Climate Change Vulnerability Analysis: Potential Current and Future Climate Change Hazards from Sea Level Rise, and Flood Risk from Precipitation, for Sunrise, FL

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CLIMATE CHANGE VULNERABILITY ANALYSIS

Potential Current and Future Climate Change Hazards from Sea-Level Rise, and Flood Risk from Precipitation, for Sunrise, FL.

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April 6th, 2018

THE INSTITUTE FOR WATER AND ENVIRONMENTAL RESILIENCE
STETSON UNIVERSITY

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The information provided in this Vulnerability Assessment does not undertake an evaluation of risk on individual properties, homes or businesses. The analysis is limited to relationships between Sunrise stormwater features, interconnections of those features to the South Florida Water Management District regional drainage system, Sunrise and other critical facilities located within Special Flood Hazard Areas, road sections within Special Flood Hazard Areas and saltwater intrusion. For individual property level inquiries about future impacts related to flood risk, inquiries should be directly made to engineering or insurance professionals.

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EXECUTIVE SUMMARY

Proactively planning for the wise use of resources and becoming more resilient to future climate impacts, or the ability to recover from weather events, have become integrally linked to sustainability planning. As part of the development of its Sustainability Action Plan, the City of Sunrise ("Sunrise") is including recommendations related to energy, sustainability, and vulnerability. The goal is to develop a set of strategies for Sunrise to more efficiently meet the needs of today while planning for the changing conditions of tomorrow.

This Vulnerability Assessment ("VA") characterizes the potential impacts to Sunrise from changing conditions stemming from climate change. The VA provides an overview of the types of known and anticipated impacts from climate change and makes recommendations for Sunrise to consider in future decision-making. The VA is a first step in preparing for these future conditions and should not be considered a final definitive approach ending at this inquiry. Effective resiliency or vulnerability planning requires an organizational recognition that all relevant decision-making will have to factor in the question:

"How will this decision be impacted in the future by a changing climate?"

The VA represents the foundation of those processes. A goal of the VA is to lay the groundwork for the development of strategies so that Sunrise may more efficiently plan ahead. The VA is based upon data that was gathered from Sunrise and other relevant sources, such as Broward County. The approach included:

- Characterization of Sunrise's stormwater relationship to the regional system and potential future sea level rise impacts;
- Expected future flood risk and assumptions stemming from predicted precipitation patterns;
- Potential strategies for future monitoring of regional water supply impacts from saltwater intrusion;
- Identification of existing Sunrise and critical other buildings, assets and facilities within Special Flood Hazard Areas ("SFHA") to show priorities for further risk inquiry;
- Sunrise's current efforts related to stormwater management and floodplain policy;
- Identification of road segments within SFHAs; and,
- Recent efforts to identify the status of stormwater features, by Basin, that may require retrofits or further analysis.

The VA is data-driven, but it also acknowledges the limitations of available data. As a result, the VA also includes numerous recommendations for: future data collection; mechanisms to consolidate data, or make its use more practical; and, areas where Sunrise should monitor forthcoming information or coordinate with other agencies for a more holistic response. Proactive approaches to resiliency planning are also outlined throughout. Key findings are included in the VA for future consideration by Sunrise. The key findings include:

Climate Data	Climate change and resilience data requires consideration of increased water stresses associated with greater occurrence of high intensity rainfall events that can cause damaging floods, and simultaneously, increased drought. Sea level rise projections from the Southeast Florida Regional Climate Compact ("Compact") or other relevant agencies such as the National Oceanic and Atmospheric Administration ("NOAA") or the U.S. Army Corps of Engineers should be continually reviewed for updates.
Other Data and Monitoring	Because surface runoff capacity downstream of Sunrise could be impacted, new data about the relationship between an elevated groundwater table and the reduction of overall groundwater storage capacity should be monitored.
Stormwater	This report recommends planning efforts to mitigate potential flood risks for finished floor elevations that could be impacted by 25-year and 100-year 3-day storm events. A future conditions hydrological analysis should also be incorporated into future updates of the Sunrise's Storm Drainage Master Plan. Sunrise should evaluate the cost-benefit of pursuing additional "future conditions" credits in the Community Rating System for the 4,641 policies currently effect against the effort to obtain them. Coordination with the Southwest Florida Water Management District ("SFWMD") is critical to address efforts related to sea level rise impacts on coastal structures upon which Sunrise's drainage capacity is linked.
Facilities and Assets	Facilities, municipal and critical, within the SFHA should receive site level investigation using survey quality elevation data and engineering assessments of resistance to floodwater as a critical next step to

	determine present and future vulnerability of facilities within the SFHA. Integration into a GIS management tool could be helpful for future use of this data.
Roads	It is important to maintain an understanding of where potential risks are from future flooding scenarios to maintain critical road access. Where appropriate, this may necessitate coordination with other agencies or jurisdictions that are responsible for certain roadway systems.
Water Supply	Further monitoring and investigation of potential saltwater intrusion into Sunrise's groundwater supply may be warranted.

By no means are these conclusions the only steps that Sunrise can proactively take to become a more resilient community. Continued and enhanced coordination, and in particular data exchange, with other agencies including Broward County, the SFWMD, the U.S. Army Corps of Engineers and Florida Department of Transportation is critical for accurate harmonized planning.

BACKGROUND AND PURPOSE

Climate Change and Regional Flood Risk

The world's climate scientists are in agreement that modern human activity is contributing to the warming of the earth's overall temperature. A wide body of evidence indicates that temperature increases over the past 150 years can be attributed to anthropogenic greenhouse gas ("GHG") emissions, which have already resulted in substantial changes to the global climate system. Climate scientists also widely agree that continued increases in GHG concentration in the atmosphere can be expected to accelerate the rate of global warming and associated climate-related risks over the next several decades.[1]

Southeast Florida has long been recognized as a region that has acute and inherent vulnerabilities to climate-related hazards. The local climate naturally experiences wide variability that historically has included periods of extended drought and water shortages, periods of intense rain and associated threats of flooding, and severe wind and storm surge flooding associated with powerful hurricane strikes.[2] While the development of Southeast Florida over the past 100 years has been made possible by infrastructure and engineering interventions that have made our communities largely resilient to existing climate variability, it is widely acknowledged that accelerated climate change will require substantial adaptation of Southeast Florida's infrastructure and built environment the next several decades and beyond.[3]

Sea-level rise is one of the most immediate and clear climate change stressors affecting communities within the Southeast Florida region. It is apparent that Sunrise, as an inland Broward County community, has much less immediate vulnerability to sea-level rise and tidal flooding as compared to most coastal areas in the Southeast Florida region. However, there are inherent features of the local and regional drainage system that do pose concerns for long-term floodplain management in Sunrise when running sea level rise projections recommended by the Compact for municipal planning purposes. Simply put, being further inland does not mean Sunrise will not be impacted by climate change, or in particular, sea level rise.

Perhaps most notably, the drainage system of Sunrise is reliant upon the functioning of a system of primary drainage canals operated by the SFWMD and additional secondary canals mostly operated by local governments. Sunrise relies on a network of retention lakes and canals which ultimately drain into SFWMD canals: C-11, C-12, C-13, and the North New River Canal. From these canals, stormwater flows east where it is carried to the sea by tidal water bodies. The low slopes within these features already pose a substantial challenge for traditional gravity-based drainage, which is augmented across Southeast Florida through a complex network of water control and pump structures. An inexorable impact of sea-level rise is a lowering of the hydrologic head

difference between coastal receiving waters and inland drainage areas, thereby reducing the volumetric rate at which stormwater can be discharged through existing drainage control structures. This poses challenges to upstream systems that rely on downstream capacity.

Sunrise, like most of Southeast Florida, is characterized by high groundwater tables with substantial connectivity to the surface hydrology. In upland areas of Sunrise that have pervious land covers, the subsurface soils and limestone rock formations that are located above the groundwater table provide substantial amounts of stormwater storage capacity that functionally reduce peak runoff volumes into surface water drainage systems. However, it is widely expected that sea-level rise will elevate the regional groundwater table throughout much of Broward County. An elevated groundwater table would have the unavoidable effect of reducing overall groundwater storage capacity, thereby increasing the surface runoff potential from given storm events. This relationship, as it pertains to Sunrise, is beyond the scope of this assessment but it is an issue for further monitoring by the city.

Although there currently is not clear scientific agreement as to how global climate change will impact future precipitation patterns in Southeast Florida, there is general consensus that risk planners should anticipate periods of more extreme drought combined with an increased probability and severity of extreme rainfall events. The combination of reduced surface water drainage rates and reduced groundwater storage capacity – both of which are already known to be occurring in Broward County – have the effect of increasing flood risks independently of any extreme rainfall event probabilities. In other words, sea-level rise can be generally expected to increase long-term flood risks in Sunrise and other inland communities throughout Southeast Florida, even under the existing range of historic rainfall patterns in which the local and regional drainage infrastructure was originally designed to function.

This report provides a general overview of the current baseline and possible future flood hazards within Sunrise in the form of a vulnerability assessment. This VA is based upon an inventory of data provided by Sunrise regarding essential, critical, and public facilities. These facilities include: (1) emergency preparation and response facilities such as fire stations, police stations, emergency operation centers, and evacuation shelters; (2) major public infrastructure such as wastewater treatment plants, stormwater pump stations, and highways; (3) care facilities such as hospitals, nursing homes, and assisted care facilities; and, (4) key community assets such as schools, government offices, parks, and various City-owned properties.[4] Although, Sunrise does not own or manage all of this infrastructure, or these facilities, their importance to the community as a whole is clear. The analysis does not include a comprehensive assessment of potential flood risks or vulnerabilities associated with private homes and businesses located within Sunrise.

REGIONAL CLIMATE APPROACH

The Southeast Florida Regional Climate Compact

In January 2010, the Compact was formed by Broward, Miami-Dade, Monroe, and Palm Beach Counties as a mechanism for coordinating climate change mitigation, adaptation, and associated policy development across the four counties. The Compact has invested substantial time and resources in the development of technical guidance to assist with sea-level rise planning, assessments, and adaptation for Southeast Florida communities. This includes the development of the *Unified Sea Level Rise Projection*, which provides a consistent baseline range of sea level rise projections that are intended "to aid in understanding of potential vulnerabilities and to provide a basis for developing risk informed adaptation strategies for the region."[5]

The Compact has also developed a list of recommended strategies, best practices, and specific actions for municipalities to adopt and implement through the Regional Climate Action Plan ("RCAP"), which was updated in late 2017 to a RCAP v. 2.0. One of the key items within the RCAP is Risk Reduction and Emergency Management, which is used to prepare "for the inevitable shocks and stresses experienced in Southeast Florida through coordinated and interdisciplinary risk reduction and emergency planning and investment."[6]

Southeast Florida is highly vulnerable to climate change-induced flooding, particularly due to the long-term impacts of sea-level rise and extreme precipitation. It is well-known that a number of coastal cities within Southeast Florida are already facing increases in tidal and stormwater flooding due to the impacts of rising seas. Several of these cities have started to implement intensive adaptation measures intended to reduce these flooding impacts. Inland areas face the challenge of managing higher-volume and frequency rain events that will stress drainage and other infrastructure that could require identification of at-risk facilities and similar adaptation measures. Adaptation measures are complex and involve expense; therefore, it is imperative for Southeast Florida municipalities to collectively engage in proactive and sustained efforts to improve floodplain management and infrastructure planning by assessing future hydrological conditions. The compact has been an important factor in regional response.

FUTURE IMPACTS FROM CLIMATE CHANGE

Sea-Level Rise

As the earth continues to warm from climate change driven increases in temperature, oceans will continue to rise. Contributors to sea-level rise include thermal expansion of sea water, ice melt from land-based sources, and an intricate network of complex feedback loops, including many not fully understood.[7] Sea-level rise can be expected to impact local governments and citizens in southeast Florida through increased flooding, saltwater intrusion of aquifers, adverse effects on stormwater drainage systems, and loss of land from inundation.

Sea-level Rise Analysis

The following polygon feature class files were used as the basis for sea-level rise analyses:

BROW_2040_C3_MHHW_P: Represents areas in Broward County projected to be lower than the adjusted MHHW line at 2040 under the NOAA Intermediate High Sea-Level Rise curve.

BROW_2060_C3_MHHW_P: Represents areas in Broward County projected to be lower than the adjusted MHHW line at 2060 under the NOAA Intermediate High Sea-Level Rise curve.

BROW_2080_C3_MHHW_P: Represents areas in Broward County projected to be lower than the adjusted MHHW line at 2080 under the NOAA Intermediate High Sea-Level Rise curve.

BROW_2100_C3_MHHW_P: Represents areas in Broward County projected to be lower than the adjusted MHHW line at 2100 under the NOAA Intermediate High Sea-Level Rise curve.

These data sets were obtained through the University of Florida's GeoPlan Sea-Level Scenario Sketch Planning Tool, which utilize high resolution Light Detection and Ranging ("LIDAR") elevation data to develop projections of specific areas that will experience daily tidal flooding under future conditions. Inundation surfaces were created using NOAA 2012 sea-level rise projections, NOAA tide gauge data and tidal surfaces, and a 5-meter horizontal resolution Digital Elevation Model; and, tidal surface grids representing MHHW and Local Mean Sea Level ("MSL") in Florida were obtained from NOAA's Office of Coastal Management. Sea-level rise based on the NOAA Intermediate-High projection was added in feet to the local MHHW condition, as based upon the Virginia Key tide gauge.[8]

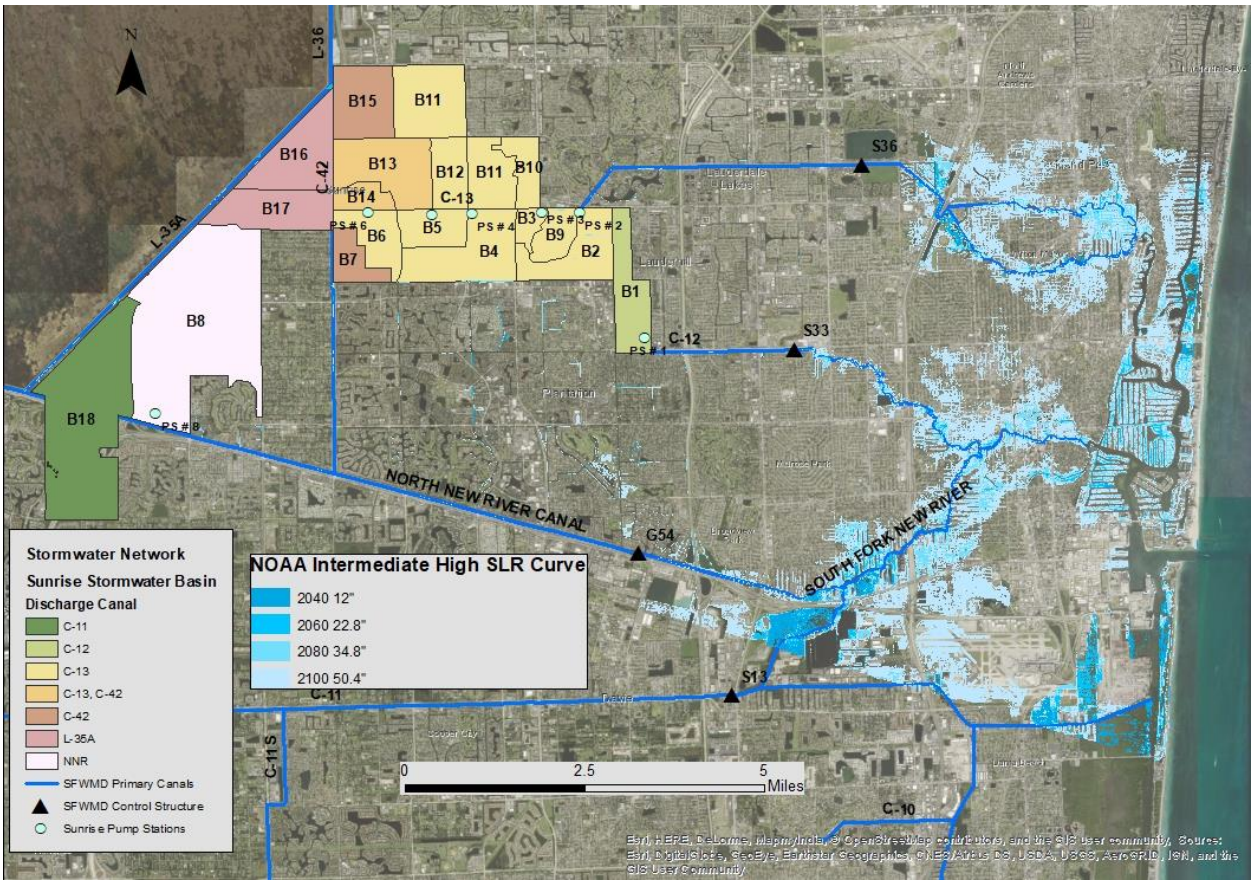
The NOAA Intermediate-High projection was chosen for this effort because it is now the standard within the CRS program:

> Recognizing that there is uncertainty inherent in estimating future sea levels, the CRS has adopted a base minimum projection for sea level rise for the purposes of CRS credit and meeting CRS prerequisites. The "intermediate-high" projection for 2100, as included in the report *Global Sea Level Rise Scenarios for the United States National Climate Assessment,* is the minimum projection that must be used for CRS purposes. Communities may use other projections provided that they are equal to or greater to NOAA's "intermediate-high" projection for 2100.[9]

The 2012 NOAA Intermediate-High projection includes a sea-level rise of 12" by 2040, 22.8" by 2060, 34.8" by 2080, and 50.4" by the year 2100, which is also within the range of projections recommended by the Compact.

A visualization of the NOAA Intermediate-High projection for Sunrise and the broader coastal drainage system that serves Sunrise is shown in ***Figure 1***. Sunrise has no critical or municipal facilities projected for direct inundation from sea-level rise through 2100 under the NOAA Intermediate-High Curve projection. However, Sunrise is dependent on the network of SFWMD primary canals to drain stormwater out of the city. Increased surface water levels and water tables from sea-level rise, in downstream canals and basins hydrologically connected to tidal forces, may impact drainage gradients. Sea-level rise will also increase water table heights along the coast, which may reduce the storage capacity of rainfall. Unless future adaptation actions are implemented, these potential gradient changes could impede the rate in which stormwater is removed from Sunrise over the next several decades. Close collaboration with neighboring jurisdictions, Broward County, and the SFWMD will be necessary to monitor mitigation of potential future impacts.

Figure 1: NOAA Intermediate-High Sea-Level Rise Inundation of Sunrise and Associated Coastal Drainage Systems



Precipitation and Future Flood Risk

Most of southeast Florida, including Sunrise, has a tropical monsoonal climate that is characterized by a warm wet season (~May 15 – October 15) and a cooler dry season (~October 15 – May 15). Average annual rainfall is around 57 inches per year in Sunrise, with high natural variability occurring among different years. While the reasons for some of this natural variability are not entirely understood, some larger climatological factors do correlate with precipitation levels in southeast Florida. Perhaps most notably, strong El Nino cycles within the equatorial Pacific are known to have a strong influence on precipitation in southeastern Florida, generally through an increase in precipitation during the dry season and less precipitation during the normal wet season. High levels of dry season rainfall, which are associated with strong El Nino events, can often cause regional-scale flooding in southeast Florida. Years in which the area is affected by tropical cyclones during the wet season also tend to have higher rainfall totals. The high intensity and duration of rainfalls associated with tropical cyclones often can also induce localized to regional flooding, depending on the size of the storm.

Climate change has a complex relationship with the hydrological cycle. Because the water holding capacity of air increases about 7% per 1°C warming, warmer temperatures inevitably lead to the potential for increased water vapor in the atmosphere.[10] Increased heating, however, also results in greater evaporation. A positive feedback loop on the climatic system affecting precipitation events emerges as temperature rises. The ability of the atmosphere to retain moisture increases with warmer temperatures and subsequently the warmer temperatures will intensify evaporation. These effects create the necessary conditions for the accelerated formation of high intensity individual storm events which pose the threat of flash floods and the potential for extreme flooding events.

Future projections of precipitation change in southeast Florida due to climate change are highly variable and, unlike some other areas of the country, do not clearly indicate whether substantial increases or decreases in annual precipitation can be expected. For example, a recent model conducted by Broward County Environmental Planning and Community Resilience Division ("BCEPCRD") indicated that anywhere from a 7.6% reduction to a 9.1% increase in precipitation could be expected in the years of 2060-2069.[11]

While the uncertainty in this projection range is substantial in terms of changes to annual average rainfall, there is a more general expectation that existing precipitation extremes are likely to become more extreme under future global warming and associated climate change. In other words, it is likely that dry years and dry seasons will tend to become dryer, while wet years, wet season, and individual rain events are likely to exhibit higher volumes of precipitation. For this reason, climate change and resilience planning in Sunrise requires consideration of increased water stresses associated with extreme drought, as well as the increased likelihood of high intensity rainfall events that can cause damaging floods.[12]

Adaptation for Future Hydrologic Conditions

If a high rate of sea-level rise affects southeast Florida over the next several decades, Sunrise and other areas of southeast Florida served by SFWMD infrastructure could experience reduced drainage capacity. While specific technical analysis of such future hydrologic conditions is outside the scope of this VA, implementation of the proposed changes to Sunrise's stormwater network, as outlined in the city's existing and updated Storm Drainage Master Plan, is a recommended step toward further mitigation of current and future flood risks within Sunrise. Sunrise officials may also want to consider including climate change-driven hydrologic conditions modeling that integrates sea-level rise and more extreme precipitation scenarios into future stormwater planning. Such modeling could potentially be conducted in coordination with SFWMD officials, Broward County, the Compact, and future updates to Sunrise's Storm Drainage Master Plan.

Saltwater Intrusion

A common concern for climate change and sustainability planning in southeast Florida includes potential saltwater intrusion of aquifers. Increased demands on water supply without adequate recharge can accelerate the intrusion of saltwater into aquifers. Rising sea levels are expected to exacerbate these issues. Sunrise relies on the Biscayne aquifer for its water demands. A number of previous scientific studies have focused on effects of saltwater intrusion on the Biscayne aquifer in coastal regions of Dade and Broward Counties. However, there is less research on potential effects from saltwater intrusion on well sites located within western portions of these counties, which contain the water supply for Sunrise from the Biscayne Aquifer.

The coastal portions of the Biscayne aquifer are known to have substantial vulnerability to saltwater intrusion. Urbanization of the coastal area, construction of drainage canals, and development of municipal well fields have historically led to a lowering of water levels in the eastern Biscayne aquifer.[13] A study from the U.S. Geological Survey ("USGS") found that chloride concentrations in groundwater wellfields in Broward County were moving west in 1980 to 1989 in response to lowered regional water levels.[14] More recent work by Prinos et al. in Miami-Dade County indicated that westward expansion of the saltwater interface in the Biscayne aquifer is continuing, especially along the drainage canal corridors.[15] Modeling by Langevin and Zygerneski at wellfields in Broward County near Pompano Beach shows that ongoing sea-level rise can be expected to further intensify saltwater intrusion threats within the Biscayne aquifer, particularly along the coastal reaches.[16]

Coastal areas east of Sunrise exhibited the strongest degree of change in modeled increased water table heights from a preliminary study on Broward County groundwater levels for years 2060-2069.[17] The results indicate that increased sea-level rise will affect water table heights from dense saltwater settling below the fresh groundwater and subsequently pushing the lighter freshwater upwards, elevating the water table. However, model results indicated minute changes in groundwater heights for Sunrise. The westward location of Sunrise from the coast may provide a buffer to saltwater aquifer intrusion. Further monitoring and investigation of potential saltwater intrusion into Sunrise's groundwater supply is warranted given this lack of direct data, but overall the westward locations of well sites should provide a strong buffer to potential saltwater intrusion.

VULNERABILITY ASSESSMENT FRAMEWORK

The primary scope of this VA is to develop a baseline inventory of critical, essential, and public facilities within Sunrise that are located in or near (within 100 feet) of areas currently designated as part of the Special Flood Hazard Area ("SFHA"), often referred to as the 100-year floodplain, by the Federal Emergency Management Administration ("FEMA"). It is important to note, however, that a 100-year flood should not be interpreted as a flood event that occurs every 100 years. In fact, the 100-year flood has a 26% chance of occurring during a 30-year period. From a technical perspective, areas within the SFHA are defined by FEMA as having a 1% annual probability of being flooded to a specific height called the base flood elevation ("BFE"). These designations are one way flood risk is identified for specific individual parcels of land.

In terms of relative FEMA designations for land area in Sunrise:

- The SFHA in Sunrise is comprised of approximately 2.75 square miles (or 15.1% of the city's total area of 18.4 square miles) of a designated AE Zone and approximately 2.02 square miles (or 11.1% of total area) of a designated AH Zone.

- For Sunrise, the AE Zone designation is used for retention ponds and other areas regularly inundated by water, and thus in practice contains little to no human property that is vulnerable to traditional flood losses.

- The AH Zone, however, does contain land areas with property and infrastructure in which a large flood event would be expected to produce some level of impact, potentially including economic loss.

- Of the remaining area in Sunrise, approximately 13.44 square miles (73.8% of total area) is designated as an X Zone that is officially outside of the SFHA. Most of the X Zone area (10.28 square miles, or ~56.4% of total area) is designated by FEMA as having a 0.2% annual flood hazard, or what is sometimes referred to as the 500-year floodplain. According to this FEMA designation, areas within the 0.2% annual flood hazard area have a 0.2% of being flooded across a calendar year.

- The remainder of the X Zone, or approximately 3.16 square miles, is designated as an area of minimal flood hazard.

Given these distinctions and implied levels of risk as designated by FEMA, for this VA we only utilized the AH Zone for inventorying potential flood risk to critical, essential, and public facilities. The assessment also includes overlays and interpretation of sea-level rise inundation risk in downgradient areas of Broward County that serve as the receiving zones for stormwater drainage from Sunrise, as well as some discussion of Sunrise's stormwater drainage system.

Methods and Approach

The first step in developing the VA was a compilation of existing geo-spatial and tabular data sets. The extensive data inventory of Sunrise infrastructure provided by the Sunrise GIS Department included: stormwater basins, stormwater pump stations, fire stations, wastewater treatment plants, assisted living facilities, capital improvement projects, city-owned facilities, emergency operations and care facilities, parks, schools, and streets. Polygon files for local water bodies and point files of drainage control structures were provided by the SFWMD. Property parcel information was obtained from the Broward County Property Appraiser's ("BCPA") office. Sea-level rise flood-level assessments and city boundary information was obtained from the University of Florida's Florida Geographic Data Library ("FGDL"). The full list of original datasets and associated sources is provided in ***Table 1***.

Table 1: Original Dataset Inventory

Dataset Description	Original File Name	Source
Assisted Living Facilities (Point)	AssistedLivingFacilities.gdb	Sunrise
Capital Improvement Projects (Polygon)	CIP_Poly.gdb	Sunrise
City Facilities(Point)	City_Facility.gdb	Sunrise
City Offices (Point)	City_Office.gdb	Sunrise
City Properties (Polygon)	City_Properties.gdb	Sunrise
EOC Shelters (Point)	EOC_Shelter.gdb	Sunrise
Fire Stations (Point)	fireStations.gdb	Sunrise
Hospitals (Point)	Hospital.gdb	Sunrise
Nursing Homes (Point)	NursingHomes.gdb	Sunrise
Parks (Polygon)	Parks.gdb	Sunrise
Public Schools (Polygon)	School_polygon.gdb	Sunrise
Streets (Line)	Streets.gdb	Sunrise
SS Treatment Plant (Point)	ssTreatmentPlant.gdb	Sunrise
Stormwater Basins (Polygon)	swBasins.gdb	Sunrise

Stormwater Pump Stations (Point)	swPumpStation.gdb	Sunrise
Parcel (polygon)	BCPA_GIS_POLYGON.mdb	BCPA
Tax Roll (table)	BCPA_TAX_ROLL.mdb	BCPA
Control Structures (point)	STRUCTURE.gdb	SFWMD
Water Bodies (Polygon)	WATERBODIES.gdb	SFWMD
City Boundaries (polygon)	par_citylm_2015.shp	FGDL
FEMA Flood Map (polygon)	dfirm_fldhazOct17.gdb	FGDL
2040 NOAA Intermediate-High MHHW SLR for Broward	BROW_2040_C3_MHHW_P.gdb	FGDL
2060 NOAA Intermediate-High MHHW SLR for Broward	BROW_2060_C3_MHHW_P.gdb	FGDL
2080 NOAA Intermediate-High MHHW SLR for Broward	BROW_2080_C3_MHHW_P.gdb	FGDL
2100 NOAA Intermediate-High MHHW SLR for Broward	BROW_2100_C3_MHHW_P.gdb	FGDL

SPATIAL ANALYSIS

Spatial analyses for the VA were performed using the ESRI ArcGIS 10.3 software package. Because datasets received from Sunrise utilized the Florida State Plane East projection (NAD 1983 State Plane Florida East FIPS 0901), datasets obtained from other sources were, as necessary, re-projected to Florida State Plane East for analytic consistency.

All elevation and flood height data are referenced to the North American Vertical Datum of 1988 ("NAVD88"). Following Compact recommendations, sea-level rise assessments define inundation as areas with elevations below the future Mean Higher High Water ("MHHW") under a given sea-level rise scenario. The MHHW level is defined as the long-term average, or mean, level of the highest tide observed each day. Baseline 1992 referencing of MHHW at 0.21 feet above NAVD88, as determined by the 1983-2001 National Tidal Epoch, is based upon the Virginia Key tide gauge.[18]

Critical and Municipal Facilities

1. Parcel data, *BCPA-GIS-POLYGON,* from the BCPA was clipped to the Sunrise boundary file, and the *BCPA_TAX_ROLL* table was then joined to the parcel data to obtain more descriptive attributes.

2. Select by location was used to identify the parcels containing the following point data: assisted living facilities, *AssistedLivingFacilities*; capital improvement projects, *CIP_Poly*; city facilities, *City_Facility;* city offices, *City_Office*; emergency operation centers, *EOC_Shelter;* fire stations, *fireStations;* hospitals, *Hospital;* nursing homes, *NursingHomes*; wastewater treatment plants, *ssTreatmentPlant.*

Base Flood Overlay Assessment

1. A state-level FEMA digital flood insurance rate map, dfirm_fldhazOct17*,* was clipped to the Sunrise boundary.

2. The Zonal Statistics tool in ArcGIS was used to determine the percentage of Sunrise land area within FEMA flood zones: AH, AE, 0.2 percent chance annual flood, and X.

3. Because AE Zones within Sunrise are water features, the AH Zone was extracted and used for the subsequent SFHA-based assessment.

4. Parcels for municipal assets and critical facilities within the SFHA were then extracted using the select by location tool and the previously generated AH Zone file to identify at-risk parcels. A full inventory of facilities by type and highest order flood risk zone found within the parcel is provided below in ***Tables 2-7***.

5. The *Streets* shapefile was clipped using the Sunrise boundary file, and then clipped to the AH Zone file to identify road segments that are within the SFHA.

6. The Zonal Statistics tool in ArcGIS was used to calculate total mileage of roads within the SFHA, as well as total mileage of individual roads within the SFHA.

Table 2: Assisted Living, Nursing Home, and Other Care Facilities

Facility	Address
Bright Horizons	4690 NW 113th Ave
Bright Horizons Welleby	3621 NW 90th Ter
Cherry Garden Assisted Living	8400 NW 28th St
Colony Club	3799 NW 88th Ave
Divinity Home Care	3680 NW 119th Ave
Good Shepard	8610 NW 24th Ct
Health South Sunrise Rehabilitation Hospital	4399 Nob Hill Rd
Magnolia Residence	4838 NW 93RD Terr
Millwood's Care	6380 NW 25th Court
Paradise Villa II	2560 NW 83rd Ave
Paradise Villa Retirement Home	11360 NW 29th St
Professional Healthcare Group	10620 NW 32nd St
Regents Park of Sunrise	4800 Nob Hill Rd
Royal Living of Sunrise	3181 NW 94th Way
Springtree Rehabilitation & Health Care Center	4251 Springtree Dr
Springtree Retirement Residence	4201 Springtree Dr
Sunrise Health and Rehabilitation Center	4800 Nob Hill Rd
The Family Continuing-Care Service	555 SW 148th Ave
Westbridge	3142 NW 109TH TER
Westchester	9701 West Oakland Park Blvd

Table 3: Sunrise Facilities and Properties

Facility	Address
Bank Atlantic Center	One Panther Parkway
CDD (or Community Development)	1607 NW 136 Ave, Building B
City Hall	10770 West Oakland Park Blvd
City Park	6700 Sunset Strip
Cypress Preserve Park	9020 NW 38th Street
Flamingo Park	12855 NW 8th Street
Flamingo Road Linear Park	Flamingo Road
Gas Department	4401 NW 103 Ave
Leisure Services	10610 West Oakland Park Blvd
New River Civic Center	60 Weston Rd
Nob Hill Soccer Club Park	10200 Sunset Strip
Oak Hammock Park	9220 NW 44th Street
Oscar Wind Park	200 North New River Circle

Piper Field	8000 NW 44th Street
Police Station New River Civic Center	60 Weston Road
Public Safety Complex	10440 West Oakland Park Blvd
Public Works	5580 NW 108th Ave
Roarke Recreation Center	1720 NW 60th Avenue
Roller Hockey Park	5201 NW 103rd Avenue
Sawgrass Sanctuary	237 North New River Circle
Senior Center	10610 West Oakland Park Blvd
Seven Bridges at Springtree Golf Club	8150 Springtree Drive
Shotgun Road Linear Park	SW 14th Street
Spring Tree Golf	8150 Spring Tree Drive
Sunrise Athletic Complex	11501 NW 44th Street
Sunrise Civic Center	10610 West Oakland Park Blvd
Sunrise Golf Village Park	1277 Sunset Strip
Sunrise Tennis Club	9605 West Oakland Park Blvd
Utilities Department	777 Sawgrass Corporate Parkway
Utilities Springtree Facility	4350 Springtree Drive
Veterans Park	Nob Hill Rd & NW 55 Street
Village Multipurpose Center	2240 NW 68th Avenue
Village Square Park	6601 Sunset Strip
Welleby Park	11100 NW 44th Street

Table 4: Sunrise Capital Improvement Projects

Project	Address	Status
9525 Parcel Improvements	West Oakland Park Blvd & NW 95th Ter	Proposed Project
Oscar Wind Park Expansion	200 N New River Circle	Proposed Project
Pine Island Road Athletic Complex	9101 NW 50th Street	In Progress - Construction
Sunrise Lakes Phase 1 Passive Park	Sunrise Lakes Blvd and Sunrise Lakes Drive West	In Progress - Design
Sunset Strip Park at NW 109th Ave	Sunset Strip R-O-W west of NW 109th Avenue	In Progress - Design
Veterans Memorial Park	5300 Nob Hill Road	In Progress - Design
Welleby Park Expansion	11100 NW 44th St	In Progress - Construction

Table 5: Sunrise Fire Stations

Facility	Address
Fire Station 39 (Village Civic Center)	6800 Sunset Strip
Fire Station 59	8330 NW 27 Place
Fire Station 83	60 Weston Rd
Fire Station 73	7801 NW 21 Street
Fire Station 92	13721 NW 21 Street

Table 6: Broward County Schools within Sunrise

School	Address
Bair Middle	9100 NW 21 MNR
Banyan Elementary	8800 NW 50TH ST
Cypress Bay 9th Grade Annex	270 N NEW RIVER CIRCLE
Discovery Elementary	8800 NW 54 COURT
Horizon Elementary	2101 N PINE ISLAND RD
Nob Hill Elementary	2100 NW 104 AVE
Piper High (EOC Shelter)	8000 NW 44 ST
Sandpiper Elementary	3700 HIATUS RD
Sawgrass Elementary	3230 NOB HILL RD
Village Elementary	2100 NW 70 AVE
Welleby Elementary	3230 NOB HILL RD
Westpine Middle	9393 NW 50TH ST

Table 7: Sunrise Wastewater Treatment Plants

Name	Address
Sawgrass WWTP	777 Sawgrass Corporate Pkwy
Southwest WWTP	15400 Slydgemill Road
Springtree WWTP	4350 Springtree Dr

Results for Critical and Municipal Facilities

An overview of the FEMA-designated flood zone areas is provided below in ***Figure 2***. Facilities listed below in ***Table 8*** were flagged as having portions of their parcel located within an AH Zone. A series of maps provided below (***Figures 3-7***) provide visualizations of the SFHA overlay with the parcels of selected facilities. It is important to note, first floor elevation information within building footprints is not available in a GIS-ready format; therefore, the VA does not make an objective determination as to whether the actual structures within these parcels would experience flooding under a FEMA-designated 1% BFE condition.

Communications from Sunrise staff indicate that many of the identified buildings and structures are constructed at or above designated BFE height, which substantially mitigates flood risk in accordance with current floodplain regulations. It is also known, that at least one of Sunrise's facilities, the Southwest Wastewater Treatment Plant, has recently been retrofitted to meet or exceed current flood avoidance and resistance standards. Minimum storm design parameters followed by Sunrise also provide for elevations of parking areas to be above the elevation for a 10-year design storm, the elevations of street lanes to be above a 25-year design storm and finished floor elevations of structures in the SFHA to meet FEMA's BFE criteria.

As Sunrise develops future updates to resilience and sustainability planning efforts, a key recommendation of this VA is the incorporation of site-level assessments for a priority group of facilities, as identified by Sunrise staff, located within the AH Zone. Such assessments could include digitization of archival Elevation Certificates, certified as-built designs, new survey-level analyses, and other relevant site-level data. These data would provide more thorough documentation of site-level flood vulnerability for specific structures contained on parcels that show an AH Zone designation. Possible flood risks to non-structural equipment and property should be considered, such as motor vehicles and other machinery that may be stored in parking areas. Potential issues associated with property access due to possible road flooding in extreme events should also be considered when conducting future assessments of critical and municipal infrastructure located within AH Zones.

Much of Sunrise is located outside of the SFHA as designated by FEMA, being located within a 0.2% (i.e., 500-year) flood risk area. Flood maps are imperfect tools and it should be noted that infrastructure and property loss can still occur outside of designated SFHA zones. Thus, observations of any unusual or nuisance flooding within critical facilities, even those located outside of the SFHA, should be carefully documented and, as appropriate, prompt more thorough site-level drainage assessments. A current initiative to update Sunrise's Storm Drainage Master Plan, as well as, ongoing regular maintenance of the local stormwater infrastructure, provide opportunities for conducting such site-level assessments as may be warranted.

Sunrise participates in the voluntary Community Rating System ("CRS") used by the National Flood Insurance program ("NFIP"). The CRS is used to reduce flood damages to insurable property, strengthen and support the insurance aspects of the NFIP, and encourage a comprehensive approach to floodplain management.[19] Sunrise has received a CRS score of seven (7) based on its many aggressive efforts to reduce flood risks as of October 1, 2017. As a result of Sunrise's effort residents receive a 15% discount for properties in SFHA and a 10% discount for properties located outside of the SFHA. Sunrise has made recent efforts to improve that score which are currently under review by FEMA.

It should also be noted that the most recent CRS Coordinator's Manual (2017) builds upon the introduction of climate, future conditions and sea level rise analysis into CRS, first included within the program in 2013.[20] There are at least ten (10) different areas where credits can be gained for efforts ranging from simple distribution of information related to future conditions and sea level rise to accounting for future conditions or sea level rise in regulatory maps or watershed master planning. Many of these credits can also be gained for future conditions analysis and are applicable to inland communities. Pursuing credits in these areas is one way that Sunrise can potentially improve its score in CRS, thus increasing the discount for property flood insurance that residents or business owners might pay. For Sunrise to understand the value of pursuing these credits, it should evaluate the effort to obtain them against the benefits to be received by the 4,641 policyholders of policies currently in effect within Sunrise. This includes an "insurance in-force whole value" of $1,366,820,200 and "written premium in-force value" of $1,818,023.[21]

Table 8: Sunrise Facilities Located on Parcels Containing a FEMA-Designated AH-Zone

Facility	Facility Type
Bright Horizons	Care
Colony Club	Care
Health South Sunrise Rehabilitation Hospital	Care
The Family Continuing-Care Service	Care
Bank Atlantic Center	City-Owned
City Hall	City-Owned
Cypress Preserve Park	City-Owned
Flamingo Road Linear Park	City-Owned
Oak Hammock Park	City-Owned
Public Safety Complex	City-Owned
Public Works	City-Owned
Seven Bridges at Springtree Golf Club	City-Owned
Shotgun Road Linear Park	City-Owned
Sunrise Civic Center	City-Owned
Welleby Park	City-Owned
9525 Parcel Improvements	Capital Improvement
Oscar Wind Park Expansion	Capital Improvement
Pine Island Road Athletic Complex	Capital Improvement
Sunrise Lakes Phase 1 Passive Park	Capital Improvement
Sunset Strip Park at NW 109th Ave	Capital Improvement
Veterans Memorial Park	Capital Improvement
Welleby Park Expansion	Capital Improvement
Fire Station 83	City-Owned Fire Station
Fire Station 92	City-Owned Fire Station
Banyan Elementary	Broward County School
Cypress Bay 9th Grade Annex	Broward County School
Discovery Elementary	Broward County School
Sandpiper Elementary	Broward County School
Welleby Elementary	Broward County School
Westpine Middle	Broward County School
Southwest WWTP	Wastewater Treatment Plant

Figure 2: Overview of Sunrise FEMA-Designated Flood Zones

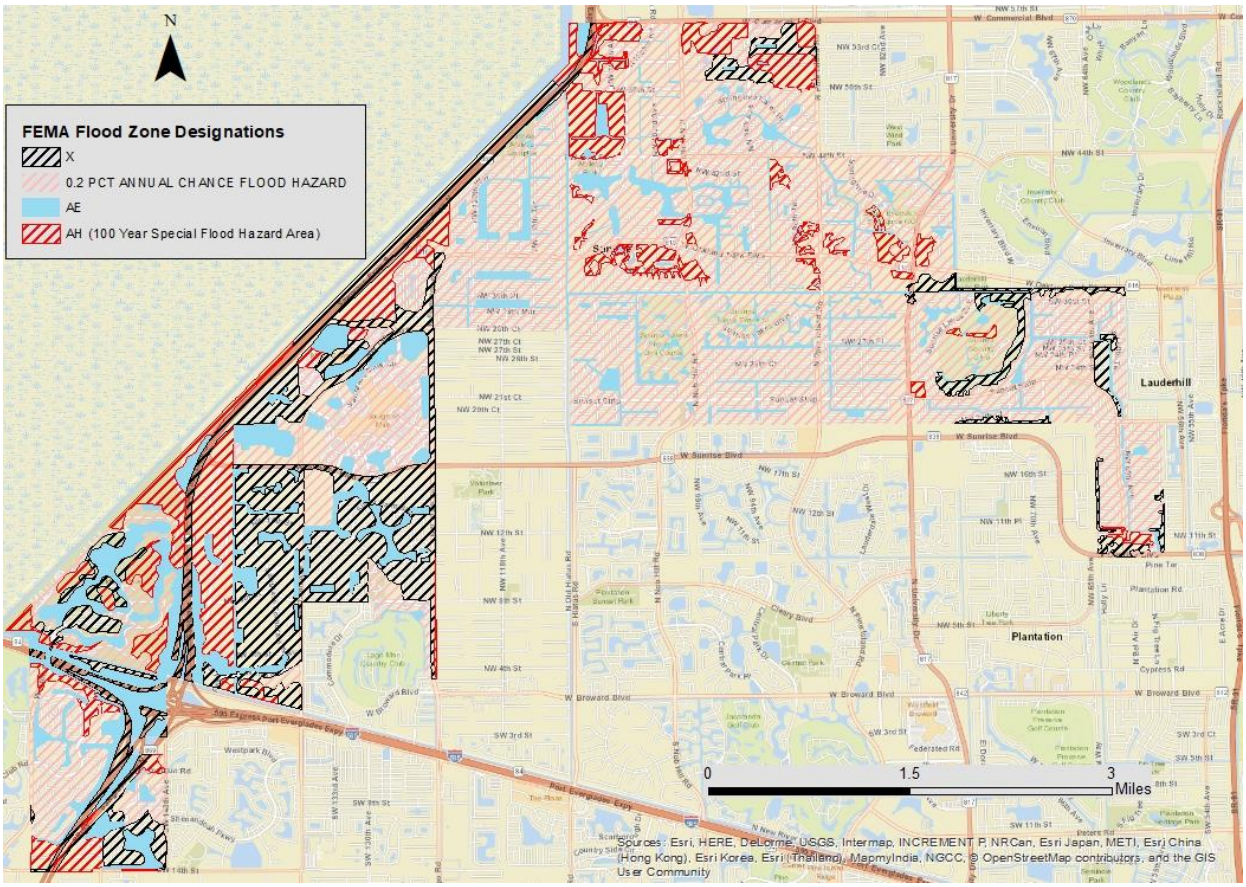


Figure 3: FEMA-Designated SFHA and Parcel Boundaries for Westpine Middle, Banyan Elementary, Discovery Elementary, Public Works, and Pine Island Road Athletic Complex

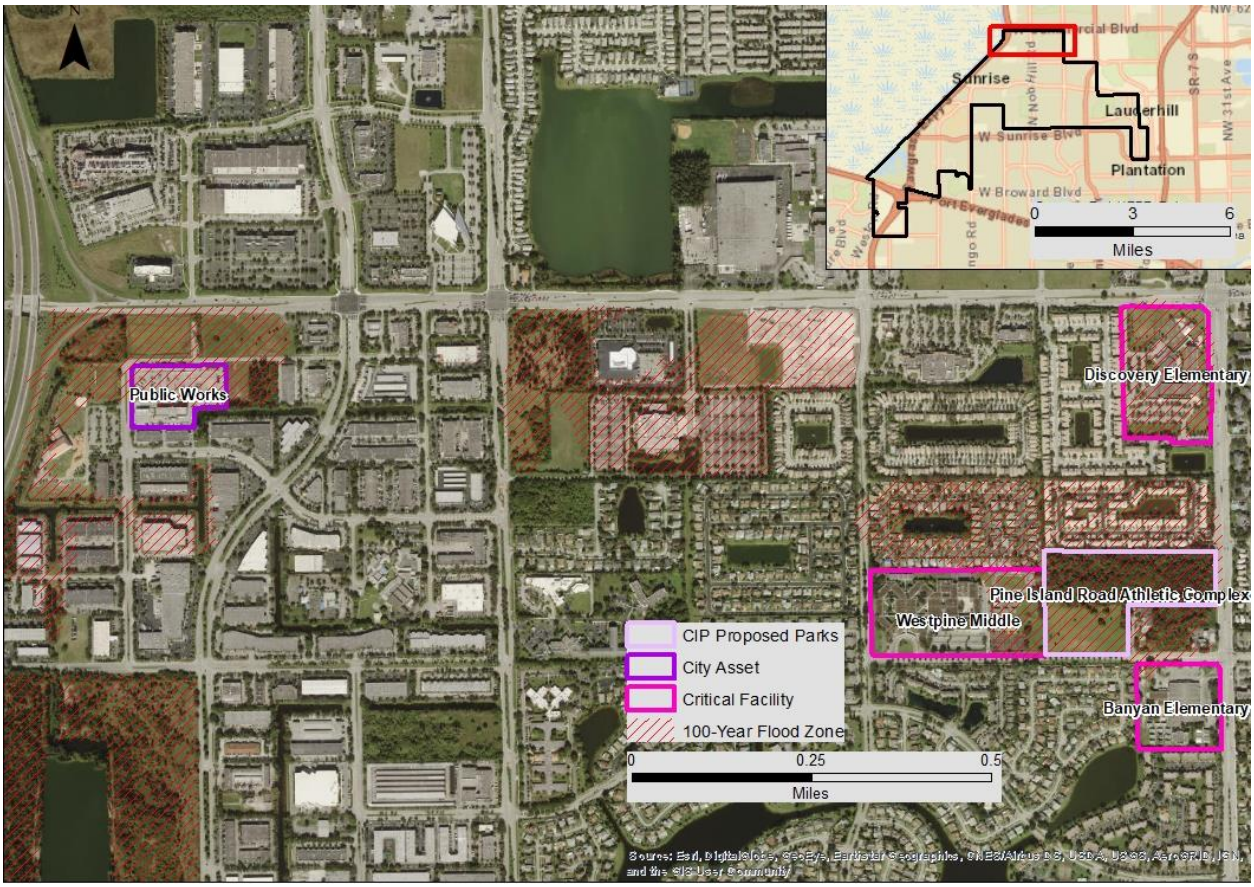


Figure 4: FEMA-Designated SFHA and Parcel Boundaries for City Hall, Sunrise Civic Center, Sunrise Senior Center, and Welleby Park

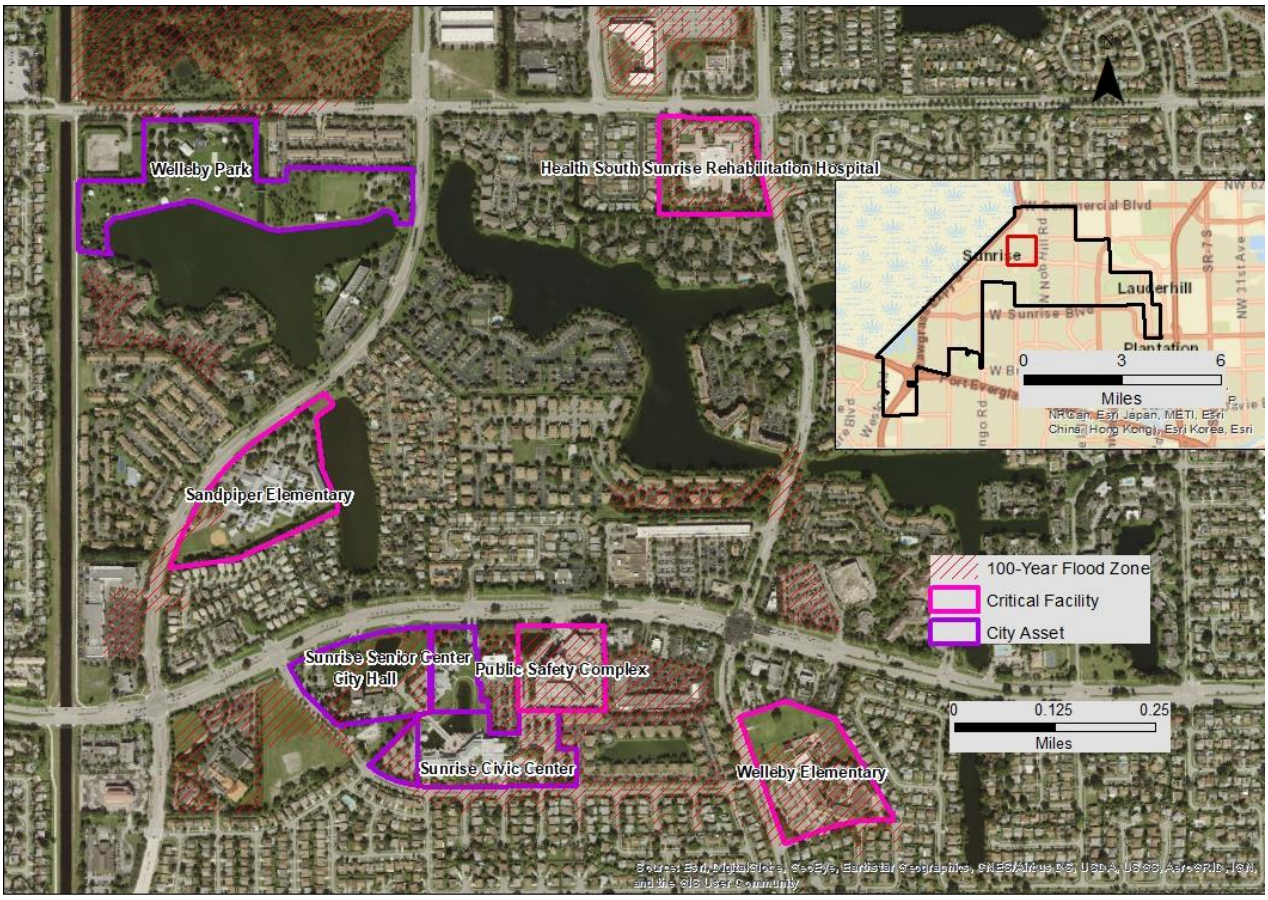


Figure 5: FEMA-Designated SFHA and Parcel Boundaries for Colony Club, Bright Horizons Assisted Living, Oak Hammock Park, Seven Bridges at Springtree Golf Club, and Cypress Preserve Park

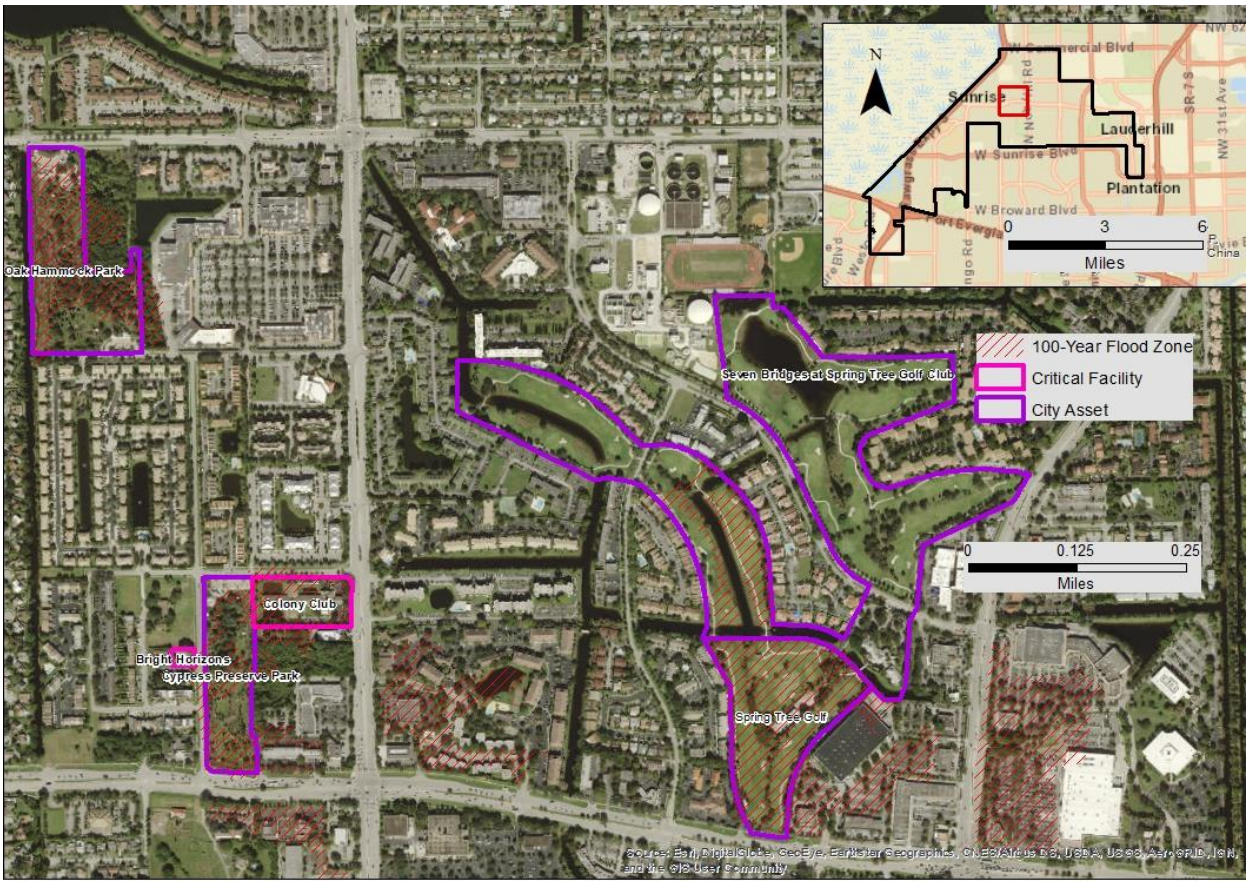


Figure 6: FEMA-Designated SFHA and Parcel Boundaries for Fire Station 92, Bank Atlantic Center, and Flamingo Linear Park Municipal Assets

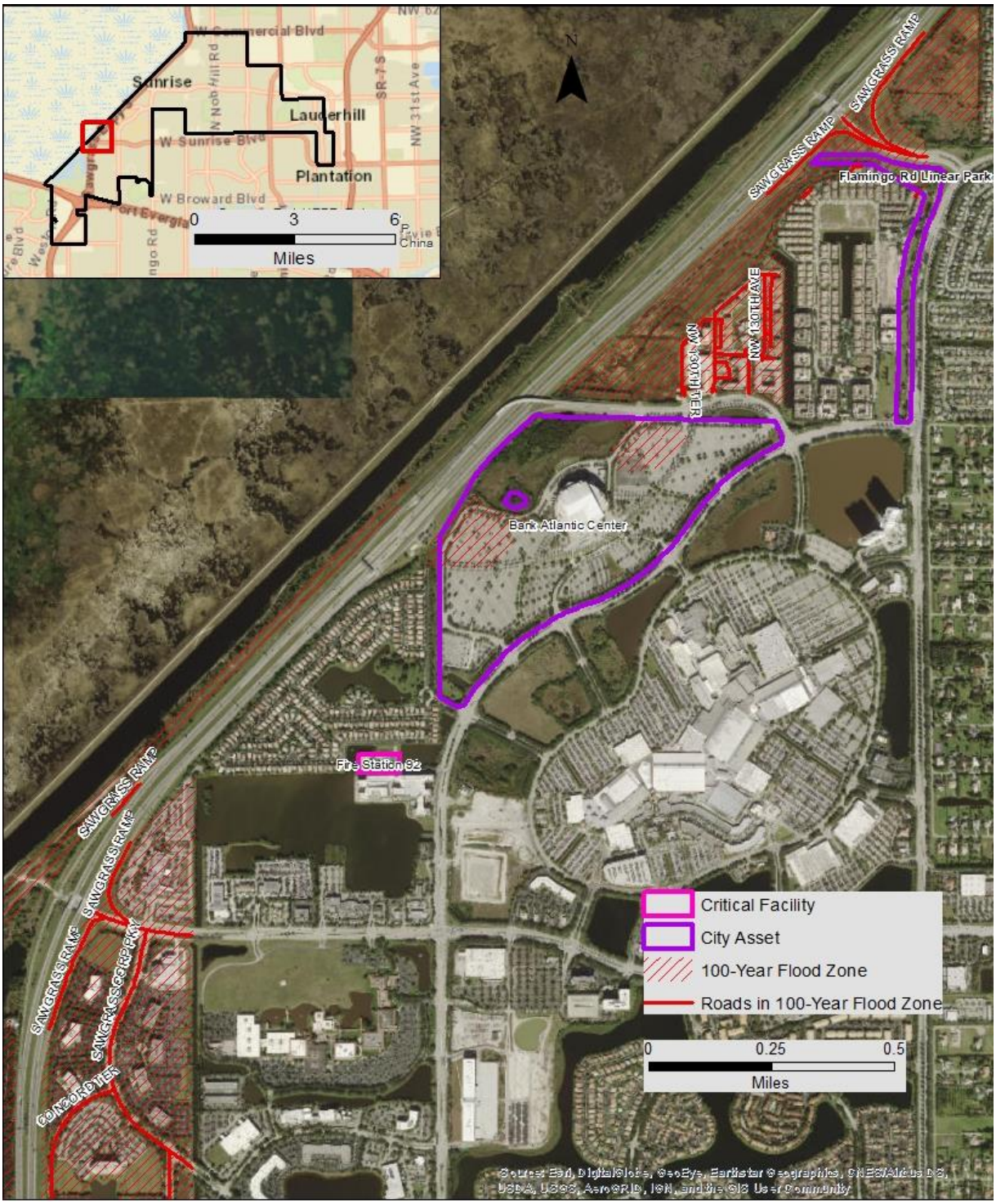


Figure 7: FEMA-Designated SFHA and Parcel Boundaries for Fire Station 83(New River Civic Center), Cypress Bay 9th Grade Annex, and Family Continuing-Care Service, Shotgun Road Linear Park, and the Proposed Oscar Wind Park Expansion

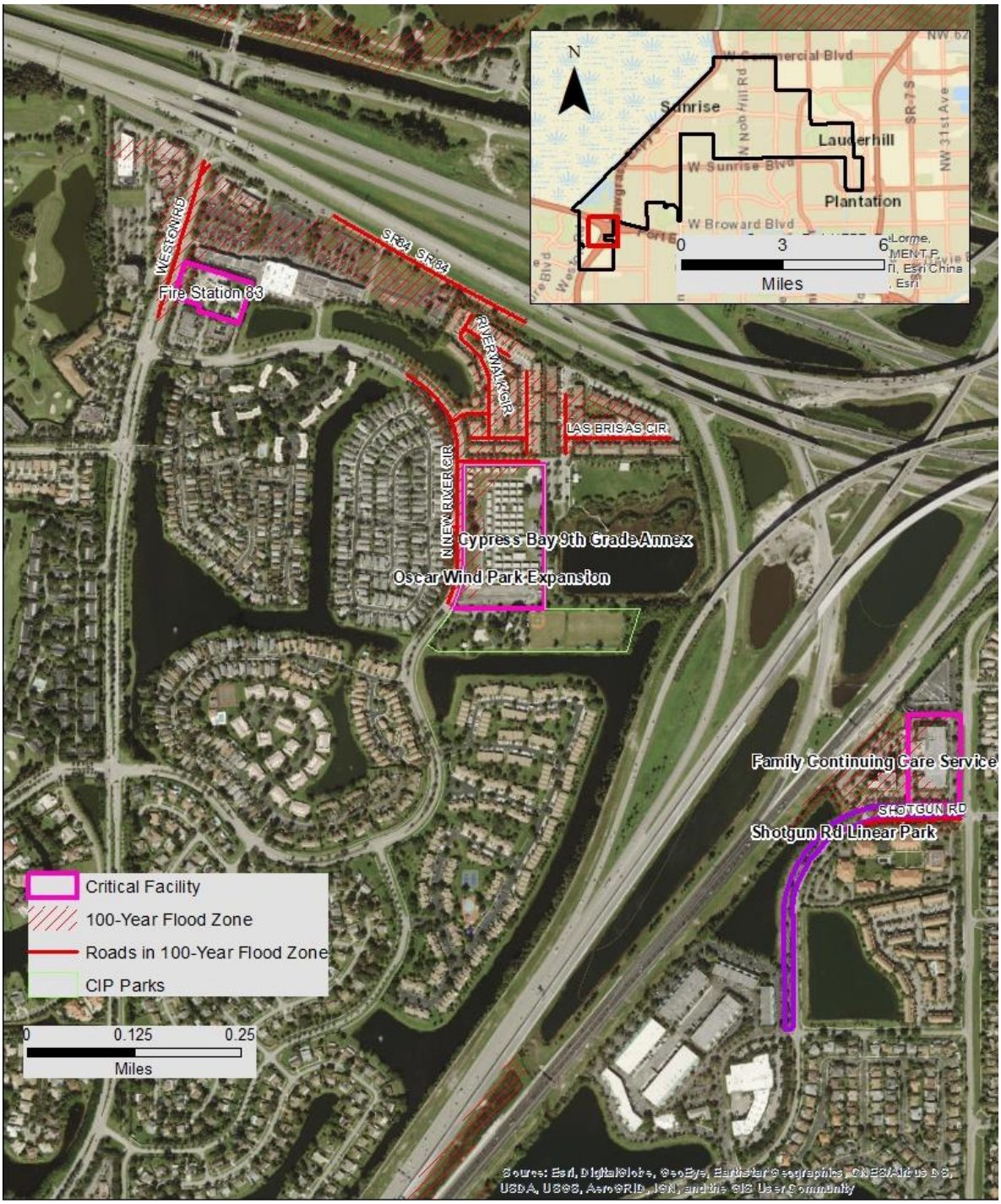


Figure 8: FEMA-Designated SFHA and Parcel Boundary for the Southwest Wastewater Treatment Plant

Road Segments within the SFHA

Road flooding tolerance is dependent on the amount of daily traffic and connectivity to critical facilities. Restricted access to impacted road segments that connect to highway and expressway facilities may pose evacuation concerns, particularly for scenarios where heavy precipitation precedes landfall of a major hurricane. Although impacted neighborhood road segments do not pose as much of a connectivity concern, restricted access due to major flooding could affect access to individual homes and impact the ability of residents to safely leave their homes to make it to evacuation routes during a flood event.

Sunrise follows Broward County's stormwater design criteria for road construction, which calls for roads to be built to withstand 25-year design storm events. Many roads are often designed and built to receive and hold water during extreme flood events, thus, diverting waters away from residential, commercial, and government buildings.

Identification of road segments located within the SFHA provides useful information in terms of identifying potential barriers to transportation during a major flood event, as well as informing Sunrise of possible retrofits that could ensure reasonable access to critical facilities – such as fire, police, hospitals, and evacuation centers – during a major flood disaster.

Visualizations of key road segments located within the SFHA are provided below (***Figures 9-13***). Detailed elevation data for road centers and crowns was not available for the VA; therefore, this assessment cannot objectively state that road segments identified as potentially vulnerable would necessarily experience flooding conditions during a FEMA-designated 100-year flood height scenario.

Figure 9: Northern Sunrise SFHA Overlap with Road Segments

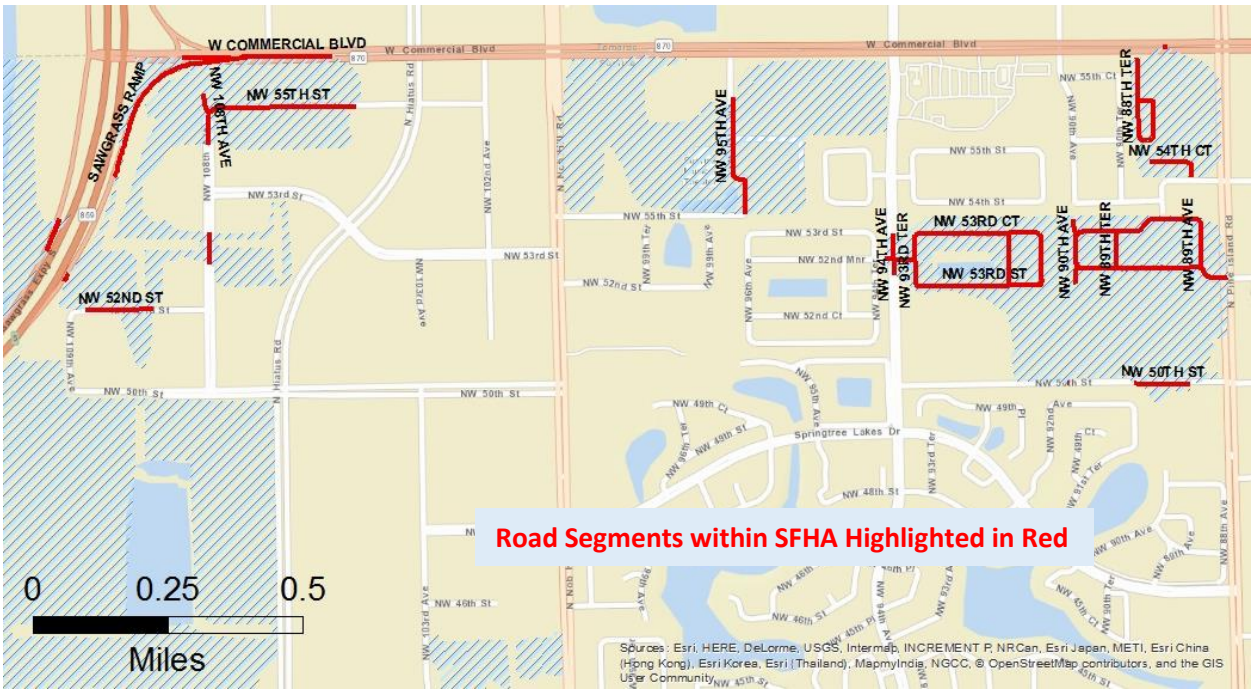


Figure 10: Central Sunrise SFHA Overlap with Road Segments

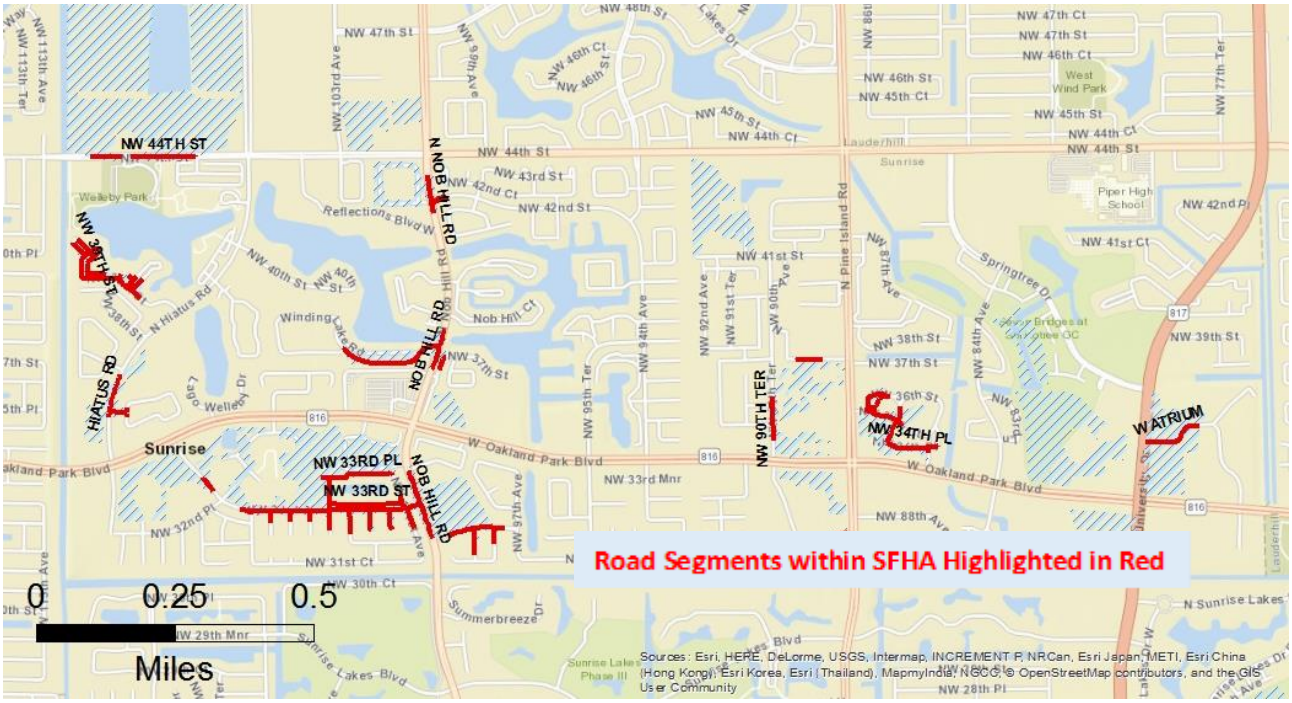


Figure 11: Southern Sunrise SFHA Overlap with Road Segments

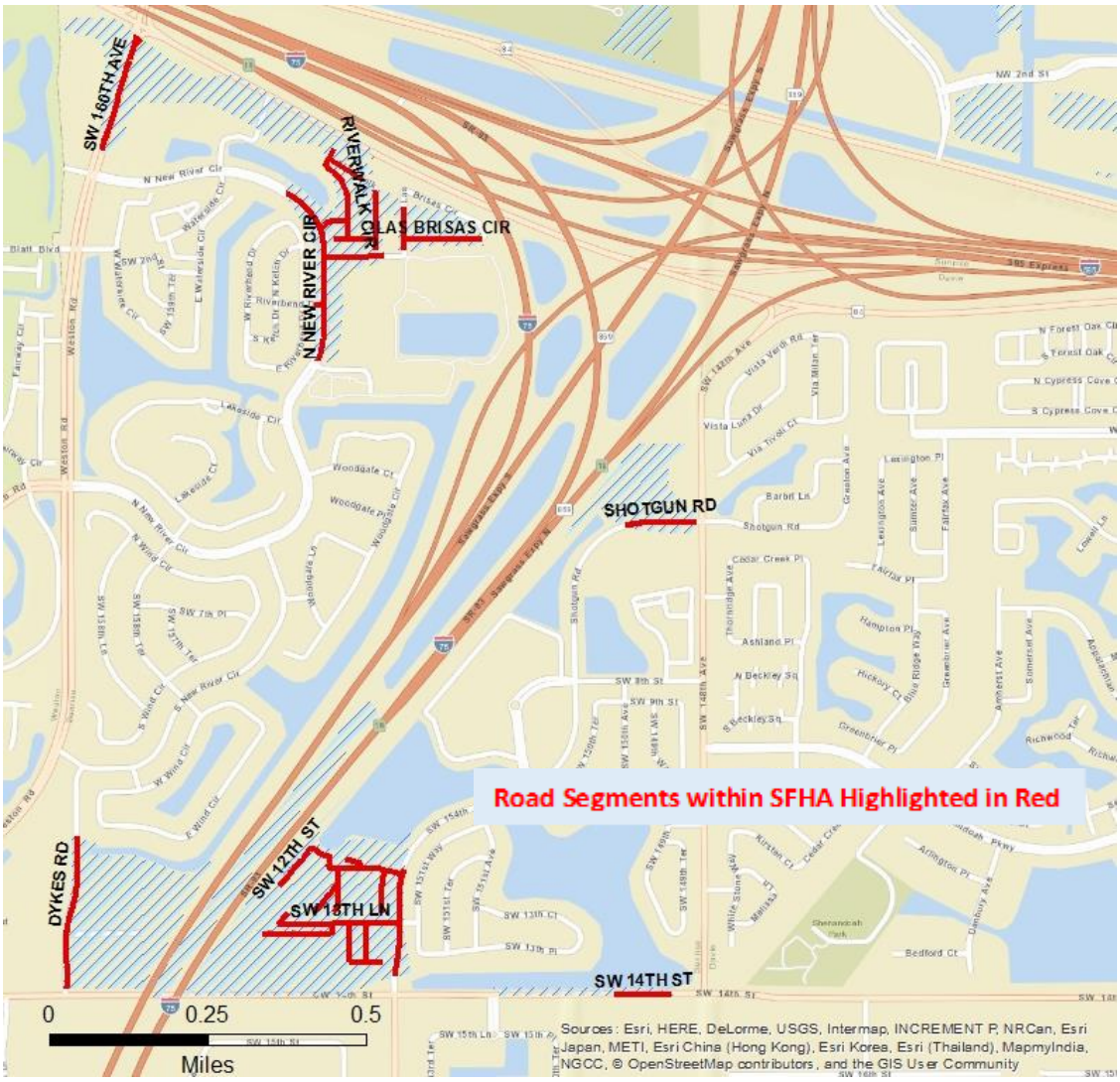


Figure 12: Central-Western Sunrise SFHA Overlap with Road Segments

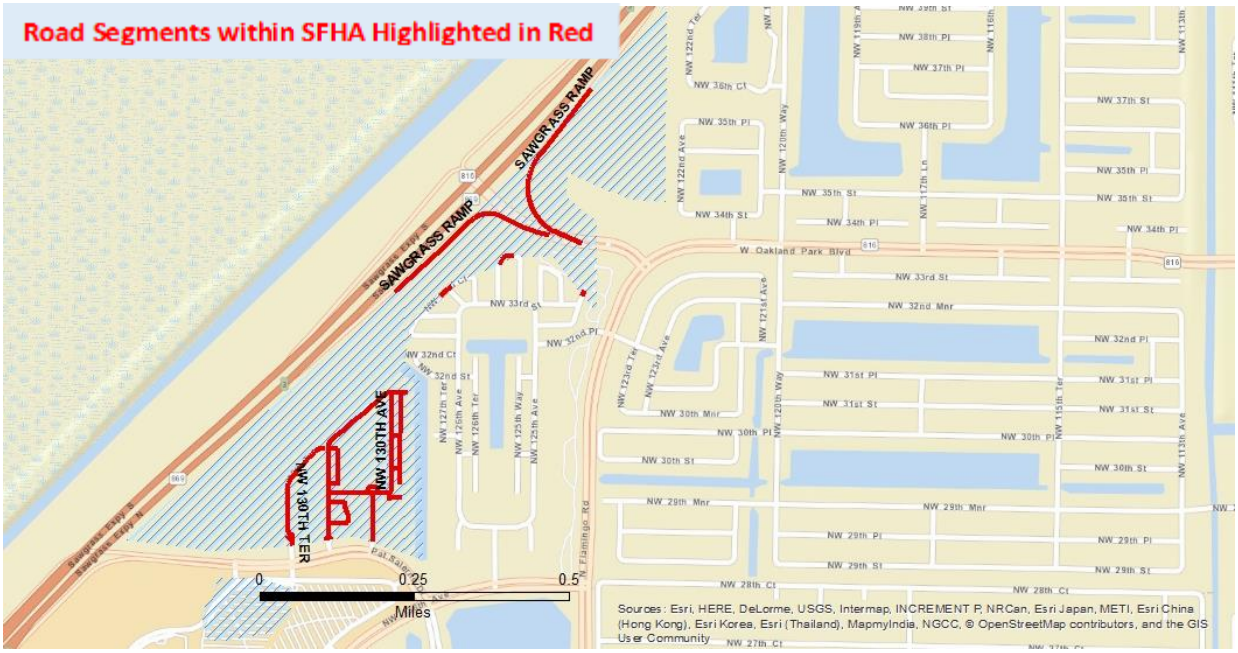
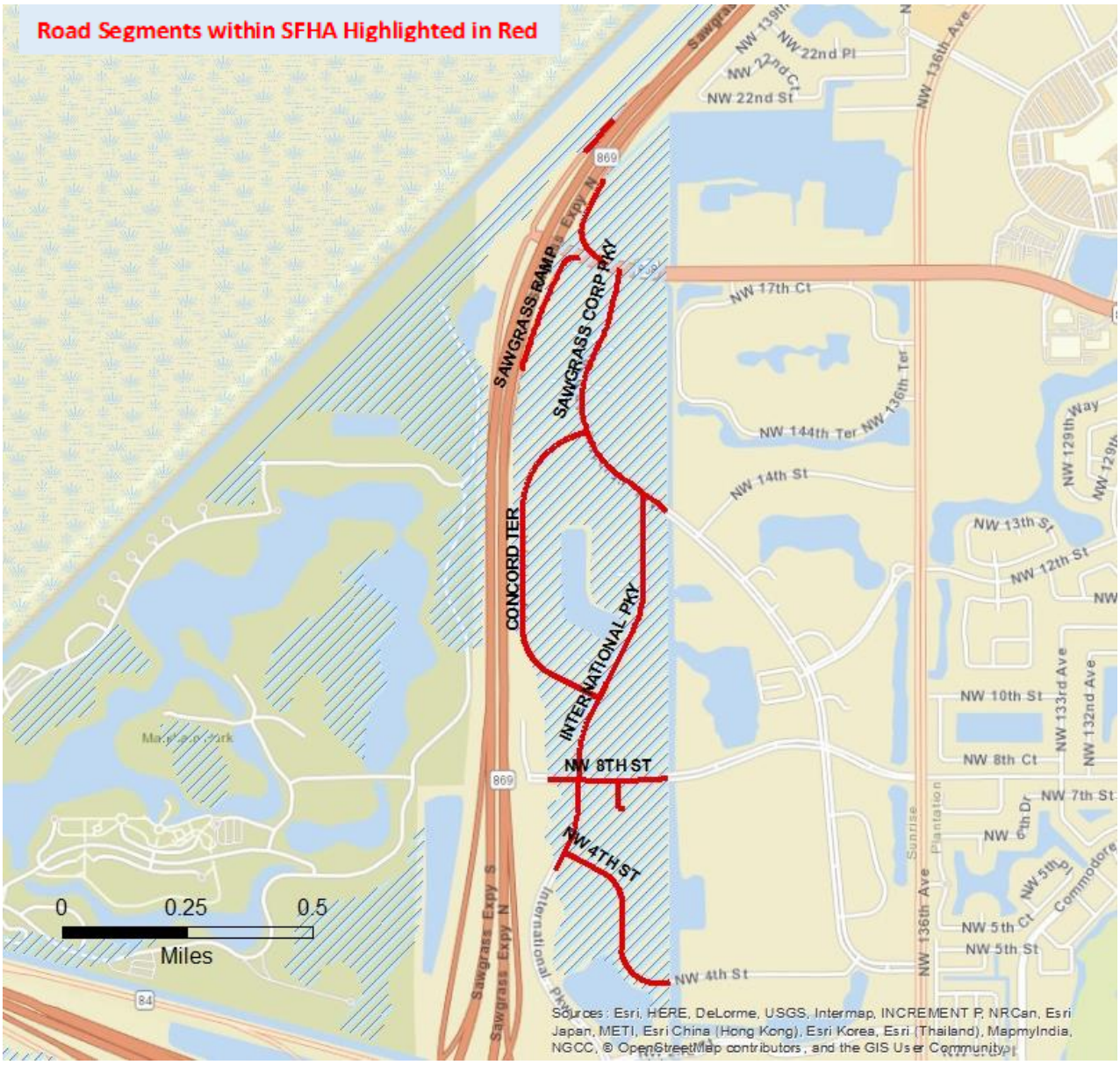


Figure 13: Southeastern Sunrise SFHA Overlap and Road Segments

Figure 14: Southwestern Sunrise Overlap with Road Segments



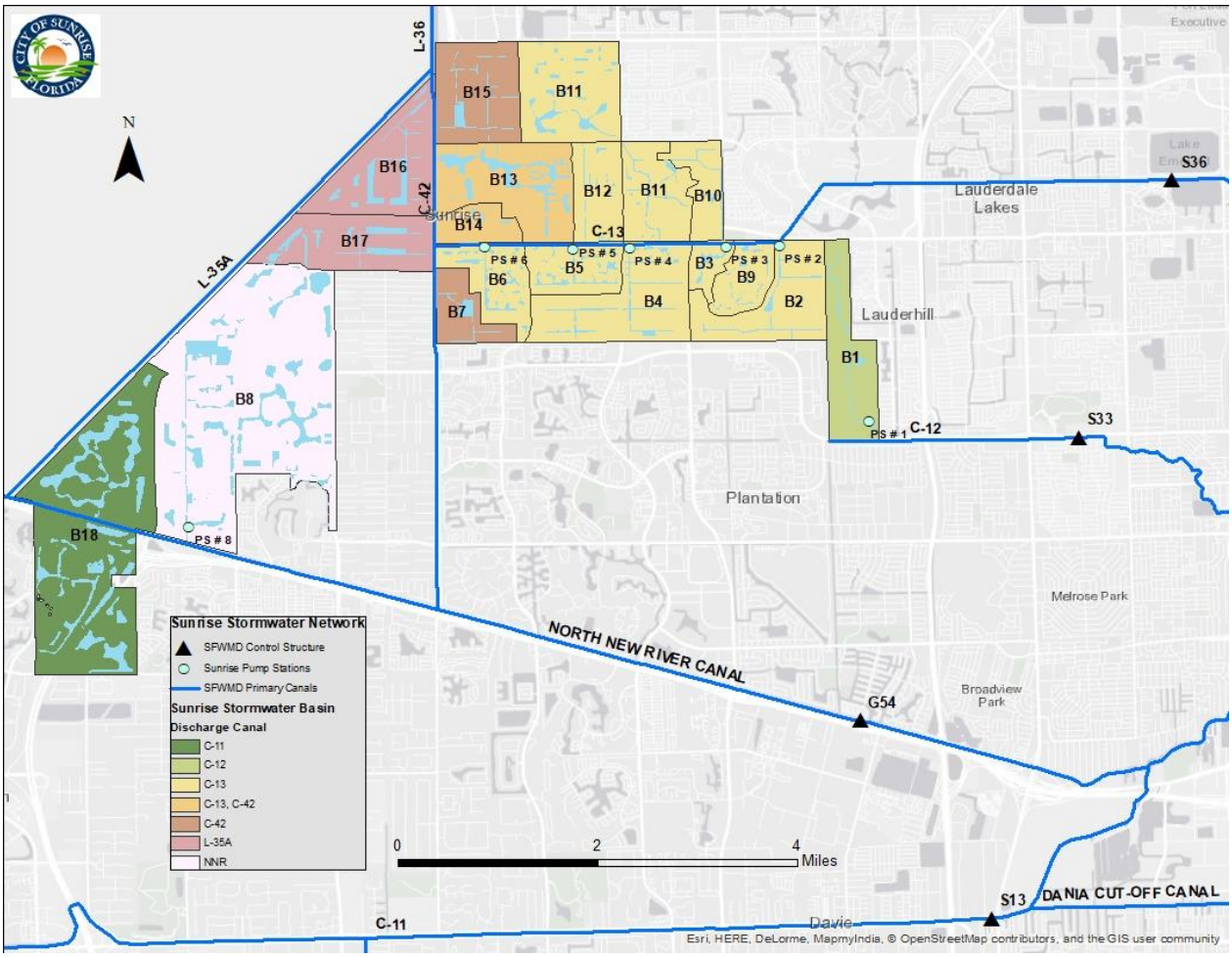
Municipal Stormwater

Sunrise's stormwater network is reliant on drainage into three (3) SFWMD primary canals: North New River Canal, C-13, and the C-12. Stormwater flows east through these canals where it is then delivered to tidal waterbodies, through large gravity-driven control structures operated by the SFWMD. The SFWMD Control Structure S-36, S-33, G-54, and S-13 correspond to the C-13, C-12, North New River, and the C-11 Canals. Sunrise also contains a network of approximately 600 acres of interconnected retention lakes and canals that provide water quality treatment and stormwater storage capacity before discharging into the SFWMD primary canals. Sunrise's stormwater network functionality is integrally linked to the performance of the SFWMD's primary canal network.[22]

Sunrise follows an extensive stormwater maintenance regimen to optimize function for flood protection to adhere to Sunrise's National Pollution Discharge Elimination System ("NDPES") Municipal Separate Storm Sewer ("MS4") Permit requirement. The NPDES program ensures proactive involvement of Sunrise to reduce nutrient and other pollutants, such as heavy metals, from entering Sunrise waterways. Adhering to the NPDES program is also one of the many ways Sunrise practices environmental stewardship. The Sunrise Public Works Division, Stormwater Section is responsible for day to day stormwater system operation and maintenance. Some of the various maintenance activities include: inspection, cleaning, and repair of drainage structures and pipes; inspection and cleaning of major outfalls; stormwater pump station maintenance; waterway debris removal; and, aquatic weed control. Maintenance is tracked using a GIS stormwater database and reported annually to the State of Florida Department of Environmental Protection to satisfy the requirements for the NPDES Permit. In particular, maintenance of the system directly impacts its response to rainfall events. These combined activities help Sunrise deliver a high level of service for stormwater management throughout the community.[23]

Sunrise is divided into eighteen (18) stormwater basins as shown in ***Figure 15*** (Sunrise pump station numbers correspond to the basin numbers on the Figure), to optimize operation and maintenance. Each basin has individual drainage systems, further divided into sub-basins, that discharge into the SFWMD canal system. Basins 1-8 utilize pump stations which are owned and operated by Sunrise. Basins 9-18 rely on gravity-based infrastructure to deliver stormwater into the SFWMD canal system. Prior to a heavy rain event, Sunrise and other Broward municipalities, coordinate with the SFWMD to begin controlled pumping and discharges to the SFWMD canal system. Pumping of stormwater will continue following a storm event until water levels in the retention lakes and canals return to permitted control elevations.[24]

Figure 15: Sunrise Stormwater Drainage Basin Locations and SFWMD Primary Canal Discharge Delineations



Work that Sunrise is currently doing to update its Storm Drainage Master Plan is directly tied to identifying and mitigating impacts related to flood risk. One way to further those efforts is for Sunrise to incorporate future conditions analysis and assumptions that lead to correcting deficiencies or retrofitting aging infrastructure. Key findings of this update effort by Basin are listed below.

Basin 1 encompasses 485.8 acres and is broken down into 10 Sub-basins (IA-IJ) and is composed of Sunrise owned canals that flow southward ultimately discharging via Pump Station No. 1, into the SFWMD C-12 Canal. Recent modeling performed for the new Sunrise Storm Drainage Master Plan by Craven Thompson & Associates indicate that this basin performs well during the 10-year and 25-year storm events, but the ICPR 100-year 3-day storm event simulation indicates a possibility of water levels exceeding some finished floor elevations in Sub-basin 1A and 1C.[25]

Basin 2 encompasses 519.8 acres and is further divided into 8 Sub-basins (2A-2H) and is comprised of Sunrise-owned interconnected canals that generally flow North ultimately discharging via Pump Station No. 2 into the SFWMD C-13 Canal. Models from the new Storm Drainage Master Plan indicate that the majority of Basin 2 performs well during the 10 and 25-year storm events with some minor street flooding, but a shopping center in Sub-basin 2A will experience parking lot flooding in the 10-year 1-day and 25-year 3-day storm events and very possible flooding of finished floors during the 100-year 3-day storm event.[26]

Basin 3 encompasses 110.5 Acres, further divided into Sub-basins 2A and 2B, and consists of a large private lake which receives stormwater runoff through a system of culverts and ultimately discharges into the SFWMD C-13 Canal via Pump Station No. 3. Modeling performed for the new Storm Drainage Master Plan indicates that Basin 3 performs well under the 25-year 3-day and the 100-year 3-day storm events but exhibits some minor road crown flooding in Sub-basin 3A during the 10-year 1-day storm event.[27]

Basin 4 encompasses 666 acres, further divided into 14 Sub-basins (4A-4N) and consists of interconnected canals that generally flow North discharging via Pump Station No. 4 into the SFWMD C-13 Canal. Basin 4 performs well during the 25-year and 100-year 3-day storm events, but models indicate that the stormwater elevations in Sub-basins 4A, 4B, and 4K may exceed the minimum road crown during the 10-year 1-day storm event.[28]

Basin 5 encompasses 312.3 acres, further divided into Sub-basins (5A-5E) and consists of Sunrise-owned interconnected canals that flow to the center of the basin and then to the North discharging via Pump Station No. 5 into the SFWMD C-13 Canal. Models indicate that Basin 5 performs well during the 10-year 1-day and 25-year and 100-year 3-day storm events.[29]

Basin 6 encompasses 330.6 acres, further divided into 7 Sub-basins (6A-6G) and consists of Sunrise-owned interconnected canals that flow to the center of the basin and then to the North discharging via Pump Station No. 6 into the SFWMD C-13 Canal. Models indicate that Basin 6 performs well during the 25-year and 100-year 3-day storm events, but there may be some areas in where water levels may exceed pavement elevations in Sub-basins 6B and 6F during a 10-year 1-day storm event.[30]

Basin 7 encompasses 296.4 acres, further divided into 6 Sub-basins (7A-7F) and consists of a network of interconnected canals and Lake Bess which generally flow north and discharge into the C-42 Canal via a gravity-driven outfall. Stormwater flows South where it is ultimately discharged into the SFWMD North New River Canal. Pump Station No. 7 was removed due to its poor condition which causes a significant reduction in stormwater removal operational functionality for Basin 7.

The Storm Drainage Master Plan outlines consequences and potential solutions:

> As a result, the model indicates that Basin 7 may experience significant flooding of the finished floors for the 100-year 3-day storm event. There are two possible solutions that may improve the 100-year 3-day flooding. One is to install a flap gate on the outfall culvert to prevent the back flow of water from the C-42 canal into the basin. The second would be to reinstall the Pump Station with a design that would be better suited to conform to the existing available area. This basin shows that flooding of road crowns can be expected during the 10-year 1-day event in sub-basins 7A – 7D. Flooding of the lower finished floors can be expected during the 100-year 3-day event in all sub-basins. Based on the results of the different 100-year simulations it is apparent that the basin imports a significant amount of inflow from the C-42 Canal. The installation of a pump station would drastically improve the current 100-year 3-day storm flood elevations as well as improve the conditions for the 10 and 25-year storm events.[31]

Basin 8 encompasses 2540.4 acres, further divided into 42 Sub-basins (8A-8NN) and consists of a network of interconnected lakes and canals that generally flow Southeast and discharged into the SFWMD North New River Canal via Pump Station No. 8. Modeling performed for the Storm Drainage Master Plan indicate that Basin 8 performs extremely well under the 10-year 1-day and the 25 and 100-year 3-day storm event simulations.[32]

Basin 9 encompasses 232.2 acres and consists of a series of small canals, ditches, and lakes connected by culverts which ultimately discharge by gravity into the SFWMD C-13 Canal and models indicate that this basin performs well during all storm simulations.[33]

Basin 10 encompasses 242.8 acres, further divided into 4 Sub-basins (10A-10D) and consists of a network of interconnected canals that generally flow toward the Southeast where stormwater is discharged via a gravity-driven outfall into the SFWMD C-13 Canal. Models indicate that Basin 10 performs well under the 25-year and 100-year 3-day storm events but exhibits minor to substantial street flooding during the 10-year 1-day storm event.[34]

Basin 11 encompasses 1035.3 acres, further divided into 20 Sub-basins (11A-11T) and consists of a network of interconnected canals that flow Southeast until stormwater is discharged into the SFWMD C-13 Canal via a gravity driven outfall. Modeling performed for the Storm Drain Master Plan indicates that periods of road crown flooding during a 10-year 1-day storm simulation will occur in nearly all of the northern sub-basins. The Storm Drainage Master Plan recommends that culvert P11G-H needs to be upgraded to mitigate flooding and recommends upgrading Pipe11F-H to increase flood protection for the residential areas within Sub-Basin F under the 100-year 3-day storm event.[35]

Basin 12 encompasses 322.6 acres, further divided into 3 Sub-basins (12A-12C) and consists of a network of canals that flow South where stormwater is discharged into the SFWMD C-13 Canal via a gravity-driven outfall. Model results performed for the Storm Drainage Master Plan indicate that road crown flooding can be expected during the 10-year 1-day storm event throughout the entire basin, and that there is a possibility of water levels exceeding some finished floor elevations in Sub-basins 12B and 12C during the 100-year 3-day storm event.[36]

Basin 13 encompasses 716.4 acres, further divided into 7 Sub-basins (13A-13G) and consists of a network of interconnected canals and lakes. Stormwater discharges over the Western and Southern weirs and flows into the C-42 and C-13 Canals. Modeling performed for the Storm Drainage Master Plan indicates a possibility of water levels exceeding some finished floor elevations in Sub-basins 13A and 13F and recommends installation of flap gates or check valves on the 2 culverts connecting to the SFWMD canals to prevent backflow.[37]

Basin 14 encompasses 186.2 acres, further divided into 5 Sub-basins (14A-14E) and consists of a network of interconnected lakes that discharge into the C-42 or the C-13 Canal. Model results performed for the Storm Drainage Master Plan indicate that road crowns in Sub-basins 14A and 14D can be expected to flood during the 10-year 1-day storm simulation, and that there is a possibility of water levels exceeding some finished floor elevations in Sub-basins 14A and 14E during the 100-year 3-day storm event.[38]

Basin 15 encompasses 551.1 acres, further divided into 13 Sub-basins (15A-15L, and 15A1) and consists of a network of interconnected canals that flow Southwest where stormwater is discharged into the C-42 Canal via a weir and an outfall. Stormwater is then ultimately delivered to the SFWMD C-13 Canal. Modeling performed for the Storm Drainage Master Plan shows that the low pavement in all Sub-basins other than 15B can be expected to flood during the 10-year 1-day storm event, and that there is a possibility of water levels exceeding some finished floor elevations in Sub-basins 15A, 15B, and 15C during the 100-year 3-day storm event.[39]

Basin 16 encompasses 647.6 acres, further divided into 11 Sub-basins (16A-16K0 and consists of a network of interconnected lakes and canals that flow North discharging into the L-35A Canal via a culvert outfall. Model results performed for the Storm Drainage Master Plan show low road crowns or pavement elevations can be expected to flood during the 10-year 1-day storm event in Sub-basins 16B, 16C, 16D, and 16J, and indicate a possibility of water levels exceeding some finished floor elevations in Sub-basins 16B-16J. The Storm Drainage Master Plan recommends installation of a stop log riser at elevation 8.5 N.G.V.D. in the drainage ditch north of the park in Sub-basin 16K to reduce potential flooding during storm events exceeding 13."[40]

Basin 17 encompasses 556.3 acres, further divided into 10 Sub-basins (17A-17J) and consists of network of interconnected canals that flow West where stormwater is discharged into the L-35A Canal. A current permit from the SFWMD calls for changing existing stormwater infrastructure to divert stormwater from Sub-basins 17A-17J East to the C-13 Canal. These changes are dependent on the pending development of Sub-basin 17J containing Sunrise Land. Models performed for the Storm Drainage Master Plan indicate this basin performing well under all storm events prior to development of Sub-basin 17J, but model results after development of 17J with the proposed changes to stormwater infrastructure indicate a possibility of water levels exceeding some finished floor elevations in all sub-basins except for 17E during the 100-year 3-day storm event.[41]

Basin 18 encompasses 1839.6 acres, further divided into 12 Sub-basins (18A-18L) and consists of a series of interconnected lakes and canals that flow Southwest where there is a weir control structure that overflows to an outfall connected to the Central Broward Drainage District's N-31 Canal. Stormwater is then delivered to the SFWMD C-11 Canal. Model results performed for the Storm Drainage Master Plan indicate that road crowns remain protected during the 10-year 1-day storm event and that the finished floors remain protected during the 100-year 3-day storm event simulations.[42]

CONCLUSIONS

Climate data. Climate change and resiliency data to support future decision-making related to impacts requires consideration of increased water stresses associated with a greater likelihood of high intensity rainfall events that can cause damaging floods as well as the potential for increased drought. The extremes will become more extreme. Sunrise should continue to engage in cooperative data exchange with Broward County and monitor updates to sea level rise projections from Compact or other relevant agencies such as NOAA or the U.S. Army Corps of Engineers.

Other data and monitoring. Given that it is widely expected that sea-level rise will eventually elevate the regional groundwater table throughout much of Broward County, Sunrise should continue to monitor new data about the relationship between an elevated groundwater table and the reduction of overall groundwater storage capacity. This relationship could increase the surface runoff potential from given storm events in areas that may or may not impact Sunrise. But it is an issue for further inspection.

Stormwater. This report recommends planning efforts to mitigate potential flood risks for finished floor elevations that could be impacted by 25-year and 100-year 3-day storm events. A future conditions hydrological analysis should also be incorporated into future updates of the Sunrise's Storm Drainage Master Plan.

Sunrise should also consider relevant opportunities to improve its score in the CRS program through the pursuit of climate, future conditions and sea level rise activities and credits. In doing so, Sunrise should evaluate the benefit of pursuing these credits for the 4,641 policies currently in effect against the effort to obtain them.

Finally, ongoing and enhanced coordination with the SFWMD is critical to address efforts related to sea level rise impacts on coastal structures upon which Sunrise's drainage capacity is dependent.

Facilities and Assets. Critical facilities and Sunrise's municipal assets within the SFHA are at a potential risk of losing function during and after a flood event and should receive more thorough review to mitigate loss of function. This report recommends that all facilities, municipal and critical, receive site level investigation using survey quality elevation data and engineering assessments of resistance to floodwater as a critical next step to determine present and future vulnerability of facilities within the SFHA. Finally, a GIS inventory of finished-floor elevation data for all critical and city-owned facilities that are within the SFHA could be helpful for future decision-making. It should be clear that while recognizing not all of these critical facilities are owned and operated by Sunrise, there are times when there may be significant reliance on them by the community, especially during weather events.

Roads. While Sunrise may not control every roadway facility, it is important to maintain an understanding of where potential risks are from future flooding scenarios to maintain critical access. Where appropriate, this may necessitate coordination with other agencies or jurisdictions that are responsible for certain roadway systems. As outlined, detailed elevation data for road centers and crowns was not available for this assessment, but survey grade-elevation data of impacted roads, specifically for the Sawgrass Expressway Ramp segments, and roads that feed into that network, provide the next step to determine enhanced accuracy of site level flood vulnerability.

Water supply. Further monitoring and investigation of potential saltwater intrusion into Sunrise's groundwater supply may be warranted because of the more western location of Sunrise's wellfields.

ENDNOTES

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