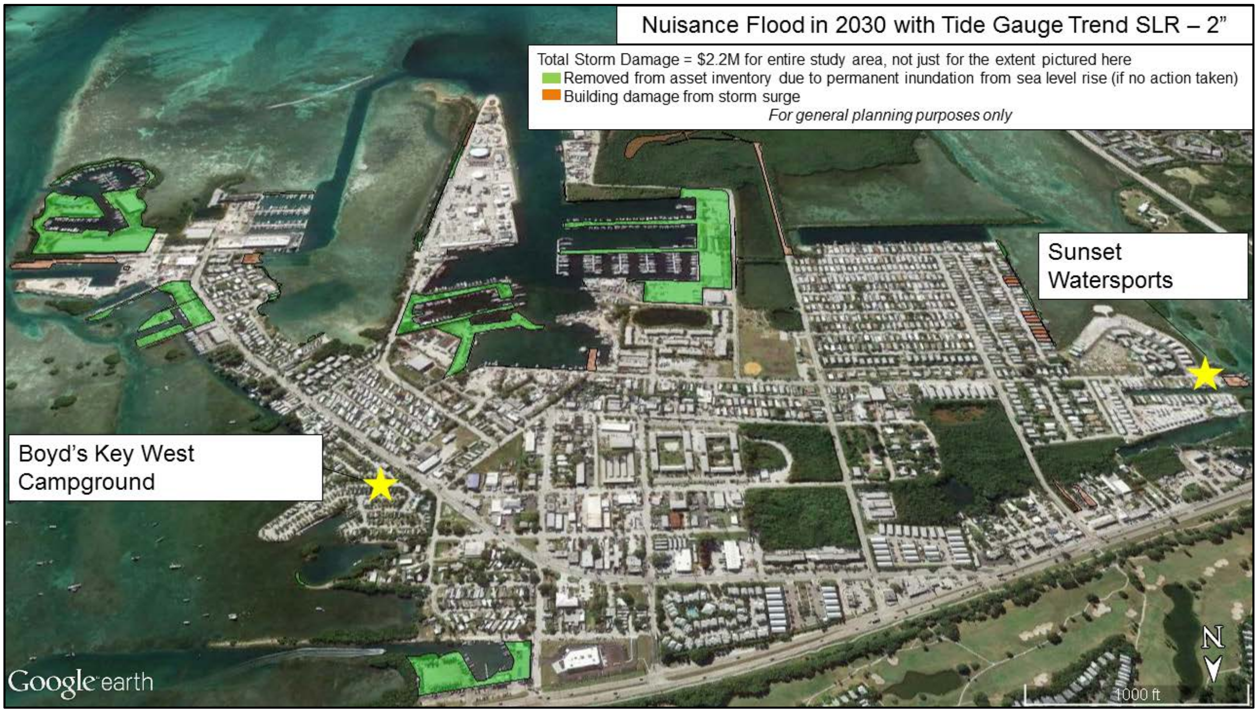

100-Year Flood in 2030 with High SLR – 7”
Total Storm Damage = $75.0M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
1 mi

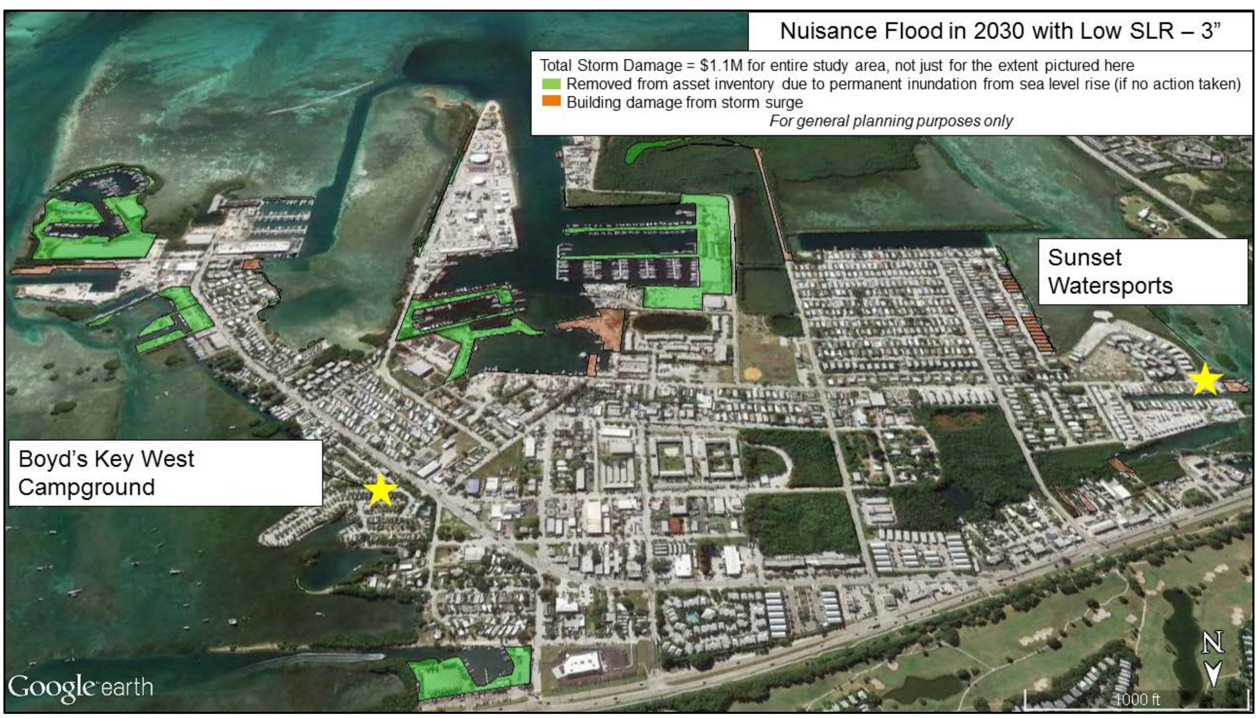

100-Year Flood in 2060 with Tide Gauge Trend SLR – 4”
Total Storm Damage = $77.7M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi

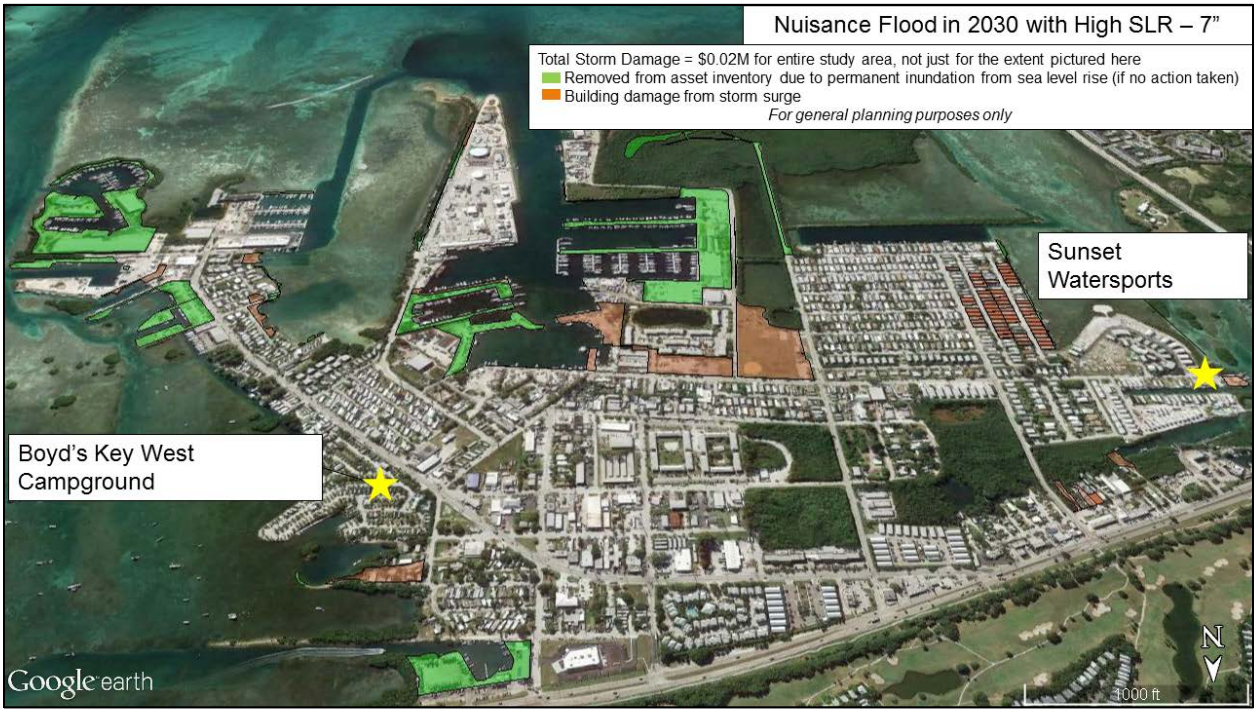

100-Year Flood in 2060 with Low SLR – 9”
Total Storm Damage = $80.8M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
1 mi

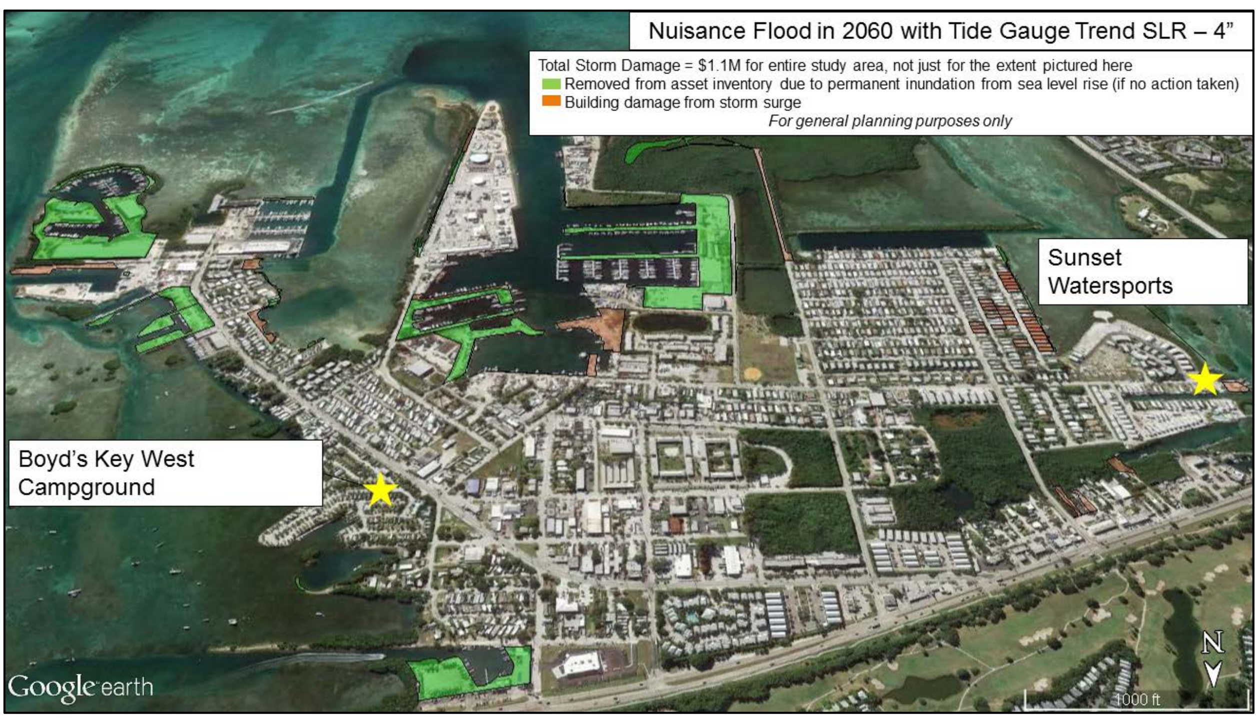

100-Year Flood in 2060 with High SLR – 24”
Total Storm Damage = $83.8M for entire study area
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Google earth
N
1 mi

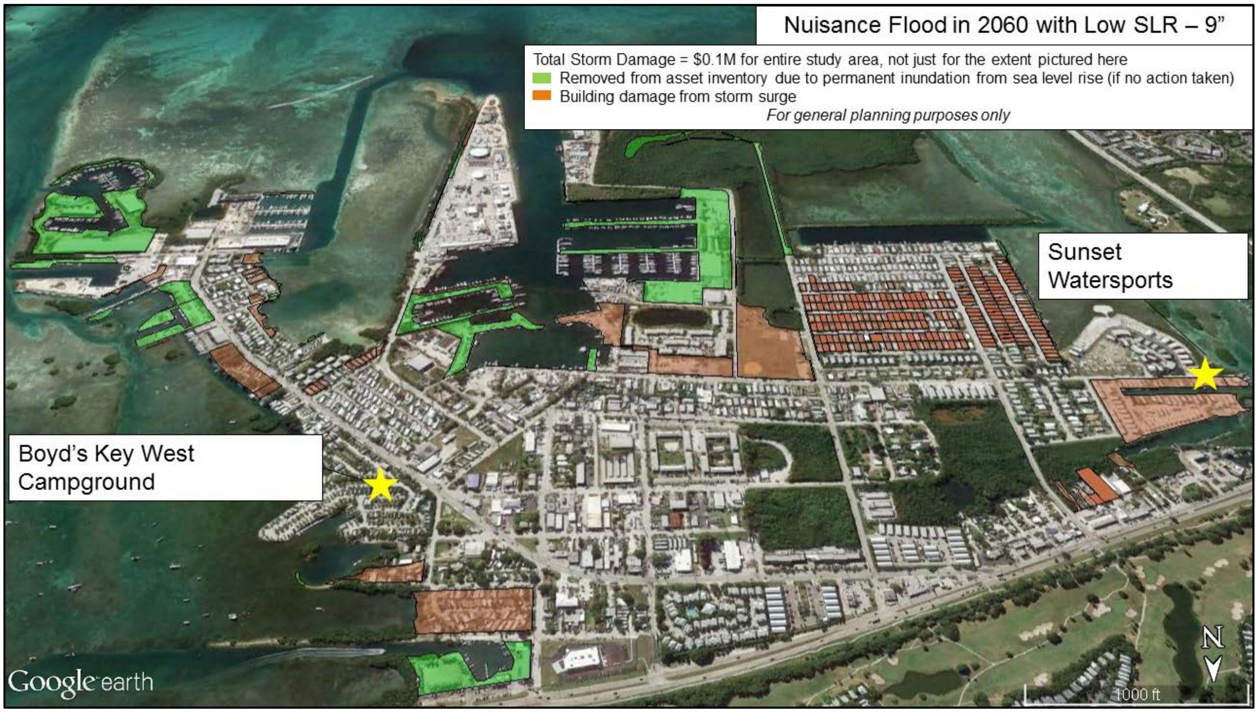

Study Area View 2 – Facing Atlantic Ocean
Sunset Watersports
Boyd's Key West Campground
Google earth
N
1000 ft

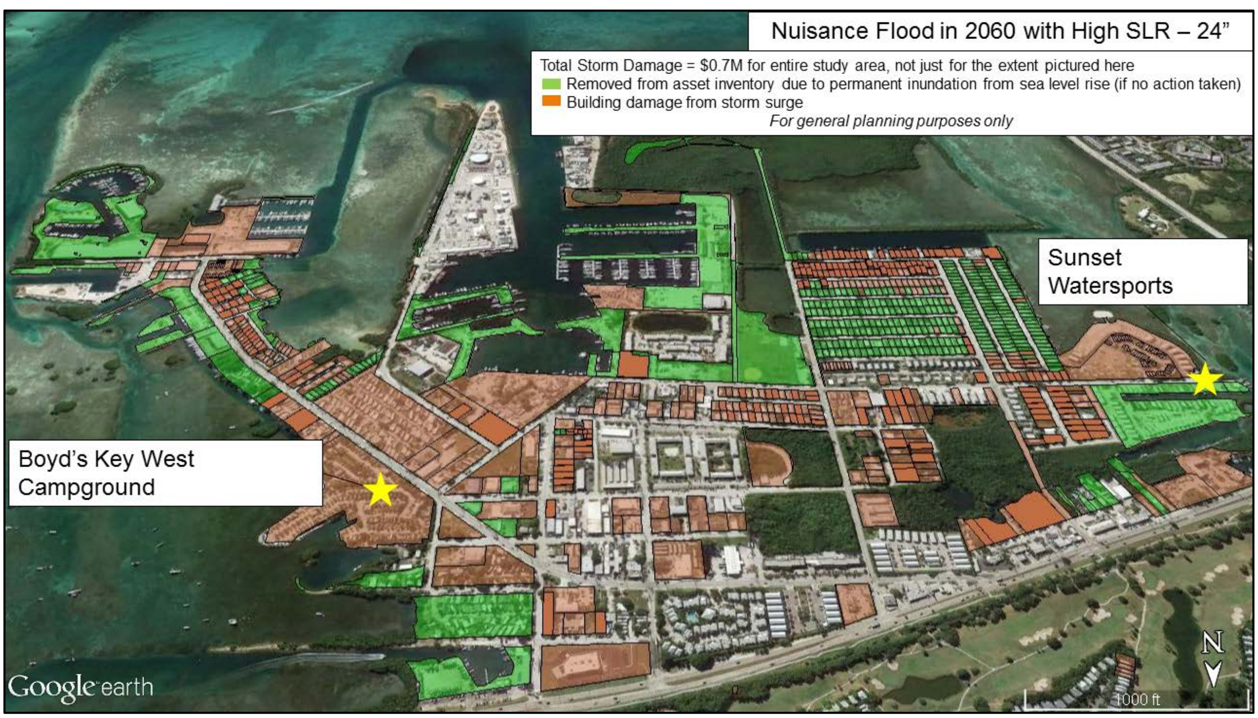

Nuisance Flood in 2030 with Tide Gauge Trend SLR – 2"
Total Storm Damage = $2.2M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
Google earth
N
1000 ft

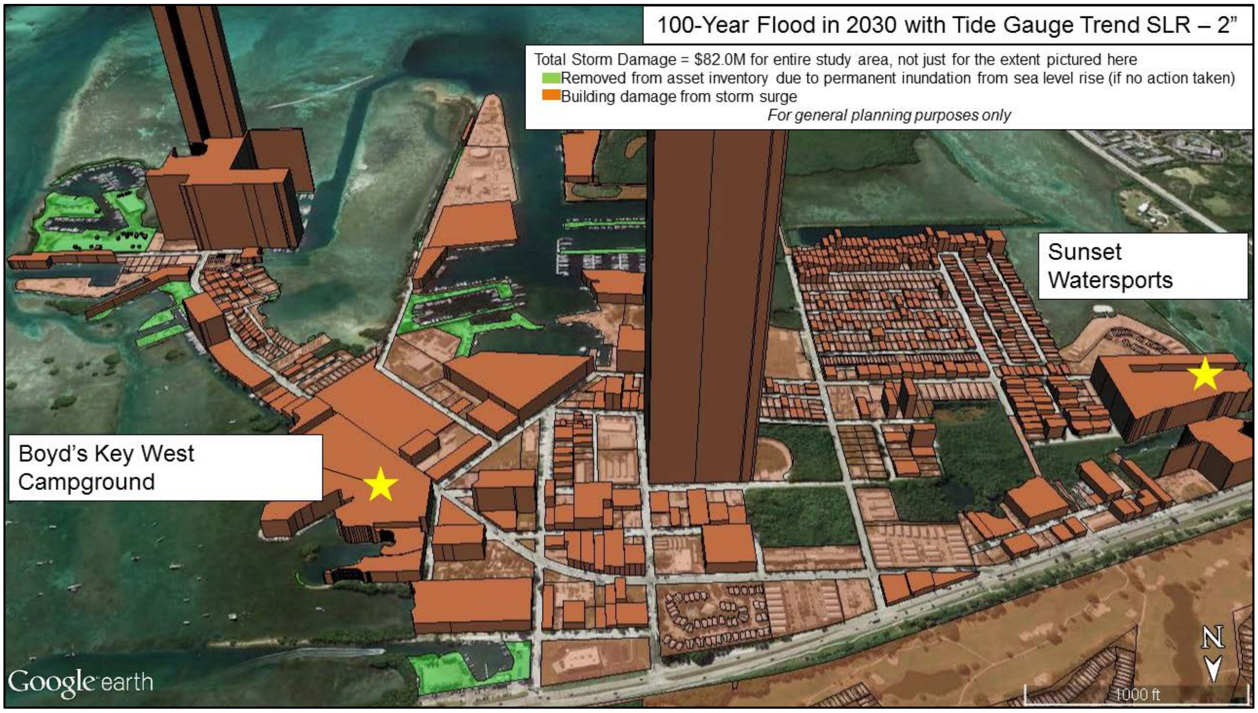

Nuisance Flood in 2030 with Low SLR – 3"
Total Storm Damage = $1.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
Google earth
N
1000 ft

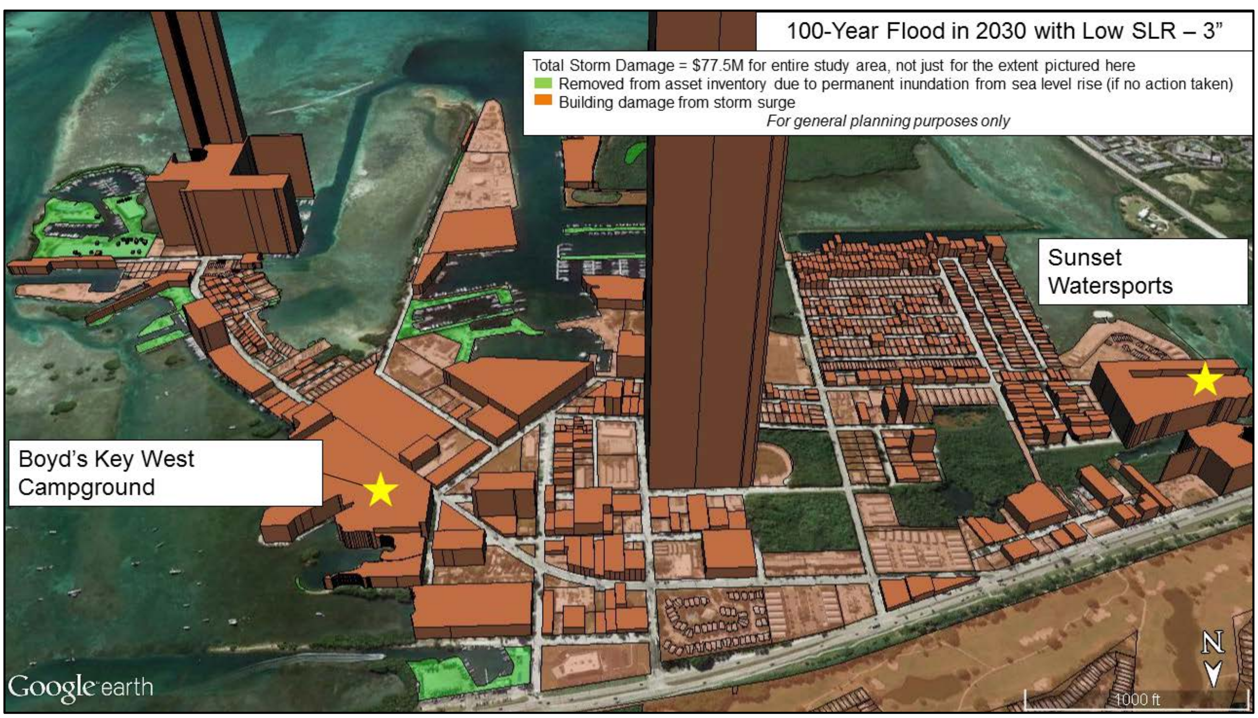

Nuisance Flood in 2030 with High SLR – 7"
Total Storm Damage = $0.02M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
Google earth
N
1000 ft

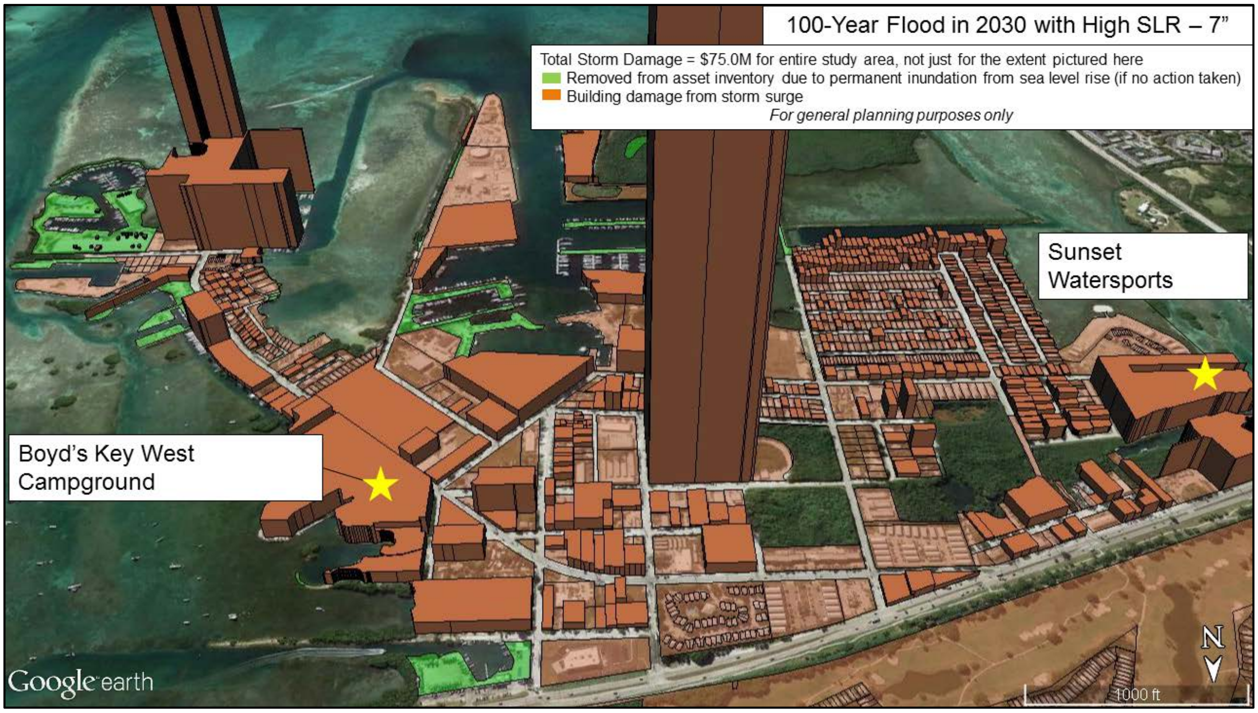

Nuisance Flood in 2060 with Tide Gauge Trend SLR – 4"
Total Storm Damage = $1.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
Google earth
N
1000 ft

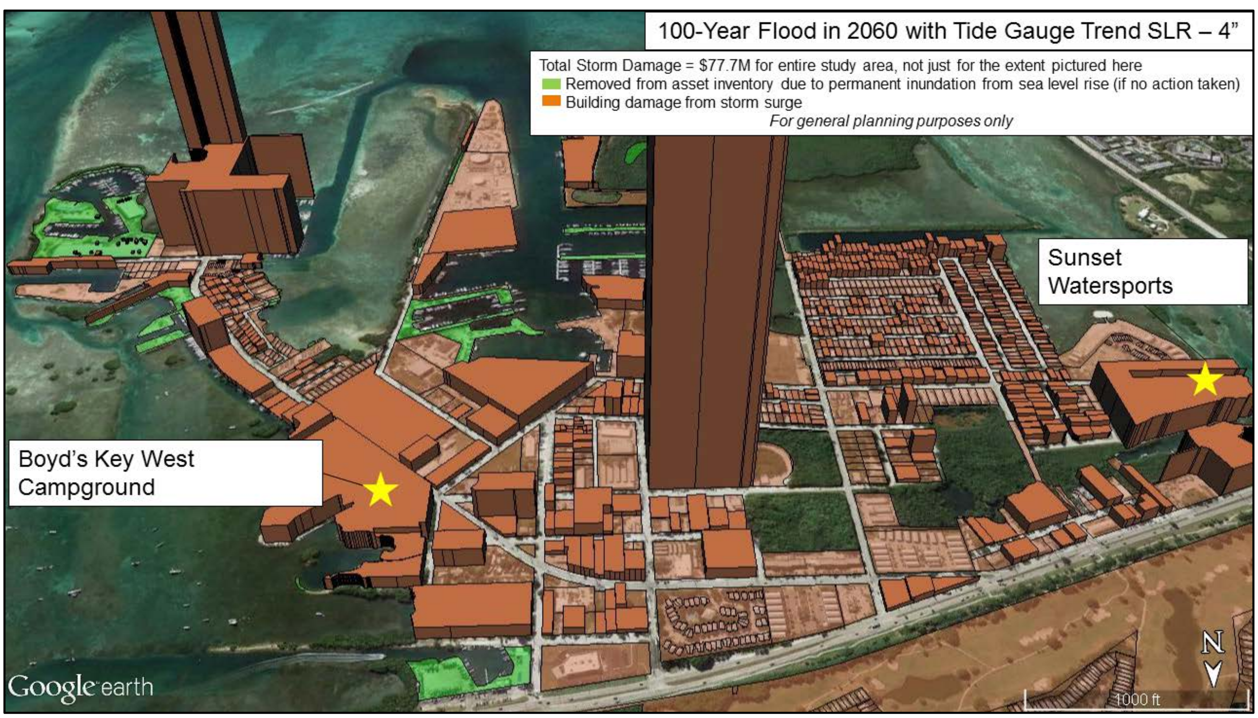

Nuisance Flood in 2060 with Low SLR – 9”
Total Storm Damage = $0.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
Google earth
N
1000 ft

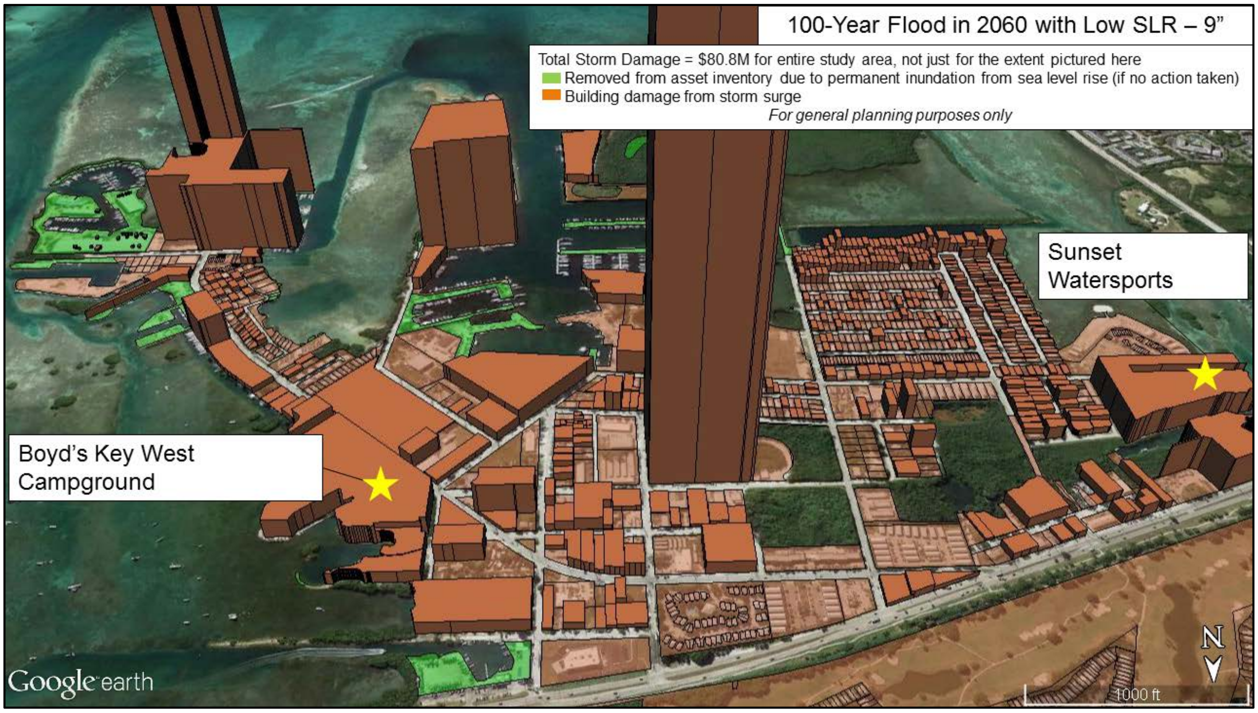

Nuisance Flood in 2060 with High SLR – 24”
Total Storm Damage = $0.7M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
Google earth
N
1000 ft

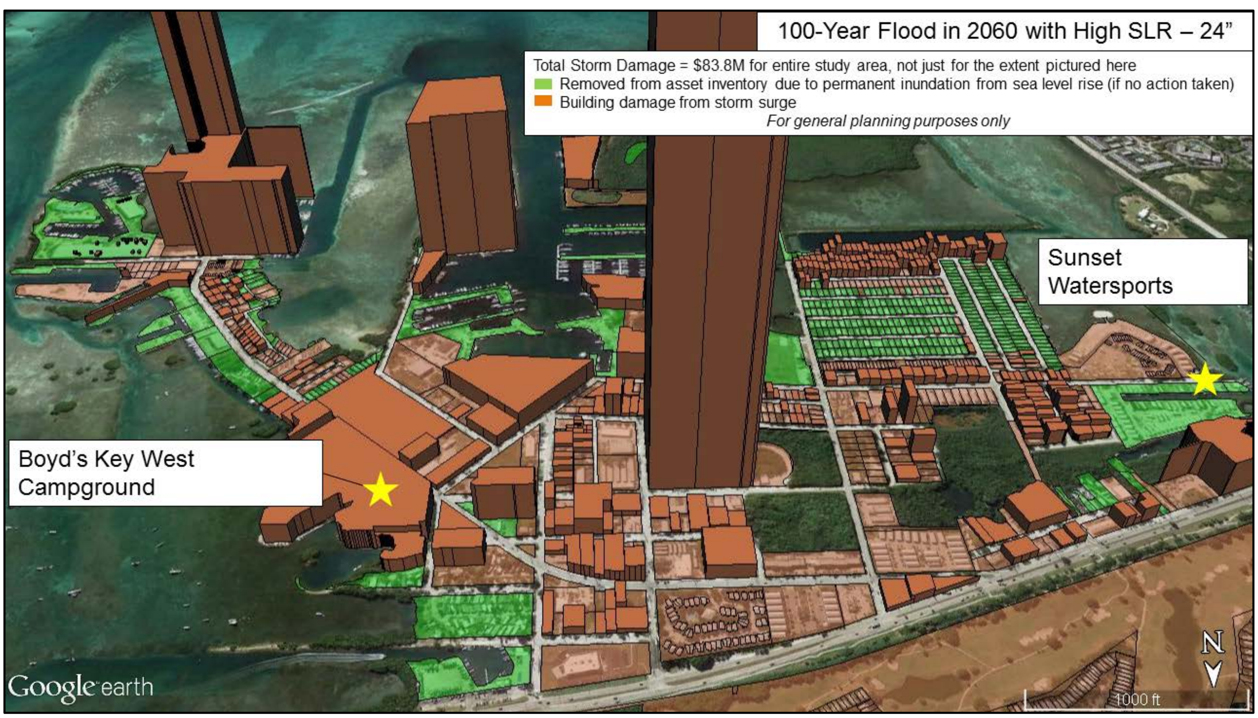

100-Year Flood in 2030 with Tide Gauge Trend SLR – 2"
Total Storm Damage = $82.0M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
N
1000 ft
Google earth

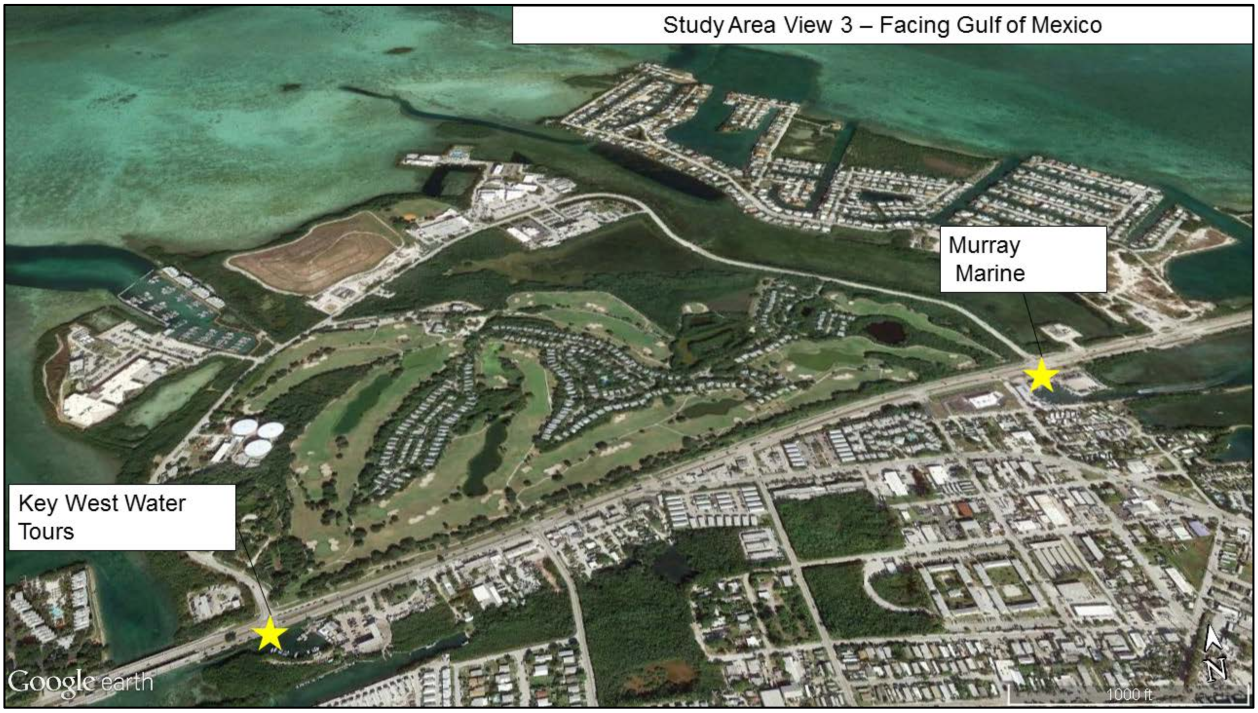

100-Year Flood in 2030 with Low SLR – 3"
Total Storm Damage = $77.5M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd's Key West Campground
N
1000 ft
Google earth

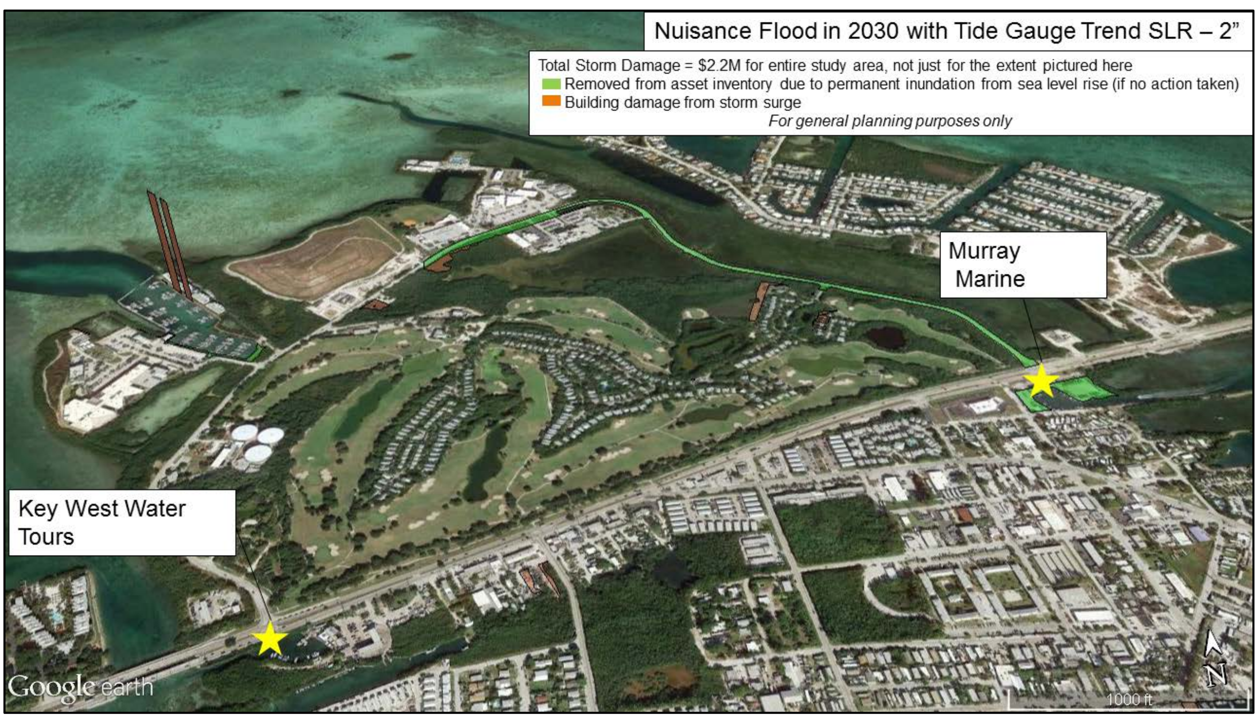

100-Year Flood in 2030 with High SLR – 7”
Total Storm Damage = $75.0M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
N
1000 ft
Google earth

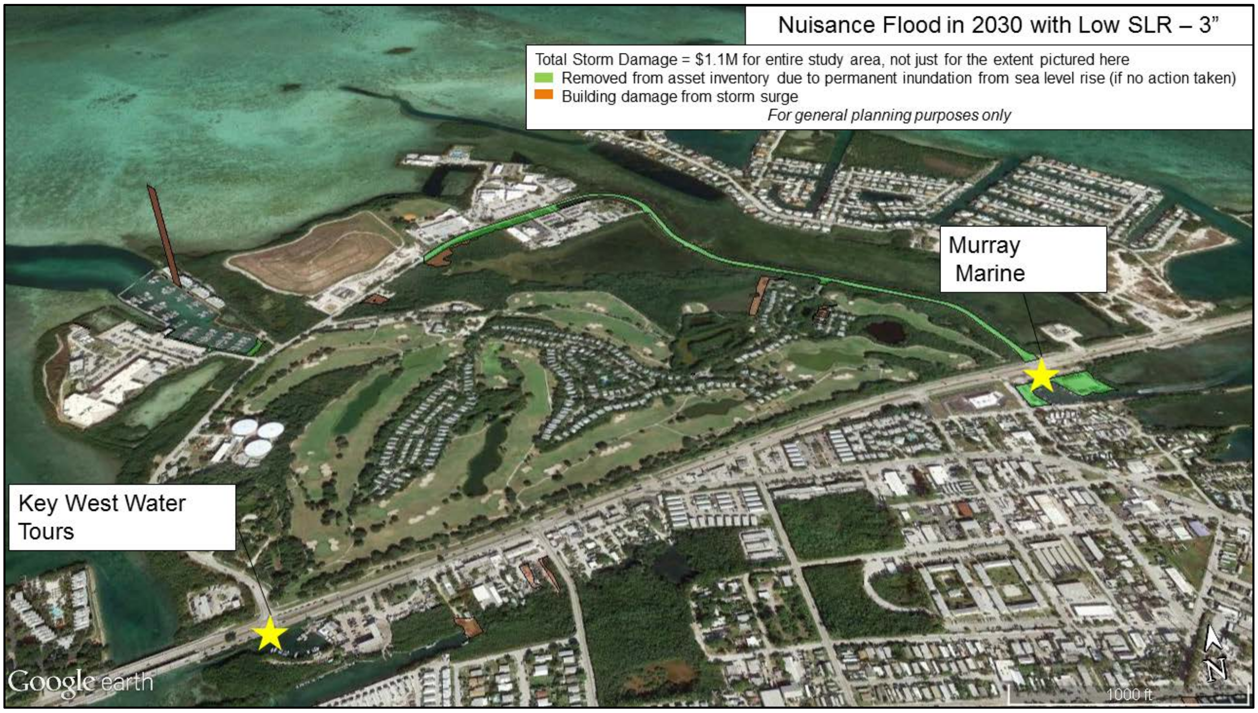

100-Year Flood in 2060 with Tide Gauge Trend SLR – 4”
Total Storm Damage = $77.7M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
N
1000 ft
Google earth

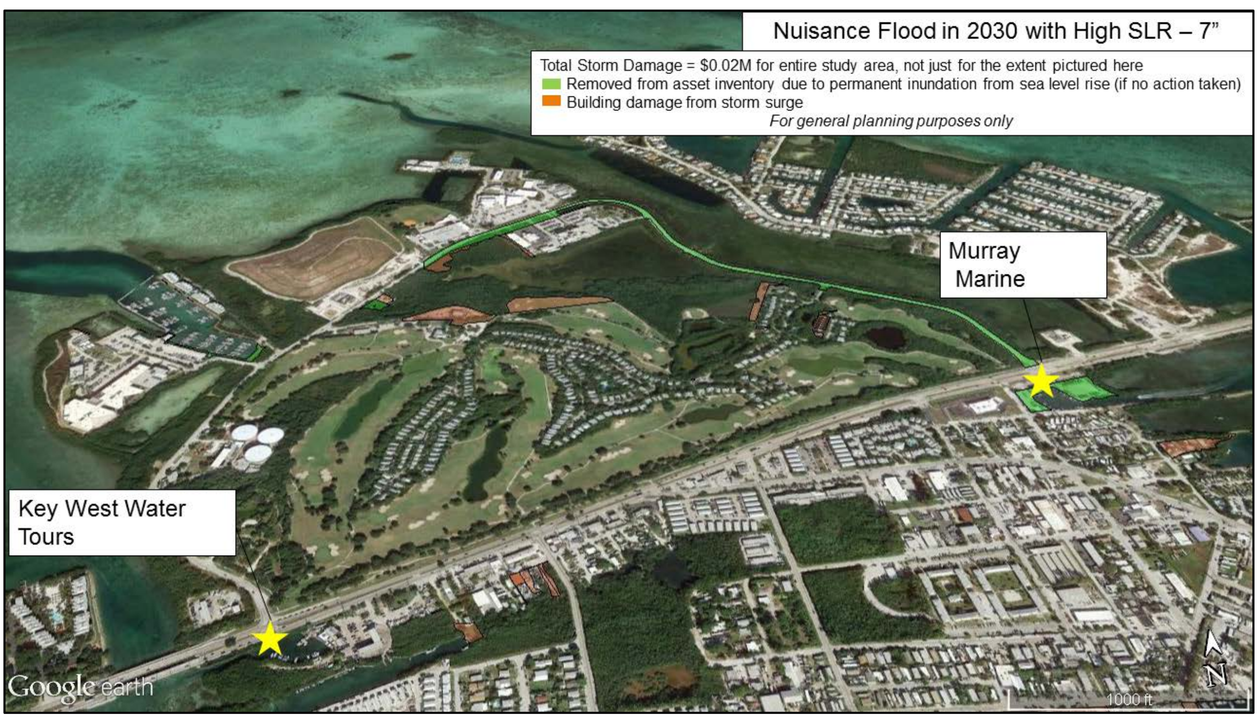

100-Year Flood in 2060 with Low SLR – 9”
Total Storm Damage = $80.8M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
Google earth
N
1000 ft

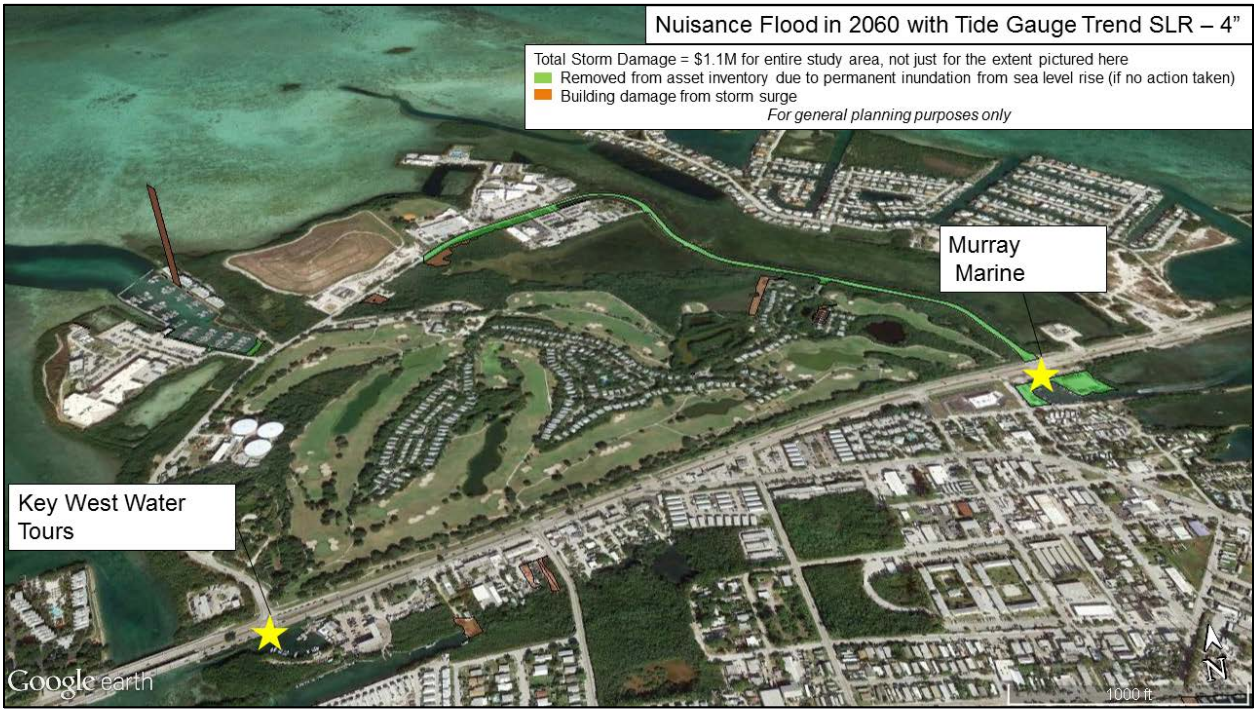

100-Year Flood in 2060 with High SLR – 24”
Total Storm Damage = $83.8M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Sunset Watersports
Boyd’s Key West Campground
Google earth
N
1000 ft

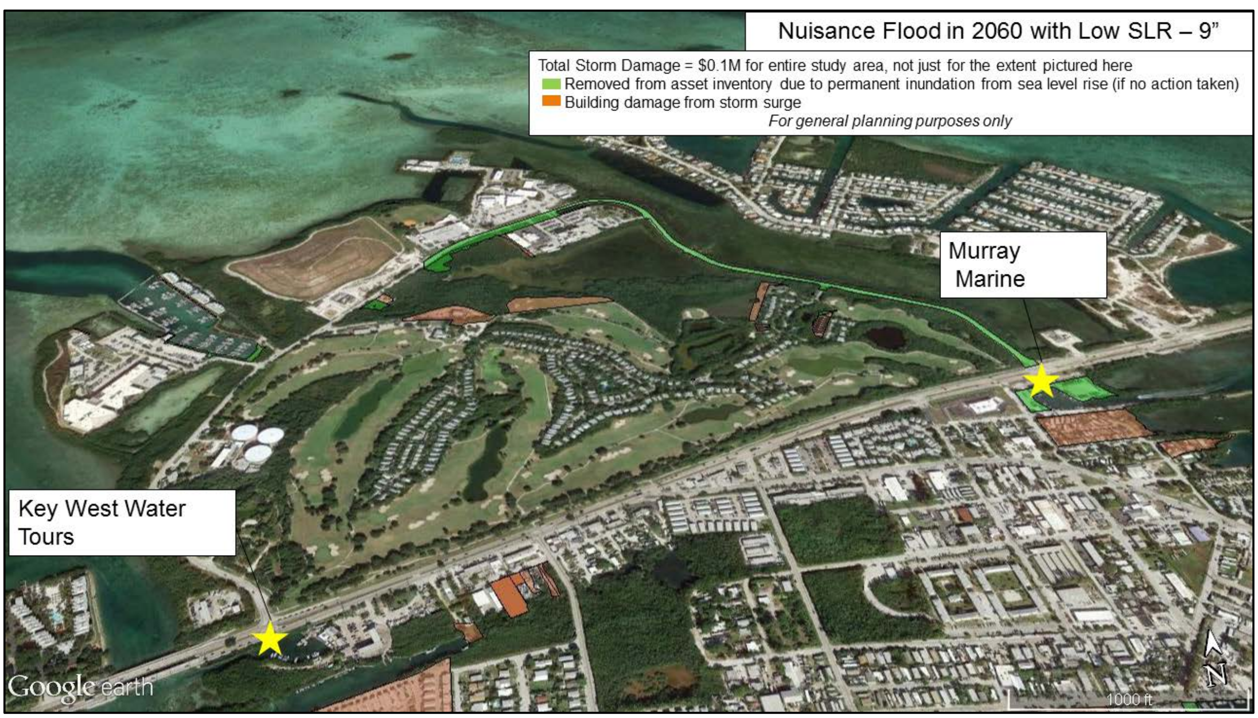

Study Area View 3 – Facing Gulf of Mexico
Murray Marine
Key West Water Tours
Google earth
1000 ft
N

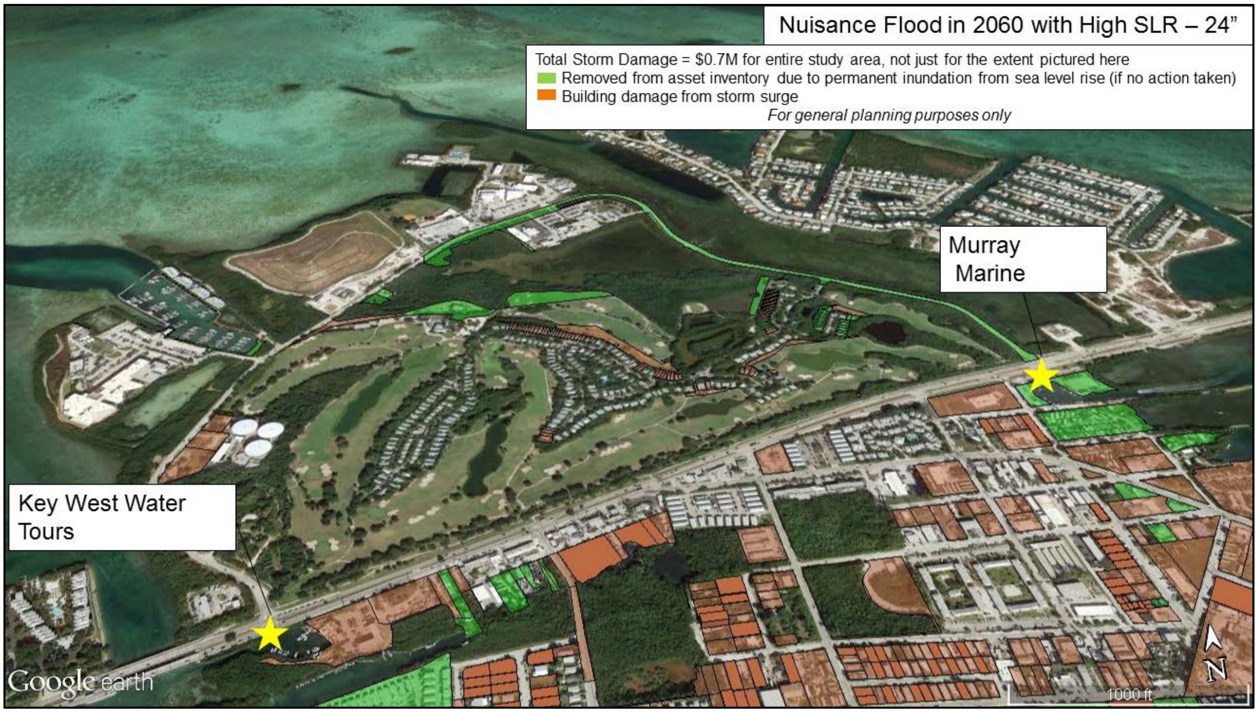

Nuisance Flood in 2030 with Tide Gauge Trend SLR – 2”
Total Storm Damage = $2.2M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
1000 ft
N


Nuisance Flood in 2030 with Low SLR – 3”
Total Storm Damage = $1.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
1000 ft
N

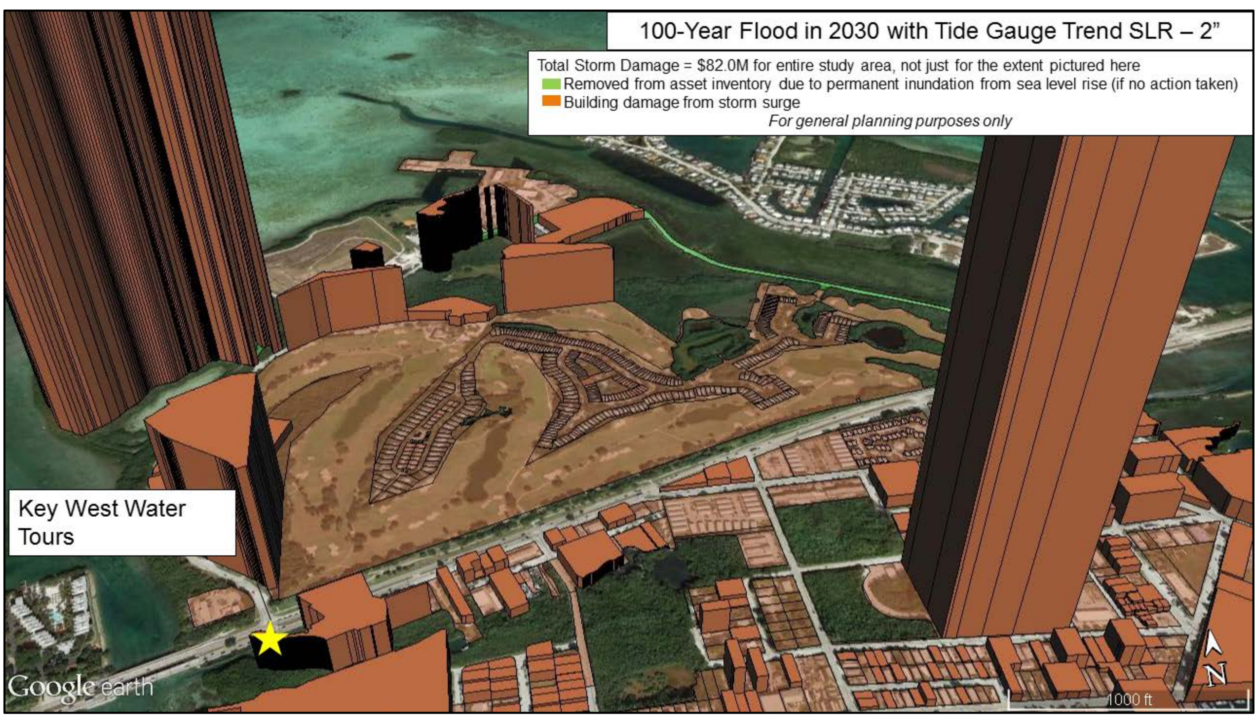

Nuisance Flood in 2030 with High SLR – 7”
Total Storm Damage = $0.02M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
1000 ft
N


Nuisance Flood in 2060 with Tide Gauge Trend SLR – 4"
Total Storm Damage = $1.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
N
1000 ft

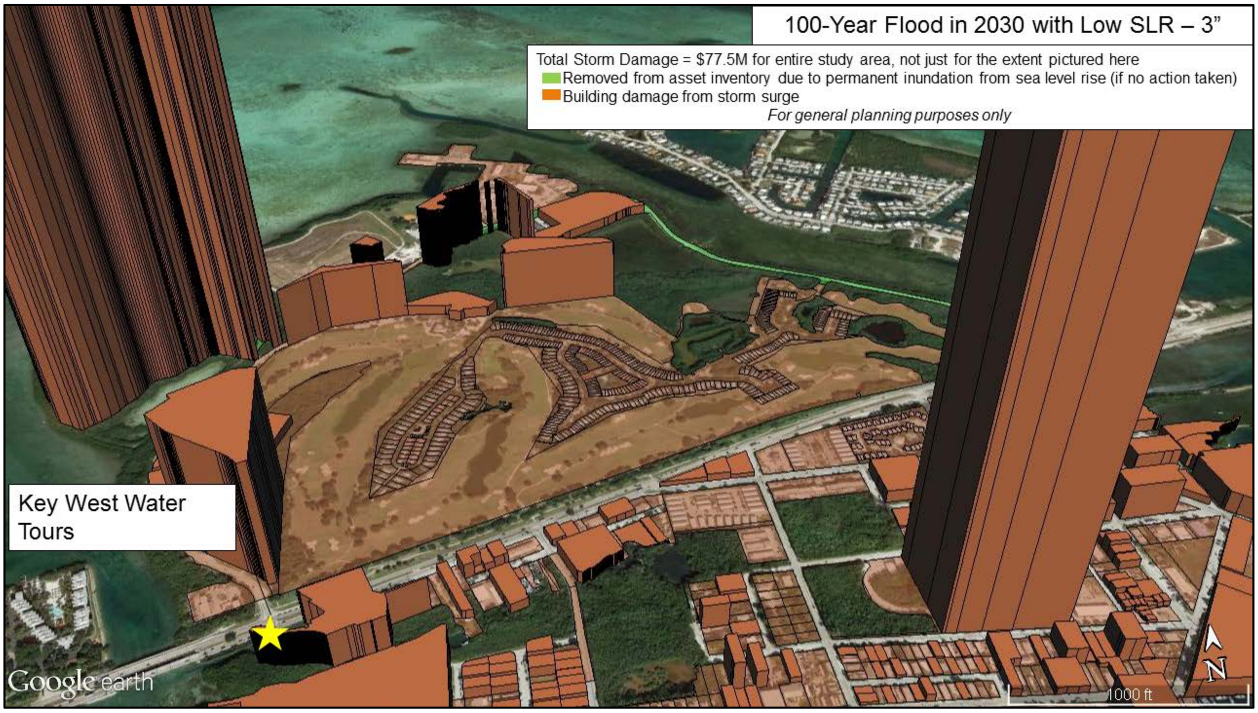

Nuisance Flood in 2060 with Low SLR – 9"
Total Storm Damage = $0.1M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
N
1000 ft

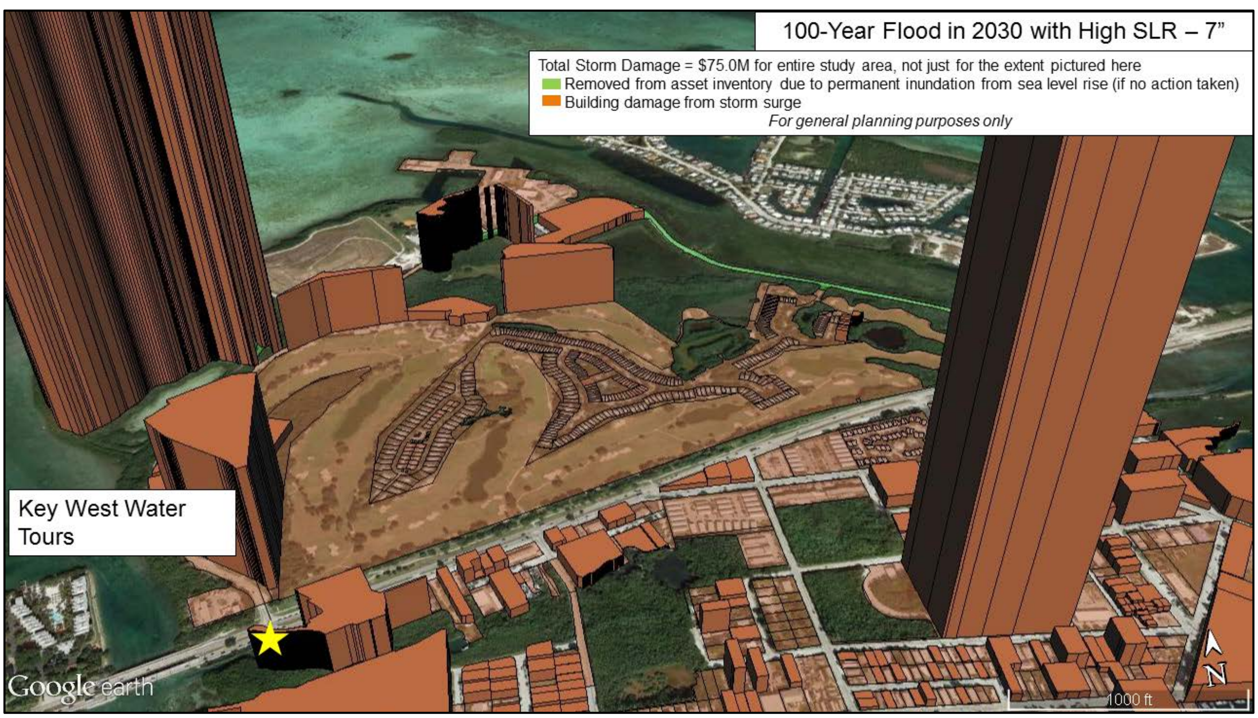


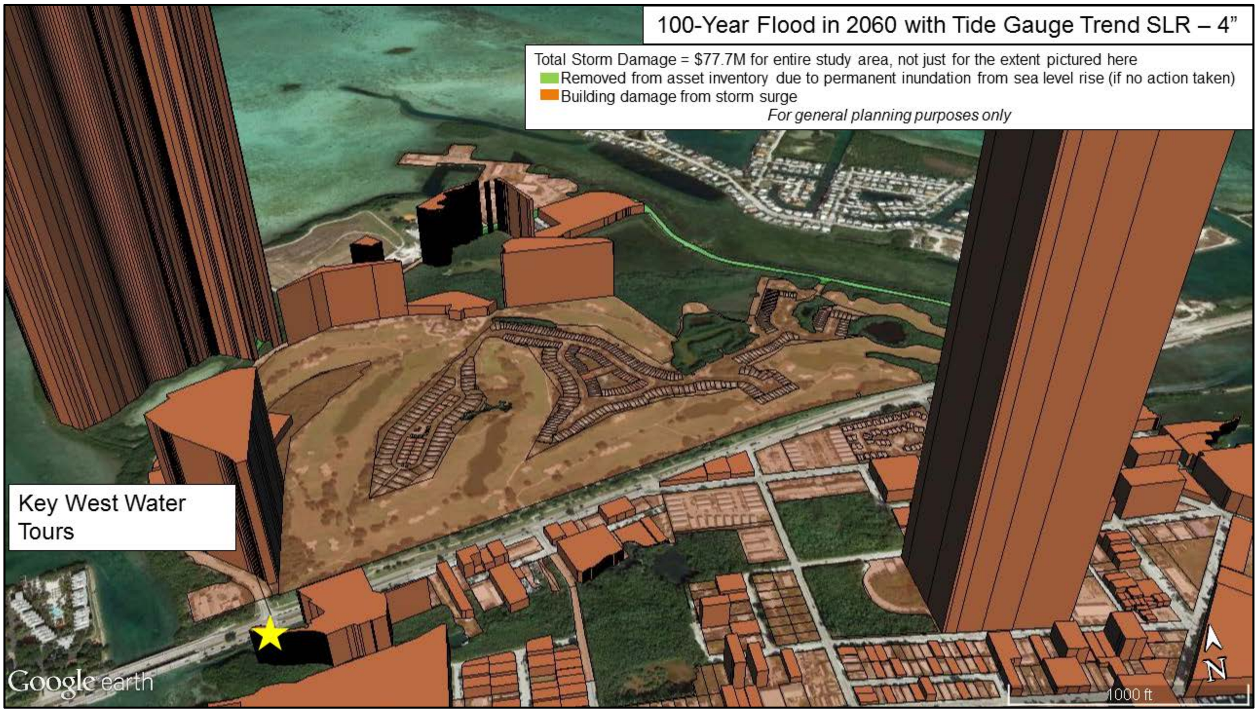
Nuisance Flood in 2060 with High SLR – 24"
Total Storm Damage = $0.7M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Murray Marine
Key West Water Tours
Google earth
1000 ft
N

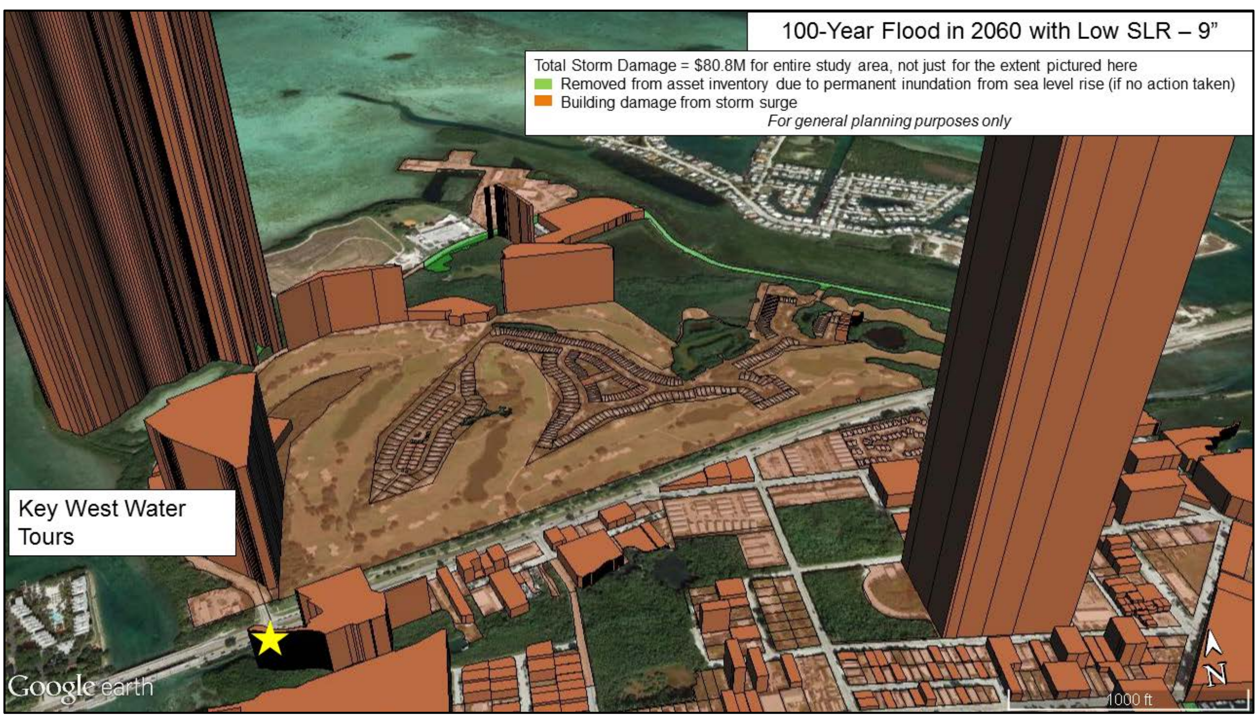


100-Year Flood in 2030 with Tide Gauge Trend SLR – 2"
Total Storm Damage = $82.0M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
Google earth
1000 ft
N


100-Year Flood in 2030 with Low SLR – 3"
Total Storm Damage = $77.5M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
Google earth
1000 ft
N


100-Year Flood in 2030 with High SLR – 7"
Total Storm Damage = $75.0M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
Google earth
1000 ft
N


100-Year Flood in 2060 with Tide Gauge Trend SLR – 4"
Total Storm Damage = $77.7M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
N
1000 ft


100-Year Flood in 2060 with Low SLR – 9"
Total Storm Damage = $80.8M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
N
1000 ft


100-Year Flood in 2060 with High SLR – 24”
Total Storm Damage = $83.8M for entire study area, not just for the extent pictured here
Removed from asset inventory due to permanent inundation from sea level rise (if no action taken)
Building damage from storm surge
For general planning purposes only
Key West Water Tours
Google earth
1000 ft
N

6.6.8 Cost Breakdown for Elevate and Floodproof Adaptation Action

The table below is a breakdown of adaptation cost assumptions for Stock Island. There is an assumption for both elevating and floodproofing. These were the same assumptions used for the geographic region of Key Largo.

	Cost Estimates for Action 1 - No Discounting, Costs paid Now				
	Number of Units Elevated in the V Zone	**Elevation Price Per Site - Low**	**Elevation Price per Site- High**	**Cost - Low**	**Cost - High**
For Elevation Component	7	$ 60,000	$ 160,000	$ 420,000	$1,120,000
	Total Bldg Market Value of Flood-proofed Units in A Zone	**Cost as percent of Building Structure Value - Low**	**Cost as percent of Building Structure Value - High**	**Cost - Low**	**Cost - High**
For Flood-proofing Component	$ 132,247,874	10%	20%	$ 13,224,787	$ 26,449,575
Total				**$ 13,644,787**	**$ 27,569,575**