Coastal Flood Risk Analysis Report

North Bay Village

Infrastructure Protection Resources

DELIVERABLE 3.1

Agreement # P0222

Improving the Planning Process to Protect Infrastructure Emerging from Coastal Flood Hazards

Acknowledgements

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Completed June 2017

Executive Summary

This summary report is the final of three resources in the *Infrastructure Protection Resources* series aimed at providing technical assistance to local governments wishing to increase resilience to coastal flooding, particularly during extreme events such as high tides and storm surge. The six specific local pilot communities for this project were selected because they have a high risk of inundation from coastal flooding and because the local governments are planning mitigation practices for existing and emerging tidal flooding conditions. The first part of the project completed in February 2017, documented data collection and analyses based on in situ measurement and modelling of current and projected King Tide flooding. The second resource, completed in April 2017, is a summary report for a series of surveys given to local governments to document the extent of existing and emerging tidal flooding conditions and any planned mitigation.

This assessment, the last in the series, gives specific focus to North Bay Village. This portion will revisit existing findings in greater detail, and subsequent sections will include a proposed comprehensive plan amendment(s) which will address deficiencies in the Village's response to Peril of Flood. This amendment was developed utilizing the best available data, including recently released storm surge data from the Sea, Lake, and Overland Surges from Hurricane (SLOSH) model to designate the Coastal High Hazard Area and 2015 LIDAR-derived elevation data. As per the goals of this project, this specific report 1) highlights existing nuisance flooding hotspots and associated consequences in North Bay Village, 2) two sea-level rise scenarios and likely timeframes, 3) FEMA flood zone designations, and a storm surge analysis that can contribute to redefining the Coastal High Hazard Area.

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Current Tidal Flooding Hotspots: King Tide and Compound Flooding

In the sampling phase of this project, SFRPC staff visited North Bay Village during September, October, and November on the days corresponding to peak predicted King Tides. Staff met with city officials and visited a handful of well-known flooding hotpots within the city. Additional locations were investigated based on low-lying areas identified beforehand in a GIS analysis. Because King Tides often occur in conjunction with other climatic events that influence sea level, such as precipitation, storms, or severe wind, a distinction must be made between the impacts of King Tides alone and compound flooding. i.e. the additive flooding result of various influences. For example, it was found in Part 1 of this project that during years where King Tides coincided with other factors, such as hurricanes, tides were at least six inches higher than years where this compounding effect did not occur (Table 1).

Year	Day	Max Height (Ft. NAVD88)	Compounding Effect
2011	9-Nov	1.34	
2012	28-Oct	2.12	Hurricane Sandy
2013	17-Oct	1.67	
2014	7-Oct	1.51	
2015	27-Sep	2.07	Super moon
2016	16-Oct	2.11	Hurricane Nicole

Table 1: Maximum verified tide heights referenced to NAVD88, measured at Virginia Key.

To account for these different scenarios, two different heights were modeled: King Tide flooding only, and compound flooding, comprised of King Tide flooding and additional effects. Both scenarios were observed during the fall 2016 King Tides. September's tides were substantially smaller than those observed in October, where impacts from Hurricane Nicole were likely present. This difference is shown in Figure 1. Because elevations in North Bay Village generally protect against minor increases in tide, very little flooding was observed in September, which agreed with the mapped results. However, October's flooding was far more apparent, especially in the southwest corner of Treasure Island. Roads and adjacent low-lying property were especially susceptible (West and South Treasure Drive, as shown in Figure 1) due to lower elevations surrounding private property.

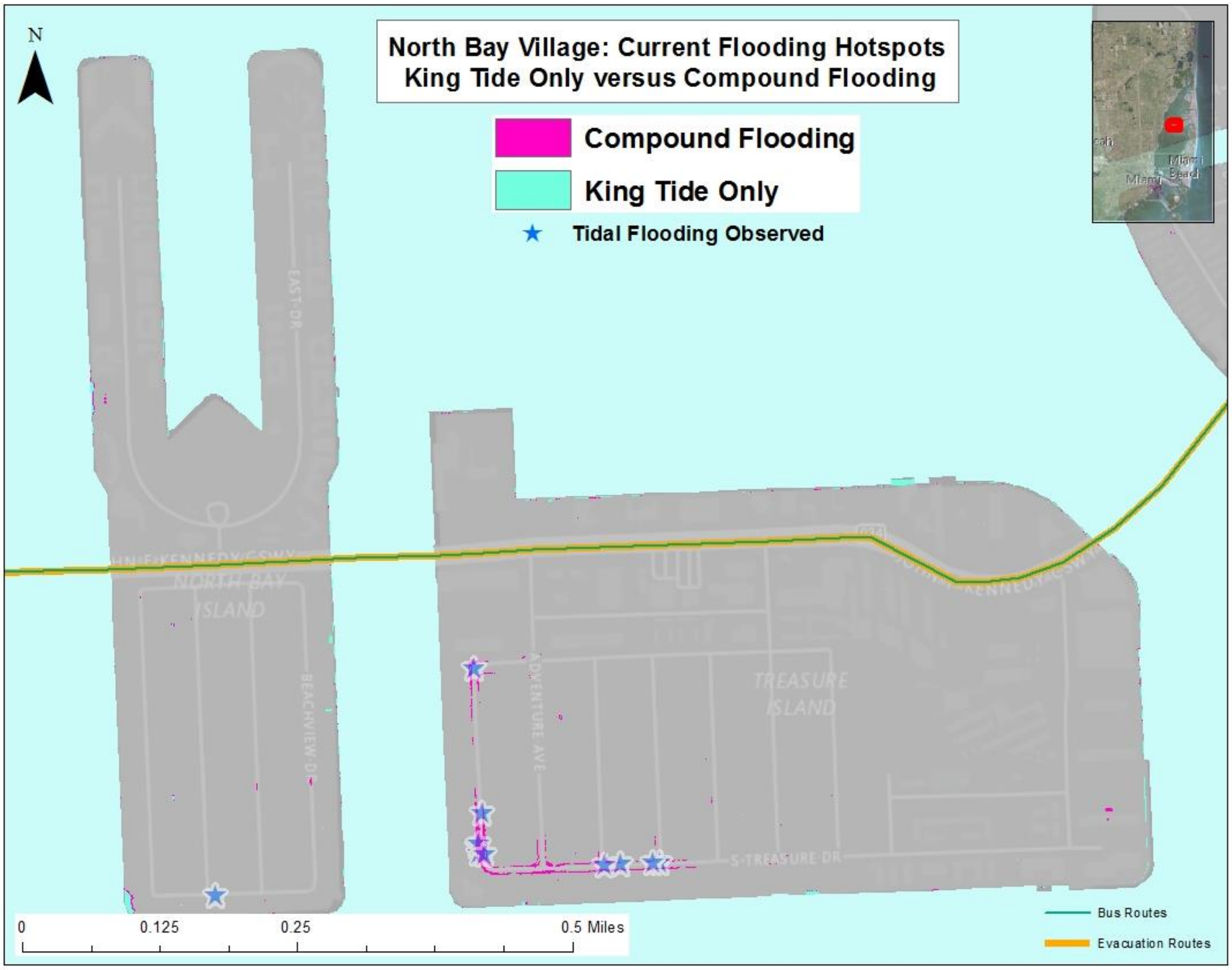

Figure 1: King Tide and compound flooding hotspots in North Bay Village.

Figure 2: Storm drain upwelling in North Bay Village during October 2016 King Tides.

Flooding during peak tides was exacerbated by storm drain upwelling, shown in Figure 2; in this case, an SFRPC staff member measured roughly 3.5 inches of standing water above a storm drain along West Treasure Drive. This happens when coastal water pressure increases due to abnormally high tides, causing backflow to occur. This also impedes, and in some cases prevents, the normal draining that occurs otherwise. Saltwater is also more corrosive than freshwater, leading to more aggressive rusting and structural breakdown, thereby shortneing the lifespan of stormwater infrastructure.

Rapid flooding and insufficient storm water infrastructure causes water to pond in streets and onto sidewalks in North Bay Village. When the carrying capacity of storm water infrastructure is exceeded, water begins to outflow via alternative routes. Figure 3 shows water bubbling through street light infrastructure; again, this can be problematic due to the corrosive nature of salt water, which more rapidly degrades the concrete and metal components intended to provide protection to vital electrical systems.

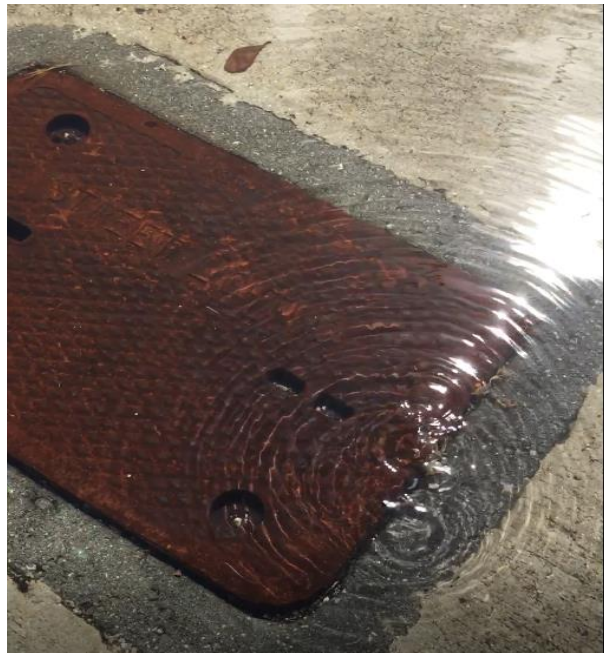

Figure 3: Flood water draining through street light system cover.

Figure 4 provides a visual of infrastructure breakdown due to the corrisive effects of salt water flooding or groundwater instrusion. This type of damage applies to water infrastructure, as well as building foundations and other types of reinforced concrete structures that may be increasingly subjected to inundation (Broomfield, 2002).

Figure 4: Reinforced concrete infrastructure corrosion. Image courtesy of TheConstructor.org.

Transportation networks in the Village suffer impedences as well; Figure 4 shows South Treasure Drive, where SFRPC staff members measured roughly a foot of standing water in some areas. Standing water slows traffic, limits pedestrian accessibility, and because of the corrosive nature of salt water, can be highly damaging to vehicles and adjacent vegetation that is not accustomed to high salinity.

Figure 5: Flooding on S. Treasure Drive during October 2016 King Tides.

Figure 6: Inundated roads and damaged lawns in North Bay Village.

North Bay Village's Planning and Zoning Board is presently in the process of performing infrastructure improvements to their storm and wastewater systems to address leakages typical of aging pipes. A byproduct of the leaking infrastructure is the deterioration of road foundations caused by the removal of fine sediment in the soils underneath.

As pipe outflow washes these "fines" away, the larger sediments settle, causing depressions in the roadway above where more structurally sound foundations are absent. Rising sea levels and increasing flood frequency may pose similar issues for the structural integrity of North Bay's road and other infrastructure networks. Figure 6 and Figure 7 show flooded streets in North Bay Village; water also pools at the base of driveways and adjacent lawns.

Figure 7: Flooded driveways and roads in North Bay Village.

Sea-Level Rise Timeframes

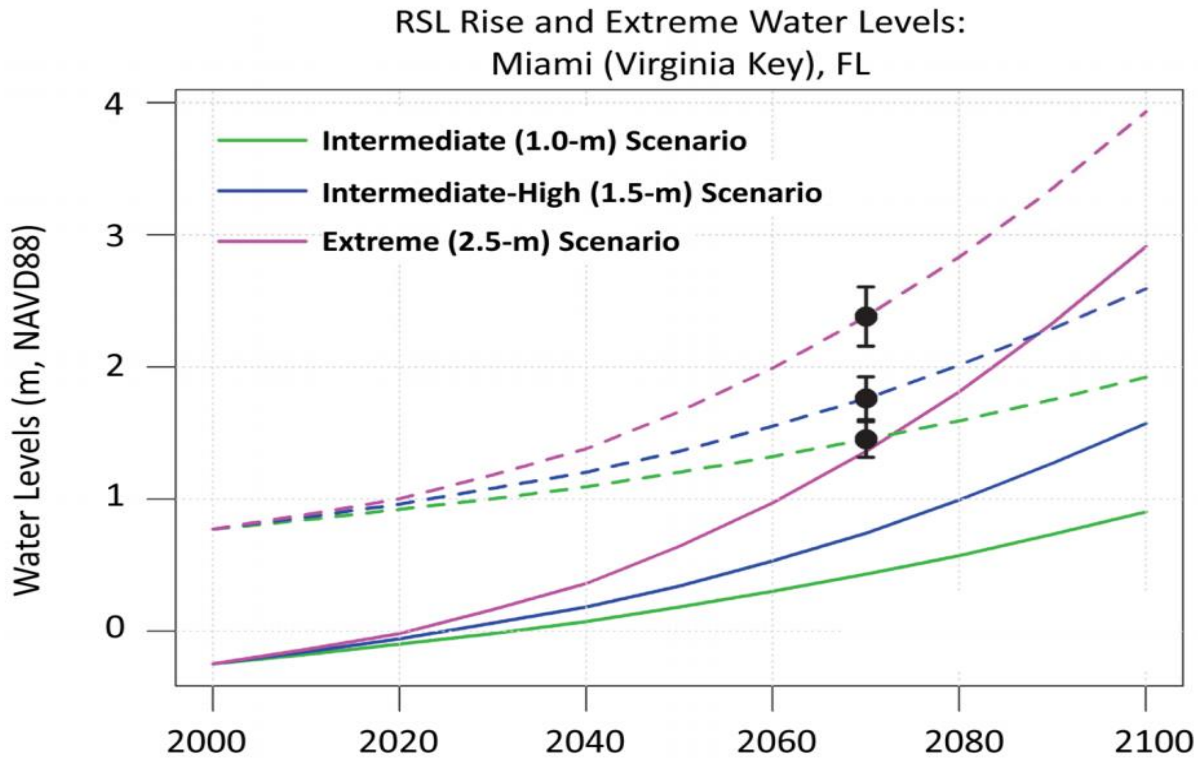

Figure 8: NOAA projections from 2017 NOS CO-OPS technical report 083.

Figure 8 presents several relative sea-level rise scenarios at Virginia Key in Miami, FL (shown as solid lines) from NOAA's recent *Global and Regional Sea Level Rise Scenarios for the United States*[1]. These projections reference NAVD88, a geodetic datum, rather than mean sea level, a tidal datum, as "0". In Key West, NAVD88 is 0.27 centimeters (0.11 inches) above local mean sea level for the 1983-2001 tidal datum epoch.

The names for each of these scenarios are taken from global mean sea level (GMSL) rise projections, which differ from relative sea level (RSL) rise rates due to a variety of factors, such as subsidence, tectonic uplift, and changing ocean circulation. Dotted curves represent the 1% annual chance of occurance for each senario.

Table 2: Global and Key West relative sea-level rise predictions from 2017 NOAA CO-OPS technical report 083.

	Intermediate	Intermediate-High	Extreme
GMSL rise 2000 to 2100	1.0 m	1.5 m	2.5 m
Key West RSL in 2070 (relative to NAVD88)	0.43 m	0.76 m	1.38 m
Key West sea-level rise in 2070 since 2000	0.68 m	1.01 m	1.63 m

[1] Full report here: https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

Figure 9 displays sea-level rise projections from the Southeast Florida Regional Climate Compact's Sea Level Rise Working Group in 2015[2]. These projections use the year 1991 and mean sea level in Key West, FL as the reference point. 1991 is the midpoint of the current National Tidal Datum Epoch (1983-2001), and the most commonly used baseline at present.

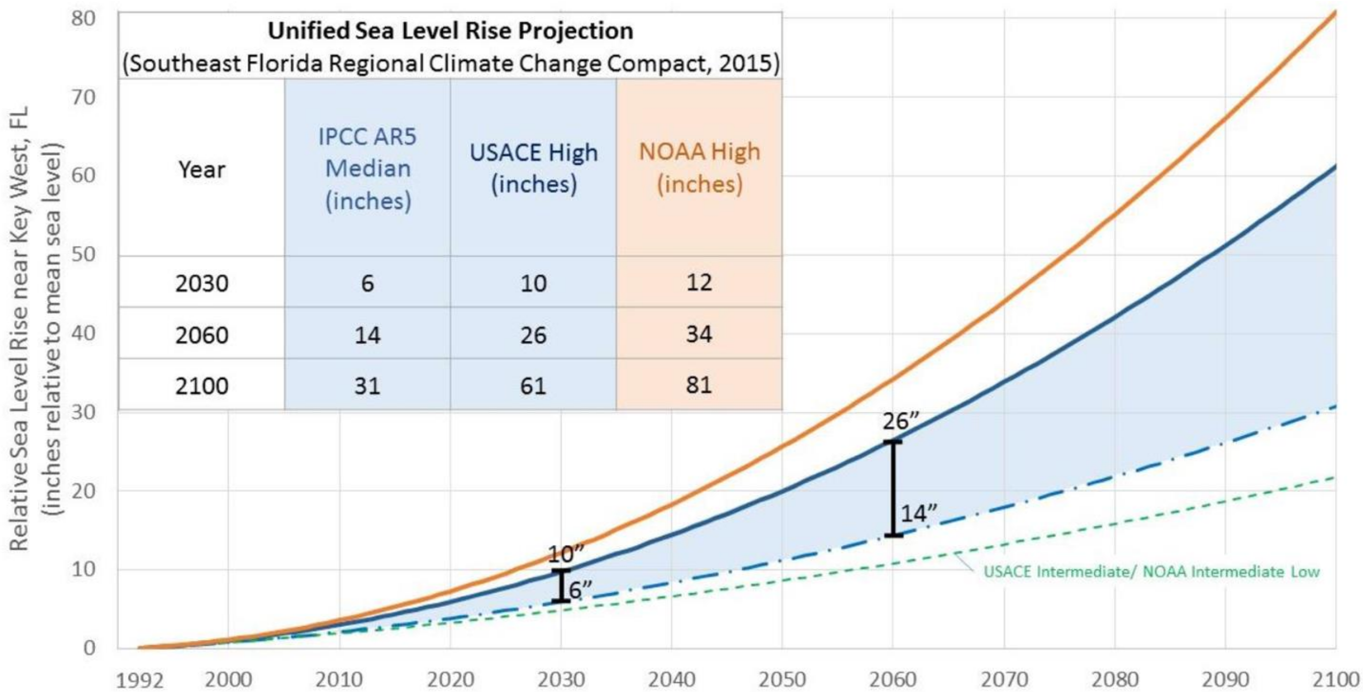

Figure 9: Multiple projections from 2015 Southeast Florida Regional Climate Compact's Sea Level Rise Working Group.

The shaded blue zone in Figure 9 represents the likely range of sea-level rise for the South Florida region. These projections indicate between 6 and 10 inches of sea level rise are anticipated by the year 2030, over the 1992 baseline. Similarly, between 14 and 26 inches are anticipated by 2060 over the same baseline. For convenience, the report also provides corrections to future increases based on estimations of sea-level rise that has, or will have, already occurred for years 2015–2019. For example, 2.6 to 5.1 additional inches of sea-level rise are expected between 2017 and 2030. Similiary, an additional 10.6 to 21.1 inches of rise are expected between 2017 and 2060. This distinction is important—for example, 12 inches of sea-level rise above the 1992 tidal datum epoch's mean sea level, as projections are usually reported to maintain consistency, is differenct than 12 inches of sea-level rise over 2017 local mean sea level, as increases have already occurred between 1992 and 2017.

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[2] Full report here: http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2015/10/2015-Compact-Unified-Sea-Level-Rise-Projection.pdf

Sea-Level Rise Risk

Recurrent tidal flooding during extreme tide events provides a real-world model of likely sea-level rise scenarios, and serves as an invaluable tool when it comes to assessing vulnerabilities and the efficacy of mitigation techniques. Figure 10 is a map showing current and future flooding hotspots based on 2015 LIDAR collected elevation data. Areas where intermittent nuisance flooding occurs are shown in red. The results below appear to indicate lower elevations along the southern portions of the three islands—this was done intentionally during the original dredging in an attempt to promote storm and floodwater drainage. As discussed in greater detail in Parts I and II of this project, these calculated hotspots correspond to in situ measurements taken during the annual King Tides in the fall of 2016, and were corroborated by city officials during the interview phase.

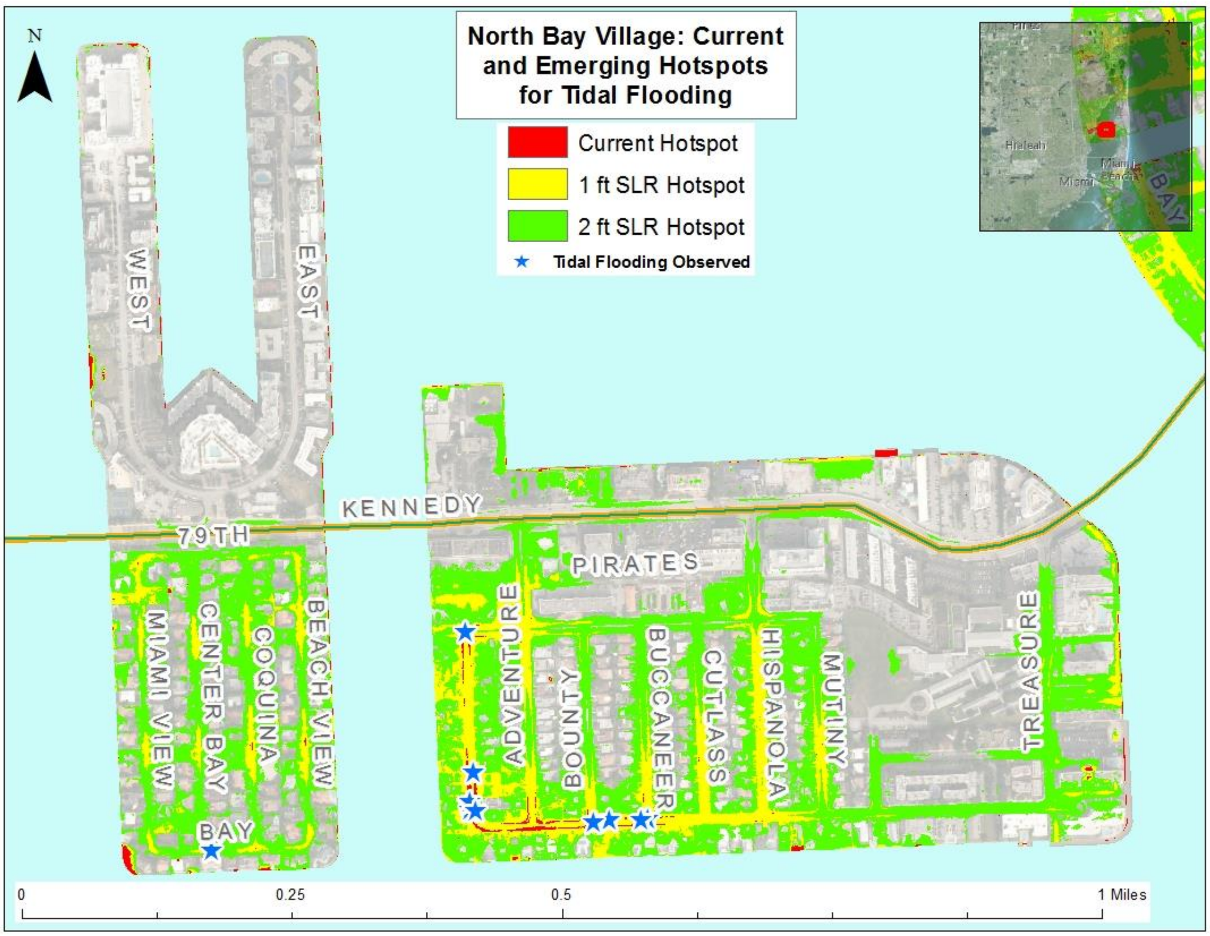

Figure 10: 1 and 2-foot sea-level rise scenarios above 1991 baseline for North Bay Village.

The heights in Figure 10 use the 1991 baseline, as is standard in sea-level rise modeling. As reported in Figure 9, the earliest year within the reported likely range for a 1 foot rise is roughly 2035; the latest based on the same likely range is approximately 2055. Using the same range of predictions, 2 feet of rise is likely to occur between 2055 and 2085.

Federal Emergency Management Agency (FEMA) Flood Zones

Figure 11 shows flood zones and base flood elevations (BFEs) for North Bay Village as of May 2016. All of North Bay Village is within flood zone AE—all zone A areas are predicted to have a 1% chance of flooding annually. The BFE is the modeled height (relative to NAVD88) to which flood waters are expected to rise during a 100-year storm (1% chance annually). These values are generally rounded to the nearest foot. BFE values are used in conjunction with a structure's elevation to assist in the determination of the flood insurance premiums.[3] Per National Flood Insurance Program (NFIP) regulations, the top of the lowest floor of a building within an A Zone must be elevated, at a minimum, to a foot above the BFE, and homes with federally-backed mortgages within this zone must carry flood insurance. Any finished areas below the BFE may violate NFIP requirements and be subject to higher premiums and/or unreimbursable flooding.[4]

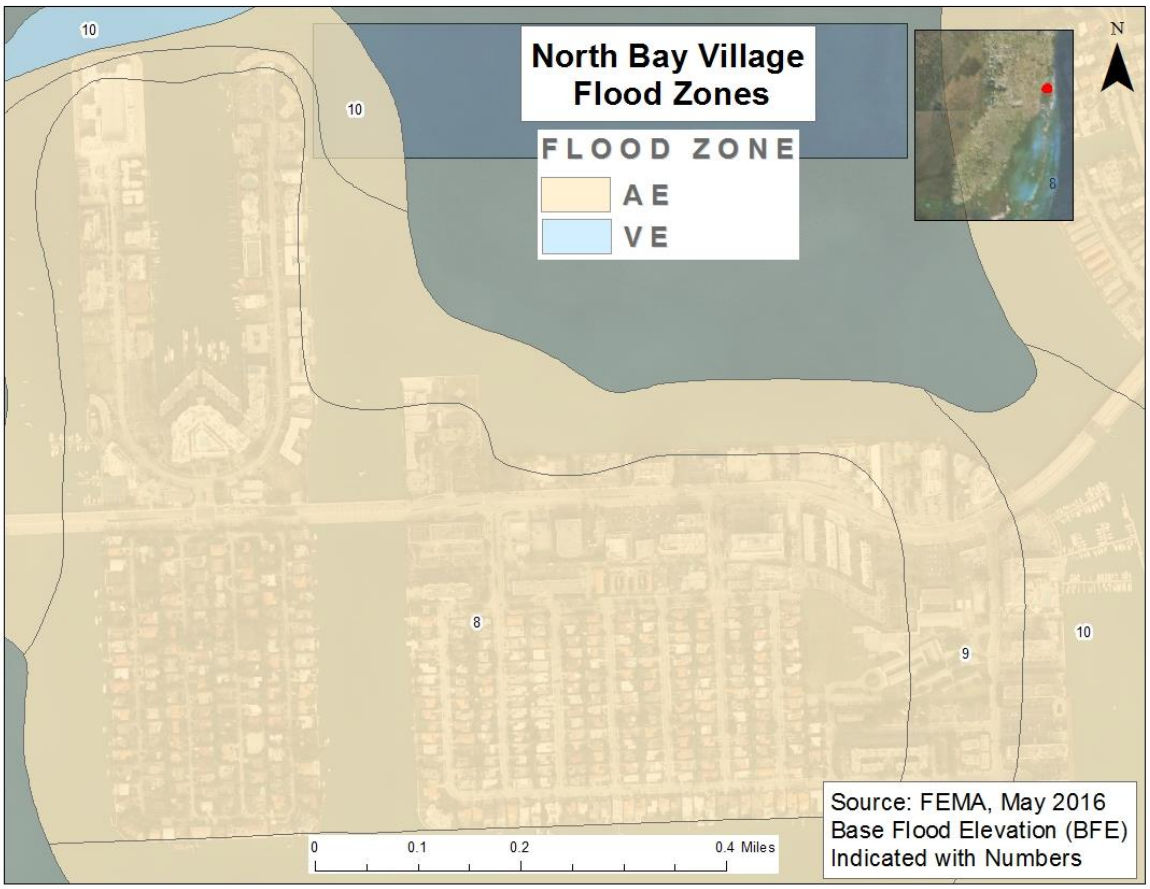

Figure 11: BFE and flood zone map for North Bay Village

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[3] More information can be found here: https://www.fema.gov/faq-details/Base-Flood-Elevation-BFE

[4] More information can be found here: https://www.fema.gov/media-library-data/20130726-1537-20490-8154/fema499_1_4.pdf

Figure 12 visually explains BFEs and freeboard measurements in two coastal flood zones; North Bay Village is entirely within Zone A. As mentioned previously, it is recommended that the bottom of the lowest floor be at least a foot above the BFE in Zone A; this distance is known as freeboard (FEMA, 2013). Increasing a building's freeboard measurement can decrease flood insurance premiums; according to FEMA, the cost of adding additional freeboard at the time of home construction is relatively modest, and costs can usually be recouped quickly via reduced premiums. The home in Figure 12 is shown on stilts, however freeboard can be increased by using fill underneath home foundations, increasing foundation height, or building a non-livable storage space underneath the ground floor.

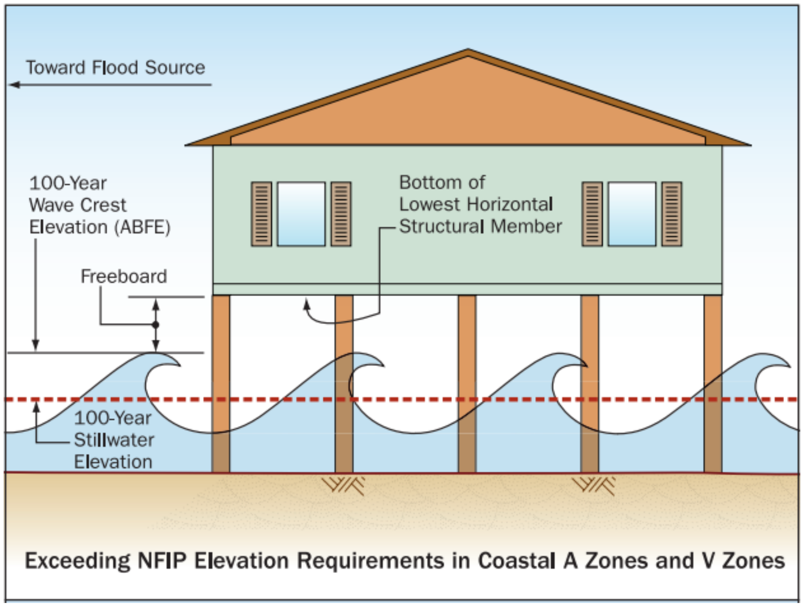

Figure 12: Recommended building elevations for A and Z Flood Zones. Courtesy of FEMA.gov.

Storm Surge Risk

Storm surge is a temporary rise of coastal waters, in exceedance of typical astronomical high tides, generated by a tropical storm or hurricane. This rise occurs when offshore wind essentially "piles" water along the coastline, creating a surge of water that often leads to inland flooding. This flooding can be made worse when surge coincides with normal high tides, as shown in Figure 13.

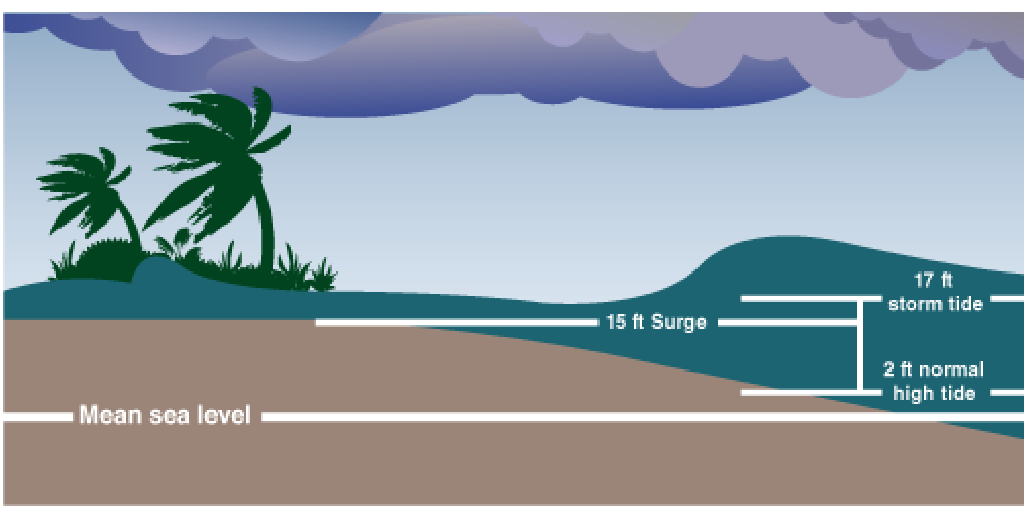

Figure 13: Mean tide, high tide, surge, and surge tide. Diagram courtesy of NOAA.

The Coastal High Hazard Area (CHHA) is a region along the coast that is particularly vulnerable to coastal flooding from tropical storms and hurricanes. It is defined by section 163.3178(2)(h) of the 2016 Florida Statutes as "the area below the elevation of the category 1 storm surge line as establish by a Sea, Lake, and Overland Surges from Hurricanes (SLOSH) computerized storm surge model." Florida Statutes also dictate that local governments clearly delineate this zone on future land use maps, and generally limit public expenditures that subsidize development in the CHHA. [5]

In 2016, the National Oceanic and Atmospheric Administration (NOAA) and the National Hurricane Center (NHC) released a significantly updated surge basin for South Florida—this new model has drastically improved resolution and accounts for additional hydrological processes previously excluded from older SLOSH models. The inclusion of these additional hydrodynamic mechanisms, as well as the consideration for up-to-date mean tide heights, into the new model has dramatically altered maximum wave heights in all regions along the coasts. This necessitates updating additional comprehensive plans.[6]

Figure 14 shows the current CHHA based on the new 2016 surge model and the most recent 2015 LIDAR-derived elevation data, collected by Miami-Dade County. Red zones indicate areas that are likely to be vulnerable to inundation during a category 1 hurricane at mean tide.

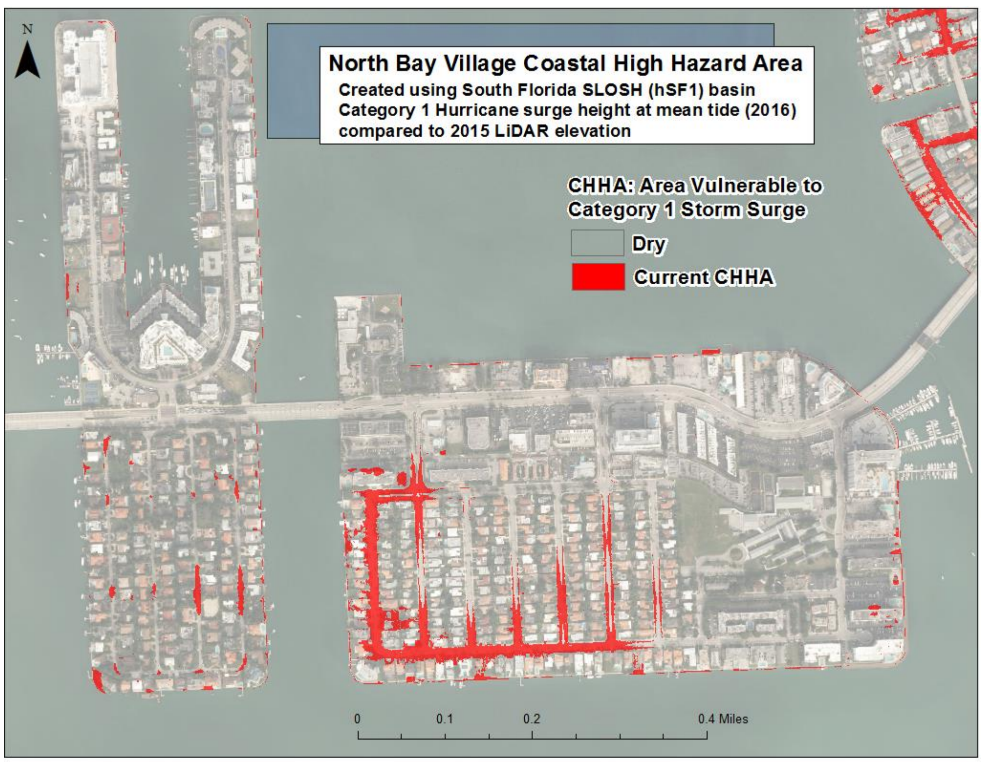

Figure 14: Current Coastal High Hazard Area, North Bay Village.

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[5] More information can be found here: http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0100-0199/0163/Sections/0163.3178.html

[6] Full mapping methodology can be found here: https://coast.noaa.gov/data/digitalcoast/pdf/coastal-inundation-guidebook.pdf

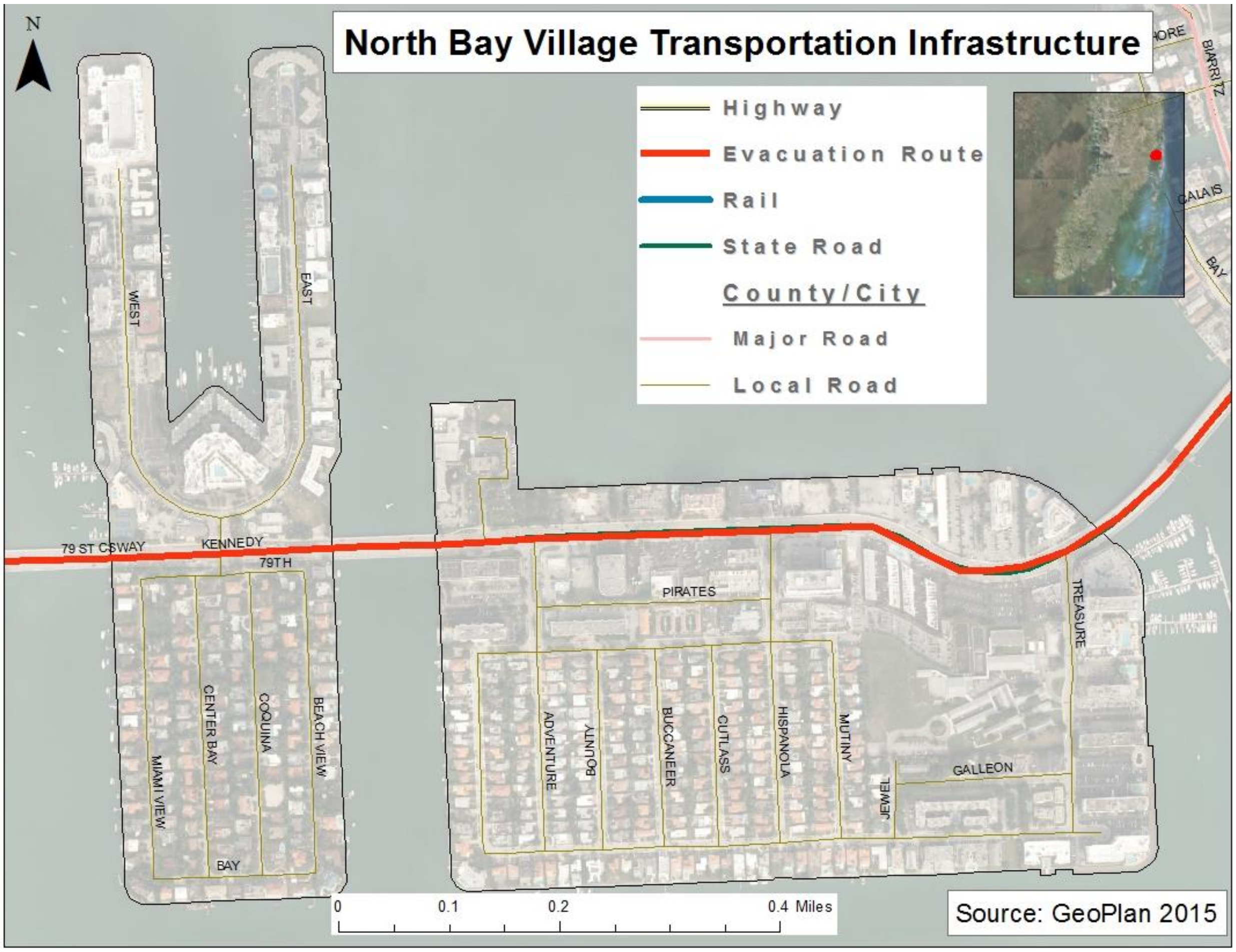

Figure 15: Transportation infrastructure classification map, per GeoPlan 2015.

Figure 15 displays transportation infrastructure in North Bay Village. The 79th Street Causeway, North Bay Village's evacuation corridor, is safe from inundation based on the projections presented in this report; it is located towards to central and north portions of the islands, where elevations are higher, and the road itself is raised above the surrounding side streets. To maintain access to the route, the Village will need to continue to implement protections for neighboring side streets.

Conclusion

This three-part project addresses tidal flooding hotspots and current and future infrastructure implications of such flooding. Ground truthing current flood models provides valuable insight into methodological accuracy, especially when coupled with first-hand accounts of inundation extents with local officials. Additionally, the results of this project should serve as a window into likely projected future sea-level rise scenarios; current seasonal King Tide flooding will closely mimic sea-level rise inundation patterns, which may prove useful in the implementation of mitigation strategies.

The report goes beyond a simple assessment of flooding extent by extending the investigation into flooding consequences. Gleaned through surveying local officials within the six pilot communities in the study and working directly with city managers in North Bay Village, the results presented in this report summarize current flooding implications. While the Village has made strides in flood mitigation, and continues to seek out additional resources for flooding and sea-level rise mitigation, the 2016 King Tides were found to be problematic for transportation networks, damaging to property, and potentially causing unanticipated corrosion to public infrastructure.

These specific issues are discussed further in Part 3B of this series, as well as other measures to increase infrastructure resilience and generally decrease coastal vulnerability to flooding and sea-level rise. While this series is not meant to serve as a comprehensive guide to tidal flooding and its impacts on infrastructure, it does provide a strong foundation on which both North Bay Village and other municipalities in the region can work from to continue addressing present and future flooding through a variety of mitigation techniques.

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Appendix of Metadata

Miami Dade 2015 LIDAR Metadata

Bare-earth 5-foot DEM as 32-bit floating point raster format in ARCGIS GRID Raster format in compliance with USGS LIDAR Base Specifications such as: georeferencing information, delivered without overlap and with no edge artifacts or mismatched, “NODATA” value for void areas, bridges removed from the surface, etc. This is a Digital Elevation Model (DEM) as a raster mosaic in ESRI float format 32bit representation on a 5ft grid created from the LIDAR collected for the 2015_ITD_LIDAR project for the Miami-Dade County Information Technology Department (ITD). The DEM extent is Miami-Dade County as provided by ITD users should be aware that temporal changes may have occurred since this dataset was collected and that some parts of the data may no longer represent actual surface conditions. Users should not use the data for critical applications without a full awareness of the limitations of the data. The data was collected under the supervision of a Florida licensed Surveyor and Mapper in compliance with Florida Statute 472.000 This control is adequate to support the accuracy specifications identified for this project.

The surveyor’s report documents and certify the procedures and accuracies of the horizontal and vertical control, aircraft positioning systems, and system calibration procedures used in this LIDAR mapping project. The horizontal and vertical control is based on direct ties to National Geodetic Survey (NGS) control stations, National Spatial Reference System (NSRS). The horizontal control references the North American Datum of 1983/NSRS current published datum (NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet). The vertical control references the NAVD88 using Geoid 12A to perform computations from ellipsoidal heights to orthometric heights. The vertical accuracy of the newly-established ground control is within one third of the specified LIDAR Fundamental Vertical Accuracy. All surveying & mapping performed for this project meets or exceeds FEMA Flood Hazard Mapping Program, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, Section A.5 Ground Control, and Section A.6 Ground Surveys and as superseded by Procedure Memorandum No.61 – Standards for LIDAR and Other High Quality Digital Topography, 27 September 2010. ACA collected the data at 8 points per square meter providing a spacing of 0.35m spacing at nadir. This product meets or exceeds the stated specifications for the state of Florida. Horizontal accuracy was tested to meet or exceed a 3.8-foot horizontal accuracy (2.2 foot RMSE) at 95 percent confidence level using RMSE(r) x 1.7308 as defined by the Federal Geographic Data Committee’s (FGDC) Geospatial Positioning Accuracy Standards, Part 3: NSSDA.

Projected Coordinate System: NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet</horizpar></horizpa><vertacc><vertaccr>This product meets or exceeds the stated specifications for the state of Florida.

The Fundamental Vertical Accuracy for LIDAR data over well-defined surfaces was tested to meet or exceed a 0.60-foot fundamental vertical accuracy in open well defined terrain at 95 percent confidence level using RMSE(z) x 1.9600 as set forth in the FGDC

Geospatial Positioning Accuracy Standards, Part 3: NSSDA. For the purpose of this document, open terrain is defined as unobscured, consolidated surfaces, with minimal slope (5%) and may contain low-lying grasses through which LIDAR pulses can penetrate; LIDAR errors in these areas will have a statistically normal distribution with a mean = 0 and variance = 1. Vertical accuracies will meet the 95 percent confidence level for open terrain, assuming all systematic errors have been eliminated to the greatest extent possible and the errors are normally distributed. A minimum of thirty (30) check points per each land cover were be distributed throughout the project area and collected for each of the following land cover categories and reported in the FVA report: Urban; Bare ground/short grass; and Brush (i.e. low lying vegetation). Check points are distributed so that points are spaced at intervals of at least ten (10) percent of the diagonal distance across the dataset and at least twenty (20) percent of the points are located in each quadrant of the dataset per 500 square mile block. See vendor's report. North American Vertical Datum of 1988 (NAVD88 The project was divided in two phases: Collection and classification of LIDAR data; and building height extraction.

The LIDAR data was collected utilizing a Riegl LMS-Q680i in a Cessna 206 from an approximate altitude of 1,800 feet above ground level, an approximate ground speed of 110 knots at a pulse rate repetition of 400kH, resulting in a minimum of 8.2 points per square meter. The sensor used a 60 degree field of view. The project was flown to have 50 percent overlap between swaths. The Global Positioning System (GPS) data were processed using Applanix POSPac Mapping Suite version 7.8 using Smart Base method and single base methods. A fixed bias carrier phase solution was computed in forward and reverse directions. The LIDAR collection took place when Positional Dilution of Precision (PDOP) was at or below 3. Occasionally, the PDOP rose slightly above 3. This had no effect on the data. The GPS trajectory was combined with the IMU data using the Applanix POSPac software. The resulting Smoothed Best Estimate of Trajectory (SBET) was exported and used in Riegl RiProcess software to compute the laser mass point positions in Northing, Easting, and Elevations coordinates. The raw laser data were merged with the SBET using Riegl Ri Process software. The data set was processed using RiProcess, RiAnalyze, and RiWorld software where each flight line was processed to a point cloud.

The data was adjusted flight line to flight line using Riegl's Scan Data Adjustment tool to ensure a proper relative calibration match between flight lines. Each flight was checked for project coverage, data gaps between overlapping flight lines, point density and then exported in LAS 1.3 format. The entire project was collected without gaps.

The LAS files were projected to the NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet and North American Vertical Datum of 1988 (NAVD88). Ellipsoidal heights were converted to orthometric heights using the current Geiod12A. The LAS files were imported to TerraSolid, LTD TerraScan software to be classified to bare earth ground and later feature coded to USGS specifications. The LAS files contain 8 classifications: 1 = unclassified; 2 = ground; 7 = noise points; 9 = water; 10 = buffered ground points surrounding breaklines; 12 = overlap; 15 = overpass and bridges.

The tiles dataset was imported to Digital Transfer Solutions EarthShaper® software to collect breaklines from LIDAR data. The single and double line linear hydrographic features were hydro-enforced with downhill constraints to model correct flow patterns. Water bodies were hydro-flattened to ensure uniform elevation across the feature. The data were adjusted flight line to flight line using Riegl's Scan Data Adjustment tool to ensure a proper relative calibration match between flight lines. Each flight was checked for project coverage, data gaps between overlapping flight lines, point density and then exported in LAS 1.3 format. The LAS files were imported to TerraSolid, LTD TerraScan software to be classified to bare earth ground and later feature coded to USGS specifications. The LAS files contain 8 classifications: 1 = unclassified; 2 = ground; 7 = noise points; 9 = water; 10 = buffered ground points surrounding breaklines; 12 = overlap; 15 = overpass and bridges.

DEMs were created using QCoherent LP360 software. The bare-earth LAS data was loaded into the software along with the tile layout and hydro shapefile collected from the LAS data set. DEMS were produced at a 5ft cell size and hydro-flattened. To QC the DEMs Global Mapper was used to check for completeness of the tiles and that the hydro features were flattened and represented correct elevations. Once the QC was complete the files were exported out of ArcGIS to create Arc DEMS.

The LIDAR data ran through an automated ground and building classification using terrascan software. A manual check of the building classification was done in LP360 and terrascan. The provided building shapefile was loaded and data cross sections were taking to check the classification of the outlined buildings. Once the manual check was completed the building LAS points were loaded into LP360 along with the building polygon shapefile supplied by ITD. In LP360 a confliction was ran to drape each building polygon to the max Z value of LAS data found in each polygon. To QC the auto process the building polygon shapefile was brought into ArcGIS using LP360 to take cross sections of the data to check the building polygon Z value.

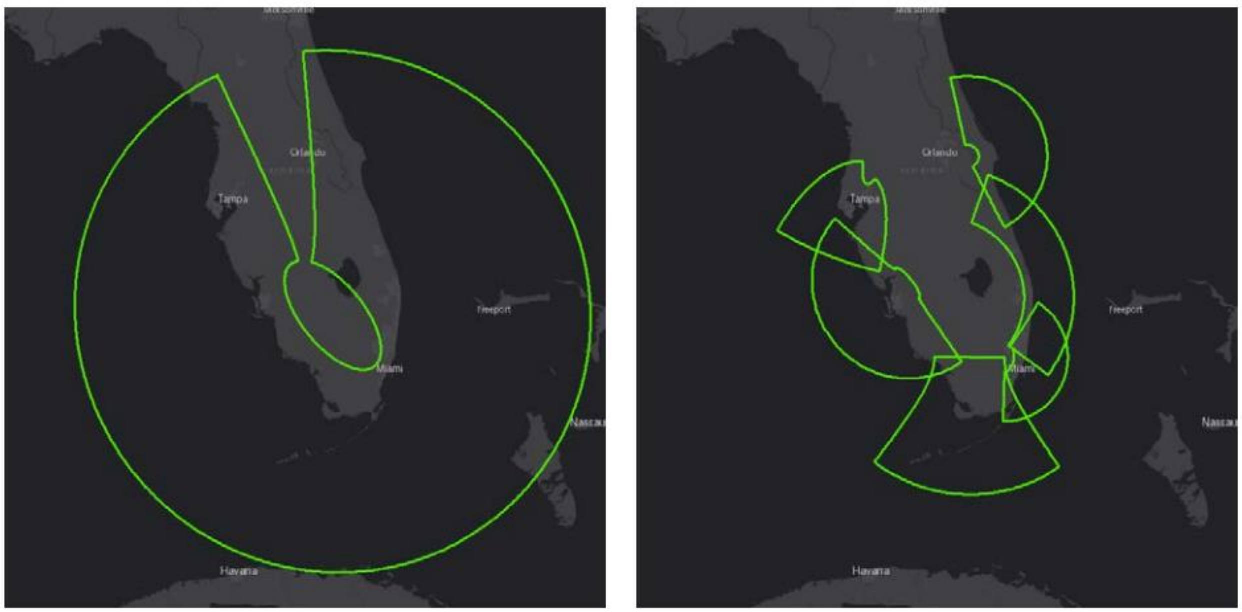
After all the building data was quality controlled and assured we joined the field height to complete the geodatabase BuildingPlanimetrics_from PSDE3.gdb provided by the county. Any building with a height value of 0 represents a building that did not exist in the LIDAR dataset.

The building geodatabase remained as ITD provided it projected horizontally to the NAD_1983_ StatePlane_Florida_East_FIPS_0901_Feet, and vertically to the North American Vertical Datum of 1988 (NAVD88).

COLLECTION DATES: 2/15/15, 2/17/15, 2/18/15, 2/19/15, 2/20/15, 2/21/15, 4/2/15, 4/3/15, 4/11/15/, 4/12/15, 4/13/15.

DEM raster dataset for Miami-Dade County. 366 flight lines of data were collected.

Project Background: For the National Hurricane Program (NHP), storm surge planning and operational products in the state of Florida are spread across 11 SLOSH basins. This often leads to confusion about which SLOSH grid to use for a particular area. In addition, areas of basin overlap between the 11 SLOSH basins results in discontinuities at the grid boundaries. To alleviate these problems and potentially simultaneously update study areas previously covered by six SLOSH basins, a single large basin "Superbasin" was developed (see Figure 1) covering all of South Florida. The grid is 424X1500 for a total of 636,000 grid cells, making it the basin with the most grid cells to date. Implementation of the South Florida Superbasin incorporated additional benefits following new research and improvements to the SLOSH modeling system.



South Florida SLOSH (hSF1) basin (left) and SLOSH grids that can potentially be replaced (right).

Improvements: The west coast of Florida can experience an abnormal rise in water by a storm traveling northward off the coast from a phenomenon known as a coastal Kelvin wave. This occurred during Hurricane Dennis in 2005. Water levels from South Florida through the Panhandle were elevated an additional 3-4 feet above the predicted water levels along the coastline due to a coastal Kelvin wave. The current SLOSH basin configurations and modeling techniques do not allow the full effects of coastal Kelvin waves to be captured along the coastline – water level information is not passed from one SLOSH basin to the next. The new South Florida SLOSH basin eliminates this problem by having one basin that spans from the west coast of South Florida and into North Florida. Ultimately, this new basin allows the increased water levels associated with a coastal Kelvin wave to be captured in the MOMs/MEOWs along the west coast of Florida.

Central and South Florida are estimated to have 469,000 acres of mangrove forests. Recent research has shown that mangroves are effective at reducing the magnitude and inland extent of storm surge inundation (Zhang et al., 2012). One must properly account for the frictional effects of mangroves when modeling storm surge in Florida. The National Hurricane Center (NHC) has developed a new friction parameterization to take into account the attenuation effects of mangroves for the South Florida SLOSH basin. This modification provides a more accurate simulation of the storm surge in this region, which is critical to the NHP.

Publication: Zhang, K., H. Liu, Y. Li, X. Hongzhou, S. Jian, J. Rhome, T.J. Smith III: 2012. The role of mangroves in attenuating storm surges. Estuarine, Coastal and Shelf Science 102, 11-23.

Specifically, the SLOSH slip coefficient was modified to allow for increased friction in shallow water and over land. A slip coefficient of 0.009 was used in shallow water depths from 1 ft to 30 ft (water depth + storm surge). A slip coefficient of 0.25 was used for over land cells up to 56 ft that become inundated by storm surge. The bottom stress coefficients were calculated using the new shallow water- and overland-dependent values for the slip coefficient.

The following briefly outlines the changes made to various subroutines in the SLOSH source code 'runslhg.f'. The subroutines modified are: 'BTMSTR(ZLATO)', 'FLW1DM', 'FRCPNT', 'MOMNTM', and 'MNTMBD'. The bottom stress coefficients were calculated using the new shallow water- and over land-dependent values for the slip coefficient. This was handled by using 2-dimensional arrays for the variables in the 'SCND' common block. Array dimension 1, index 1 in the common block arrays is for the shallow water modification and dimension 1, index 2 is for the over land modification. The calculation of the new bottom stress coefficients is in subroutine 'BTMSTR(ZLATO)'. In the other subroutines, a check for land cells is conducted to invoke the proper index for the bottom stress coefficient arrays. Extremely minimal, if any, slow-down of the SLOSH code was observed due to this modification.

Verification: The new friction parametrization and grid configuration was validated against high water marks and inundation extents as well as other numerical modeling results (Zhang et al., 2013) for Hurricane Wilma (2005) and Hurricane Andrew (1992).

Publication: Zhang, K., Y. Li, and H. Lui, J. Rhome, and C. Forbes. 2013: Transition of the Coastal and Estuarine Storm Tide Model to an operational forecast model: A case study of Florida. Weather and Forecasting 28, 1019-1037.