Coastal Risk Consulting (CRC)

Climate Vulnerability Assessment for Village of Key Biscayne
Deliverable 1.1 in Statement of Work.
Preliminary Vulnerability Assessment Identifying Flood Hotspots

Introduction

The overarching goal of this project is to provide actionable and credible information to the Village of Key Biscayne (VKB) in terms of its vulnerability to sea level rise (SLR). This information will then be used over the next few weeks to develop adaption strategies that, along with input from the residents of Key Biscayne, will try to address all of the potential hazards facing the Village of Key Biscayne in a finalized adaption plan. One deliverable of this project is a comprehensive SLR vulnerability assessment report, which highlights the current situation in Key Biscayne, its unique problems and baseline risks, what steps have already been taken to address the problems, and the future risks faced by the community.

Background/ Unique Problems

Key Biscayne is located within the southernmost barrier island of the Atlantic coast in Miami- Dade County, Florida. Its unique location between the Atlantic Ocean and the Biscayne Bay gives the Village direct exposure to the Atlantic Ocean; a factor, which coupled with Key Biscayne's very low elevation (average of 3.4 feet above the Mean Sea Level), makes Key Biscayne vulnerable to sea level rise and the associated increases in storm surges. Moreover, the only access to Key Biscayne is through the Rickenbacker Causeway and its three bridges: the West Bridge, the William Powell Bridge and Bear Cut Bridge. And, even though Bear Cut Bridge was recently renovated in 2014, more exposure of these structures to the corrosive effects of seawater is to be expected with sea level rise, and thus leaves not only the two structures yet to be renovated vulnerable, but the recently renovated bridge as well (Smith and Tirpak 1989).

The lack of natural beach nourishment from littoral drift processes that would normally transport sand from north to south along the Florida coastline is also a major challenge.

This sand nourishment has been impaired by deep artificial inlets such as the Government Cut, and has led to various beach stabilization and re-nourishment efforts for over four decades (Shoreline Characteristics and Previous Beach Renourishment Projects - Village of Key Biscayne n.d.). A further complication is the lack of mangroves to serve as barriers to sea level rise in three-quarters of the beaches on Key Biscayne. The ocean-side beach, which does have mangroves, also has a host of other structures, which increases the cost, and complexity of beach re-nourishment or replacement where necessary. Furthermore, there are buildings in the Village itself with rusting foundations, as well as deteriorating infrastructure. While many of the older buildings have been replaced with modern ones, there are still some that have old infrastructure, leaving them potentially susceptible to the effects of sea level rise, erosion, seasonal inundation, and tidal flooding.

Current/Baseline Risks

The current/baseline flood and climate impact risks faced by the Village of Key Biscayne was analyzed using Coastal Risk Consulting's (CRC) unique Coastal Risk Rapid Assessment (CRRA™). The CRRA™ takes into account variables associated with SLR risk such as: heavy rainfall and groundwater flooding, hurricane storm surges, erosion, sewage overflows, social and ecosystem vulnerabilities, and the built environment. The specific components are:

i. **The Climate Risk Categories:** an account of the climate-related, government-designated risk zones that the Village of Key Biscayne currently lies within. The risk zones include the Federal Emergency Management Agency (FEMA) Wind Zones (Fig. 1), Evacuation Zones (Fig. 2), Flood Zones (Fig. 3), Community Rating Score, Special Flood Hazard Areas, and Base Flood Elevation.

Wind Zone III

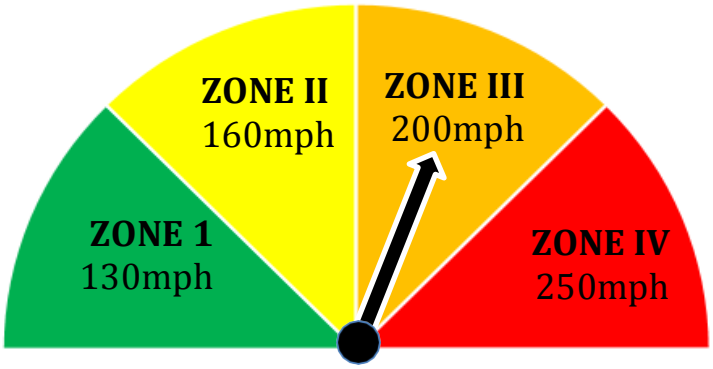


Fig. 1. The structures in the Village of Key Biscayne should be constructed to withstand 200mph winds.

Evacuation Zone: A

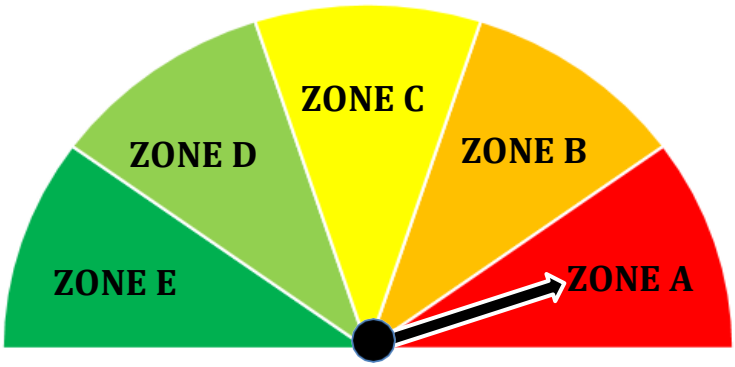


Fig. 2. The Village of Key Biscayne is in evacuation zone A, meaning evacuation is required for a Category 1 or higher storm.

Flood Zone: AE and VE

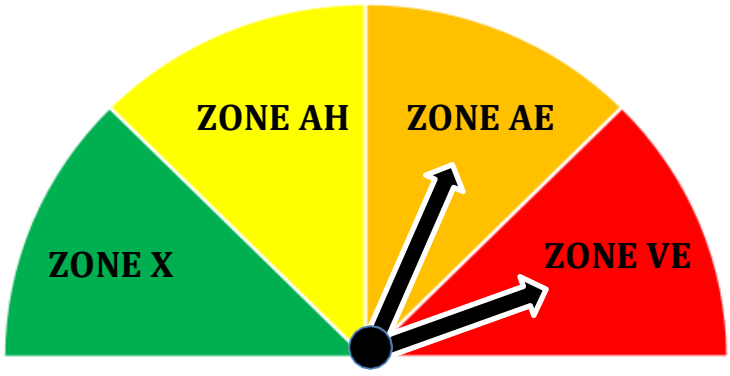


Fig. 3. The Village of Key Biscayne is in a 100-year FEMA flood zone and is considered at high risk of flooding by NFIP. It is also in the Special Flood Hazard Area (SFHA).

ii. **FIRST Score®**– This score provides the total number of tidally induced, non-storm flood days the site is projected to experience over the next 30 years. A flood day is defined as a day when the measured water level, enhanced by SLR, is greater than a threshold elevation of the site. CRC uses the NAVD88 vertical datum, an internationally standardized reference, to calculate elevation values. The map in Figure 4 shows how much of each parcel will be influenced by flooding from a combination of high tides and sea level rise.

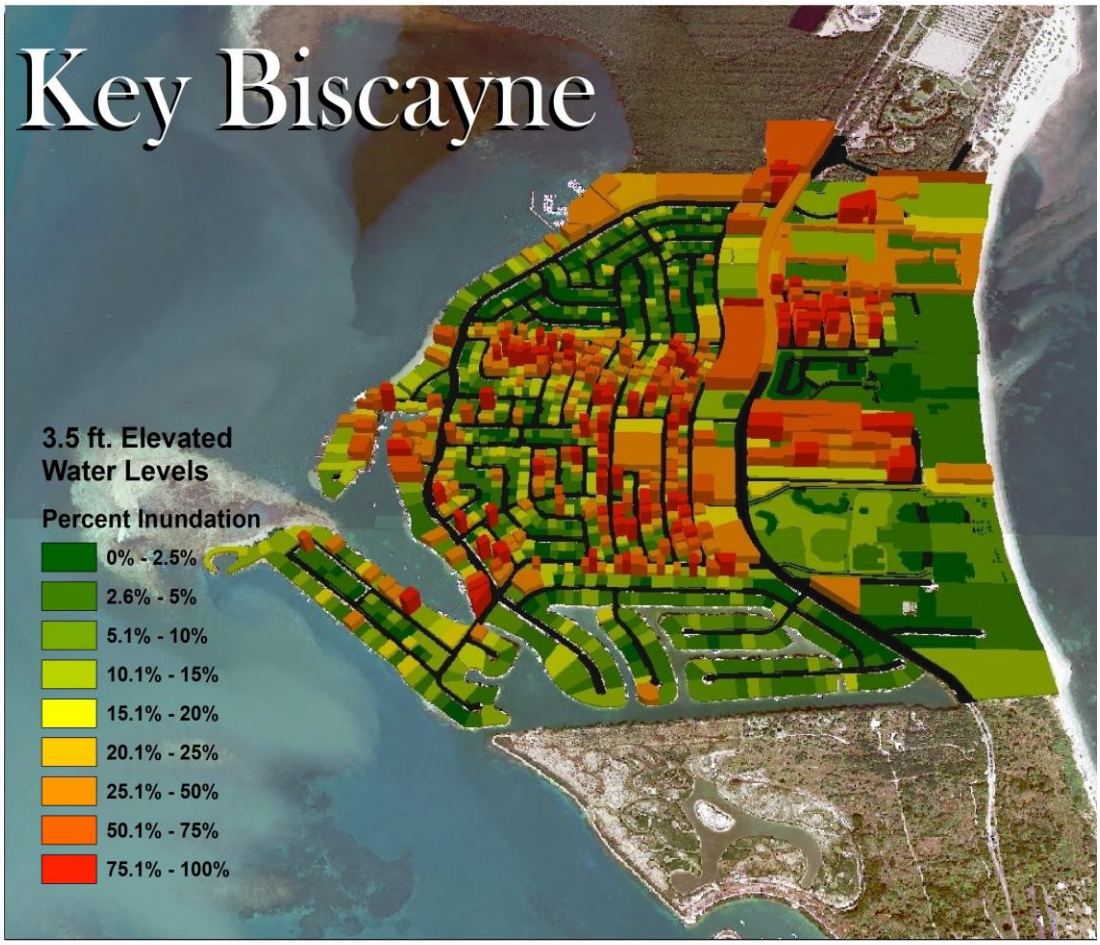


Fig. 4. This map shows the percentage of inundation for each parcel in the village of Key Biscayne for tidal levels that are 3.5 feet above the NAVD88 datum. That water height is equivalent to the projected highest water level that will be reached in the highest tidal cycles (i.e, "King tides") by approximately 2050.

iii. **Parcel-Specific Tidally-Induced Flooding and SLOSH Model** - Overlays on the CRRA™ GIS maps to show tidally-induced flooding and storm surge risks in Key Biscayne as calculated using CRC's Parcel-Specific SLOSH Model. This model is a proprietary, CRC application of the SLOSH model developed by the National Oceanic and Atmospheric Administration (NOAA n.d.). [The CRC model uses maximum storm surge from a Category 3 hurricane layered with tidal cycles and sea level rise.]

iv. **Airborne LiDAR High Resolution Elevation Map** - The Airborne LiDAR High Resolution Elevation Map provides detailed elevation information for the areal extent of the Village. This map provides a graphical visualization of the location of low-lying areas and helps give context to the results of the CRRA™, FIRST Score® and SLOSH models, assisting with evaluation, prioritization, and decision-making.

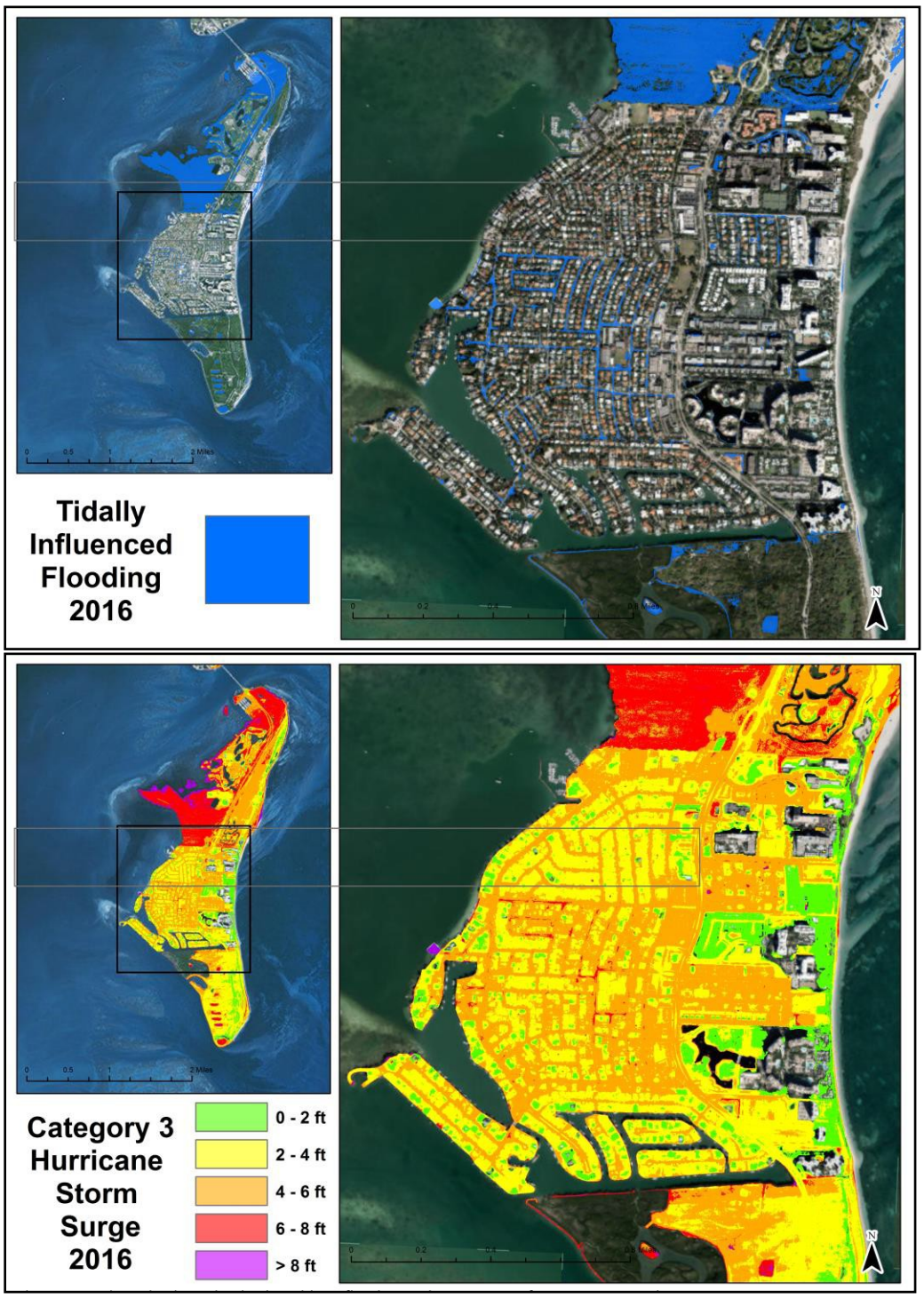


Fig. 5. a) This map depicts tidally-influenced flood susceptible areas (in blue) and b) then uses SLOSH Models to determine the storm surge flood height of a Category 3 hurricane directly hitting the Village of Key Biscayne. The island could experience up to **2.56** feet of tidal flooding (a) and more than **8** feet of storm surge flooding from a direct hit from a Category 3 hurricane (b) in **2016**.

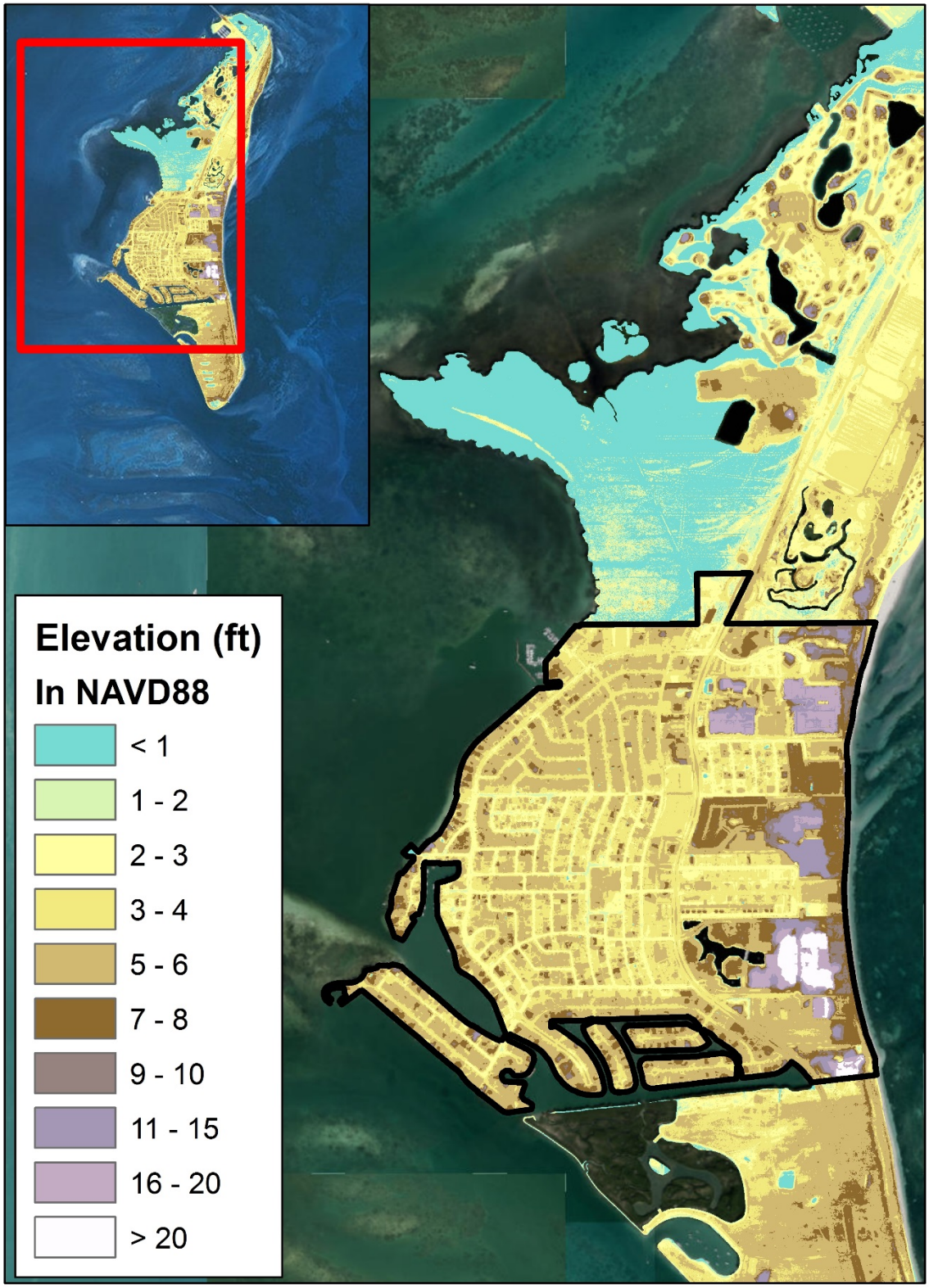


Fig. 6. Airborne LiDAR high-resolution elevation map showing range of elevation in Village of Key Biscayne: Areas below sea level are indicated in red. These elevations are based on the NAVD88 vertical datum. This is calculated based off a gravitational fields of the Earth rather than the Mean Sea Level (MSL) of the area. Therefore, it is more accurate overall, but can vary by up to a couple feet from the local MSL.

Future Risks

The CRC hazard analysis identifies the vulnerabilities and hazards that are facing the residents and infrastructure of Village of Key Biscayne due to impending sea level rise. These hazards include: extreme tides, storm surge, and groundwater storage reduction, as well as, specific vulnerabilities such as beach erosion, or critical buildings and infrastructure deterioration.

Extreme Tides Hazard Profile and Vulnerability Analysis

Tides on Key Biscayne can vary throughout the year by up to 3 feet. When sea level rise is factored in, this can result in flooding in all areas below the threshold elevation. The threshold elevation is calculated by analyzing tidal patterns from the past five years in order to determine the highest potential water level for the upcoming years. In our analysis, we quantify tidally-influenced flooding in order to show the regions that will be affected, as well as how often the flooding will likely occur throughout the year – in 2016 and in the future, as well.

Fig. 7. This map highlights regions vulnerable to tidal flooding (shown in blue) due to 0.29 feet of sea level rise projected to occur by 2025.

Fig. 8. This map highlights regions vulnerable to tidal flooding (shown in blue) due to 0.65 feet of sea level rise projected to occur by 2035.

Fig. 9. This map highlights regions vulnerable to tidal flooding (shown in blue) due to 1.08 feet of sea level rise projected to occur by 2045.

Storm Surge Hazard Profile and Vulnerability Analysis

Storm surge is the abnormal rise of water generated by a storm and pushed ashore by strong winds, over and above the predicted astronomical tide (NOAA, 2016). Storm surge usually occurs when there are low atmospheric pressure levels associated with tropical storms and hurricanes. For any geographic area, storm surge is the difference between the observed water level and the predicted tide. Because of its location between the Atlantic Ocean and Biscayne Bay, the Village of Key Biscayne has increased risk of storm surge both from the ocean and the and high intensity rain associated with storms.

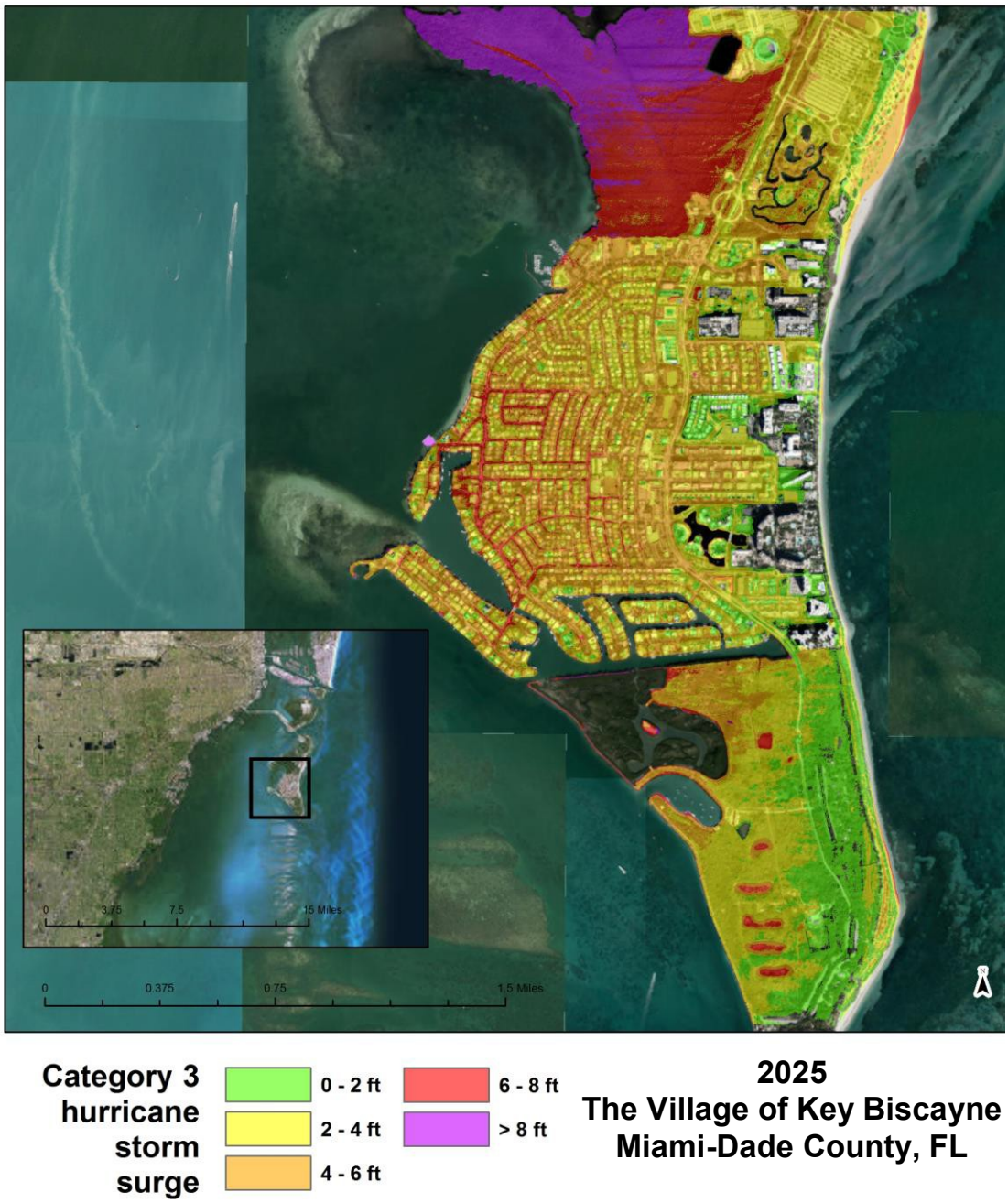


Fig. 10. This map depicts the maximum height of storm surge from a direct hit from a category 3 hurricane making landfall on or near Key Biscayne on 2025 after a projected rise in sea level of 0.29 feet. The storm surge is presented as the depth of water above ground level.

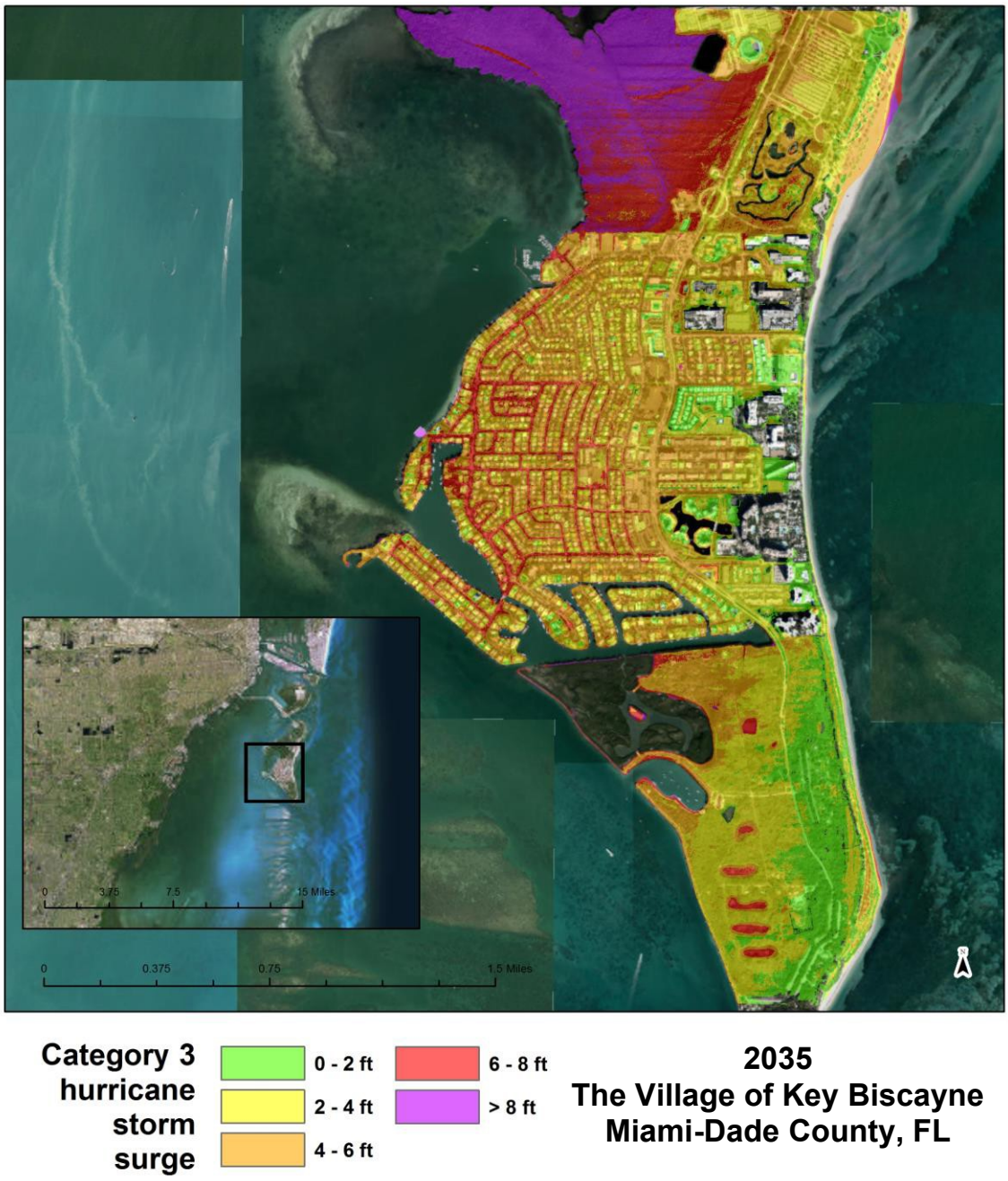


Fig. 11. This map depicts the maximum height of storm surge from a direct hit from a category 3 hurricane making landfall on or near Key Biscayne on 2035 after a projected rise in sea level of 0.65 feet. The storm surge is presented as the depth of water above ground level.

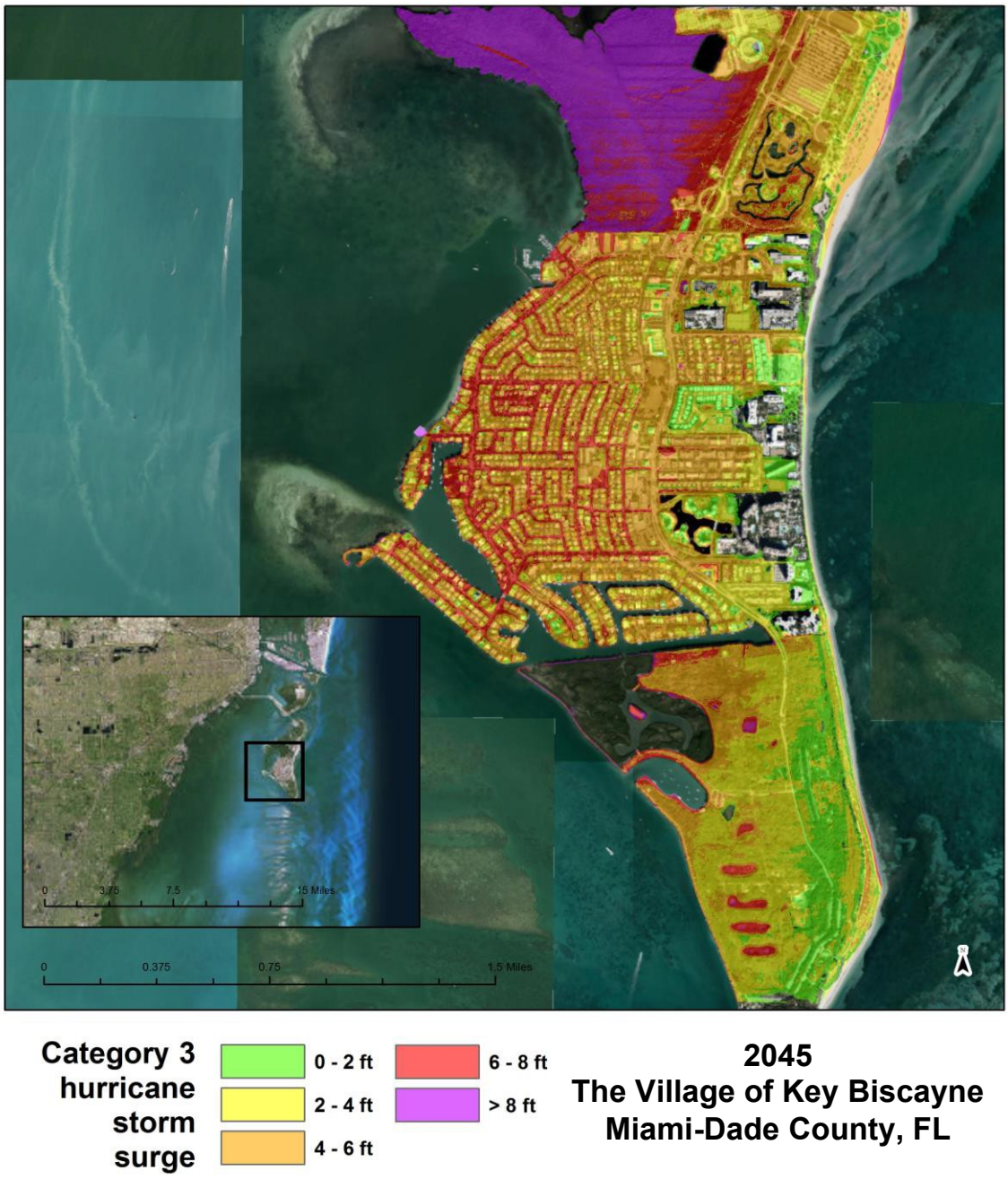


Fig. 12. This map depicts the maximum height of storm surge from a direct hit from a category 3 hurricane making landfall on or near Key Biscayne on 2045 after a projected rise in sea level of 1.08 feet. The storm surge is presented as the depth of water above ground level.

Groundwater Storage Reduction Hazard Profile and Vulnerability Analysis

Due to Key Biscayne's low mean elevation of only 3.5 feet above NAVD88, the storage of groundwater can be a big issue. Poor drainage can lead to large areas of standing water after even small rain storms. As the mean sea level rises, heavy rainfall flooding will become more and more frequent as the average water table height rises.

<u>Groundwater/Heavy Rainfall Flooding:</u> High/Medium Risk

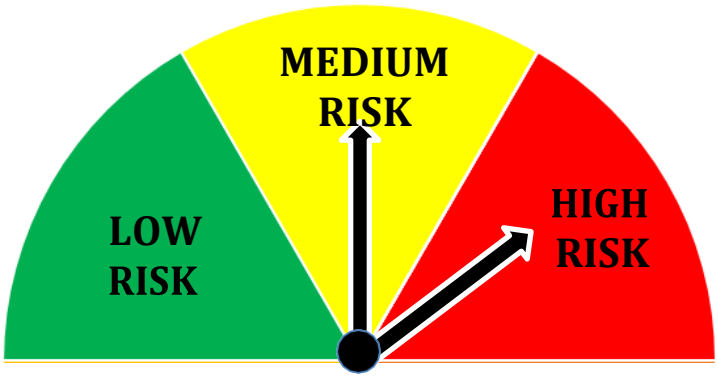
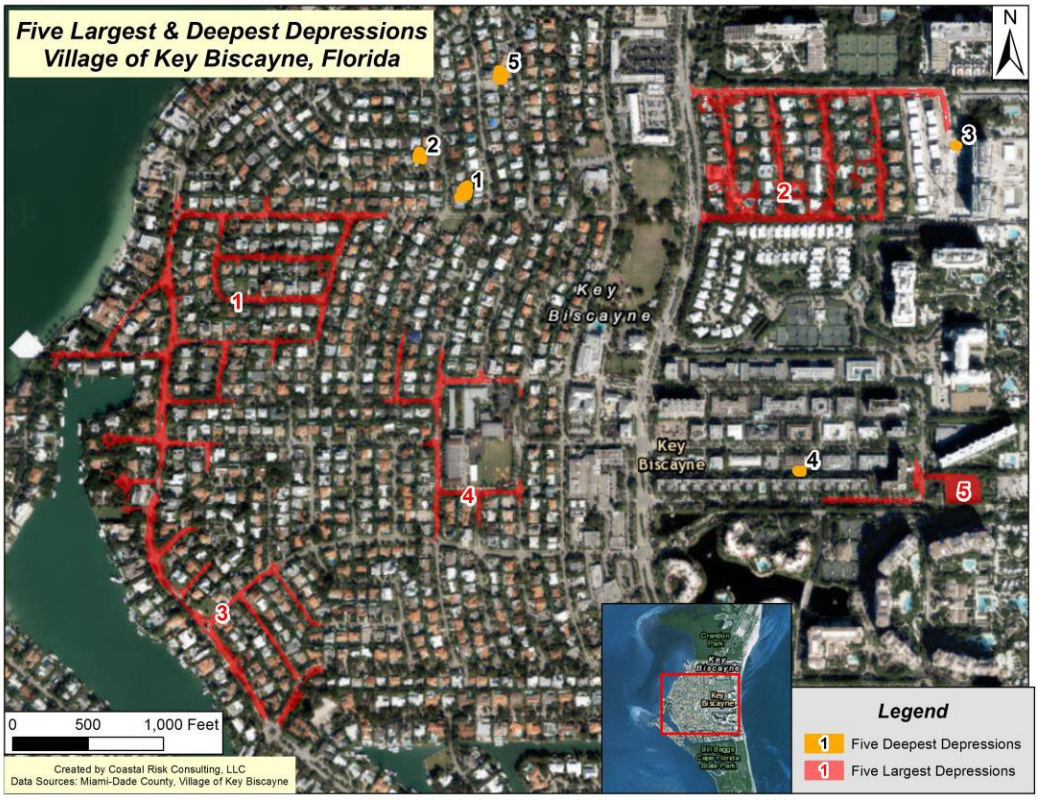


Fig. 13. The Village of Key Biscayne is in two Groundwater Flooding zones. Parts of the Village have **medium** risk while others have a **high** risk of heavy rainfall accumulation and groundwater flooding, depending on elevation, and drainage systems. Groundwater flooding can occur when precipitation infiltrates into the ground and causes the water table to rise above normal levels. In the future, the height of the water table is also projected to rise toward the surface in this area due to sea level rise and other factors.



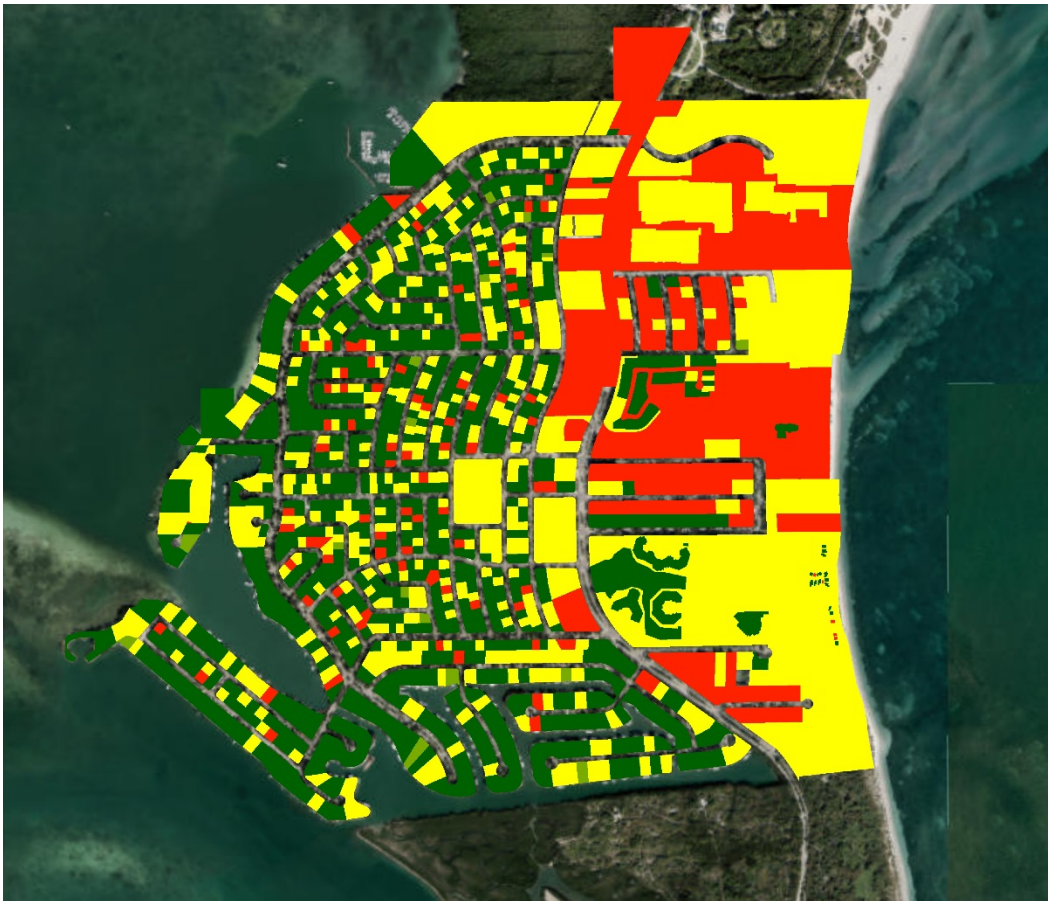


Fig. 14. Top: Map of largest and deepest depressions in Village of Key Biscayne, which may be affected by groundwater flooding. Bottom: Heavy rainfall flooding risk from low risk (green) to high (red).

Conclusion:

Altogether, the Village of Key Biscayne is highly-susceptible to projected sea level rise over the next 30 years. Tidally-influenced flooding will affect the majority of streets throughout the village, as well as many residential and commercial properties. The entire island is vulnerable to storm surge flooding, which will only get worse as sea level continues to rise. And, as the water table gets higher, heavy rainfall flooding will become a large problem for many of the island's residents, because the rainwater has limited areas available in which to drain.

With all this in mind, the next step of this project is to create a climate and flood impacts adaption plan. With input from the residents and businesses of Key Biscayne, we will work with Village officials to create a draft multi-step, adaption plan that will address the concerns of the Village. Then we will presenting the final plan at a second town hall meeting in order to present the preliminary results, gather feedback, and answer questions.

Citations:

NOAA. Sea, Lake, and Overland Surges from Hurricanes (SLOSH). http://www.nhc.noaa.gov/surge/slosh.php.

Shoreline Characteristics and Previous Beach Renourishment Projects - Village of Key Biscayne. http://keybiscayne.fl.gov/index.php?src=gendocs&ref=BeachCharacterPreviousRenourishProjects&category=Beach Renourish-Maintenance.

Smith, J. B., and D. A. Tirpak. 1989. *The Potential Effects of Global Climate Change on the United States*. Washington D.C. books.google.com/books?id=VooTAAAAYAAJ&pg=SA2-PA13&lpg=SA2-PA13&dq=does+sea+level+rise+affect+corrosion+on+bridges&source=bl&ots=4mQoI1qhk5&sig=VyRQ-6fP3zEu3kjt0-3AwcZY6Vs&hl=en&sa=X&ved=0ahUKEwiLmvG3_ovQAhXJZCYKHSHpAFcQ6AEINDAD#v=onepage&q=does sea level.