



SECTION 4: Stormwater Analysis

Section 4 Stormwater Analysis

4.1 Background

Wilton Manors has the distinction of being almost entirely surrounded by water – on the north by North Middle River and the south by South Middle River. The rivers are tidal and converge on the west side of U.S. 1 (North Federal Highway). The Middle River then meanders south and connects into the Intracoastal Waterway. The river receives stormwater discharges from areas west of Wilton Manors (C-13 Basin) via South Florida Water Management District’s S-36 Structure.

Similar to many of the natural rivers in Florida, the Middle River has been heavily impact by channelization, diversion and the loss of riparian wetlands that flanked much of the river. **Figure 4-1** shows an aerial photograph of Wilton Manors taken in March of 1947, just a few months before the City was incorporated. Almost all of the City has since been developed into residential, commercial, industrial and recreational land uses.



Figure 4-1: 1947 Aerial Photography

Much of the City’s development occurred prior to regulatory requirements that were established in the mid to late 1970s as a result of the Clean Water Act of 1972. Therefore, many developments lack stormwater detention areas which are used for both flood protection and water quality treatment. Additionally, older developments often include insufficient stormwater conveyance capacity compared to today’s standards. Undersized pipes and poor roadway surface grading are common in older communities.

Some large developments within the City; however, were built more recently and meet the current regulatory requirements. Many of these development exist in the southern portion of the City and include systems of total retention, which means that these areas are designed not to discharge stormwater for storm events up to and including the 25-year, 3-day storm. These systems rely on dry detention areas and exfiltration trenches for total retention. Exfiltration trenches have also been retrofitted into older areas to provide flood relief and water quality.

As part of the Clean Water Act of 1972, there have also been rules implemented to address to water quality of canals, rivers, lakes and estuaries. The National Pollutant Discharge Elimination System (NPDES) was established to inventory stormwater outfalls, monitor pollutant concentrations and enforce upstream reduction of illicit discharges regardless of when the upstream development was constructed. Water quality monitoring of the C-13 East and Middle River (WBID 3274) have found excesses of fecal coliforms, which has required the FDEP to establish a Total Maximum Daily Load (TMDL) for the river with the goal of reducing fecal coliforms.

Sea Level Rise (SLR) is also of special concern for Wilton Manors because it is virtually surrounded by tidally influenced waters. Some residents have noticed higher king tides than they have seen in the past. Higher levels in the river mean higher tailwater on the drainage system resulting in lower discharge rates and less flood protection. SLR also results in higher future groundwater levels which reduce the capacity of the soils to absorb and store water. This also will impact the effectiveness of the existing exfiltration systems.

In 2003, the City of Wilton Manors adopted Chapter 20, Article V of the City's Code of Ordinances to impose a stormwater utility user fee for the purpose of funding the maintenance, repair, improvements, and administration of the stormwater facilities throughout the City.

The purpose of this Stormwater Master Plan is to address all of the above by assessing the existing system for existing and future conditions. The Master Plan will develop recommendations for improvements that can be implemented on a phased schedule with the goals of preserving and improving flood protection and water quality.

4.2 Drainage Questionnaires

Resident input is an important aspect of assessing stormwater systems. Despite the advancement of models and the data used in the models, eye witness accounts can help provide confirmation of the model results or can draw attention to events that the models may not be accurately capturing. They can also indicate locations where other problems may be occurring related to the condition of the system.

A drainage questionnaire was developed in an attempt to determine where flooding has been observed and what the residents believe the causes may have been. **Figure 4-2** shows a sample questionnaire which was created in Adobe Acrobat with text fields and check boxes.



City of Wilton Manors Public Drainage Survey

(Please complete a separate form for each problem area and provide as much information as possible)
Email completed forms to WMSurveys@Baxterwoodman.com or mail survey to:
6600 N. Andrews Ave. #100, Ft. Lauderdale, FL 33309

1. What type of problem have you observed? (check all that apply)
 flooding potholes damaged gutters/drains/manholes other _____

2. Where is the problem located? Please indicate an address or intersection: _____

3. Approximately how long has the problem existed? _____

4. Has the problem gotten any worse over time? Yes No

5. The extent of flooding depends on the amount of rain that occurs. Please answer to the best of your ability the following questions concerning the amount of flooding:
 Does it take a large storm to flood the area? _____
 On average, how often does the area flood? _____
 On average, how deep is the flooding? _____
 On average, how long does it take for the floodwater to go away? _____
 What is the worst flood you have seen in this area? _____
 Approximately when did the worst flood occur? _____

6. Is there any trash left behind when the floodwaters are gone? Yes No

7. Do you have any ideas about what may be causing the problem? Please explain below:

8. Additional Comments:

9. Do you have any photos of the problem? (Please email photos to the address above) Yes No

- Neighborhood Association: _____
 Name: _____
 Address: _____

 Phone: _____
 Email: _____

Figure 4-2: Sample Drainage Survey Questionnaire

The questionnaires were sent to the presidents of three (3) homeowner associations within the City: Westside Association of Wilton Manors, East Neighborhood Association of Wilton Manors and the Central Area Neighborhood Association of Wilton Manors. The homeowner association presidents were asked to distribute the questionnaires to their respective residents. Respondents were encouraged to provide as much information as possible regarding repetitive flooding in their neighborhood as well other parts of the City where they are aware that flooding is also occurring. In total, nine (9) completed questionnaires were received via email and one (1) was received by mail. Some returned questionnaires covered more than one site. The ten (10) completed questionnaires are provided in *Appendix B*.

Two (2) of the returned questionnaires reported overflow from a sanitary manhole that would then drain into the stormwater system. One resident even provided a video of the occurrence. This is indicative of a problem with the wastewater collection system which may be experiencing groundwater infiltration at that location or a possible blockage. This issue is addressed in detail in *Section 3* of this Master Plan. Such occurrences are common in older wastewater collection systems in low lying areas. It is especially concerning; however, considering that the river has been designated as an impaired waterbody due to excess fecal coliforms.

The residents were asked their opinions of what may be causing the flooding. The responses ranged from inadequate pipe sizes to possible clogging. In some cases, recent nearby development was cited. *Figure 4-3* shows the locations of the flooding complaints and a brief summary of the problem and potential causes.

Overall, ten (10) responses is not a sufficient sample size to adequately characterize the flood conditions that are occurring within the City. Every piece of information; however, is important and was taken into consideration in conjunction with the modeling efforts.

Additionally, the City provided complaint logs received through correspondence with residents. *Figure 4-4* shows the locations of the flooding complaints received by the City and a brief summary of the action taken by the City to resolve the problem. A majority of the complaints received by the City pertain to cleaning and maintenance of the stormwater system and issues due to recent construction projects.

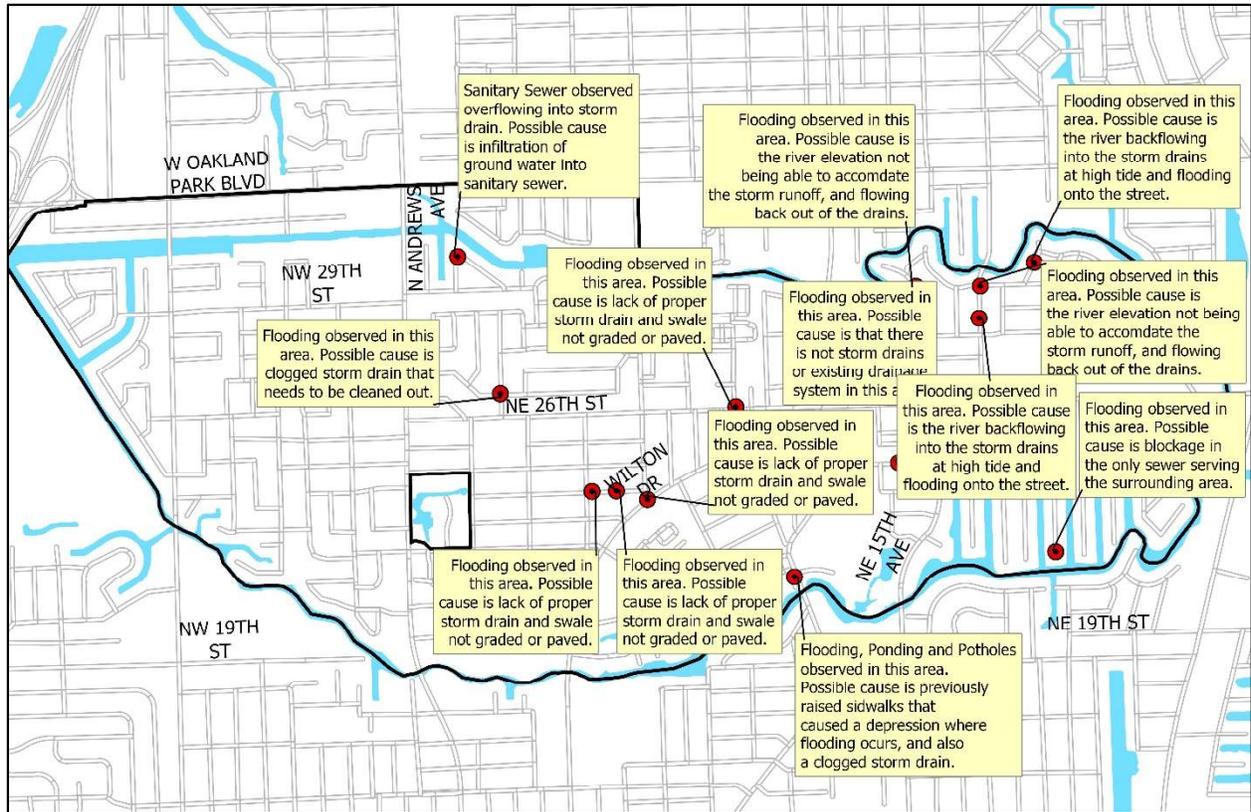


Figure 4-3: Flooding Complaints Received from Drainage Questionnaire

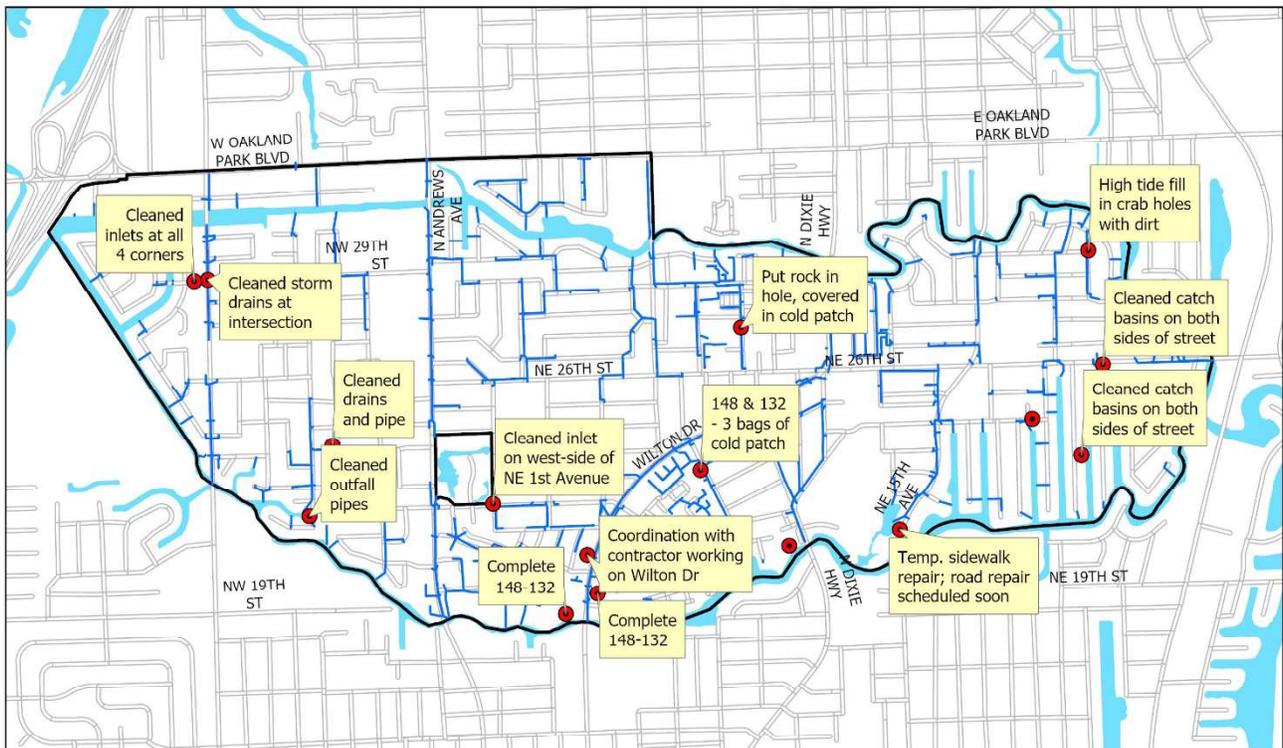


Figure 4-4: Flooding Complaints Received from City

4.3 Regulatory Requirements

4.3.1 Environmental Resource Permitting

The South Florida Water Management District (SFWMD) is the agency with jurisdiction with regard to regulation and enforcement of construction related activities that effect Waters of the State. The Middle River is considered Waters of the State. SFWMD has delegated permit review for Environmental Resource Permits (ERPs) to Broward County which also issues a County Surface Water license. The requirement for an ERP and County license are very similar. They impose a pre- versus post-requirement for peak discharge rates and stages associated with a 25-year, 3-day storm event and also require water quality treatment of a determined volume of runoff based on the amount of proposed impervious area. Pre- versus post- simply means that the proposed parameters (discharges rates and stages) cannot exceed the existing parameter values. Since no new impervious area will be proposed in the Master Plan recommendations, the pre-versus post- rule will be the primary criterion to be followed.

SFWMD and Broward County will encourage the incorporation of water quality Best Management Practices (BMPs), which coincides with the City's goal for the improvement of the water resources that are integral with City. Additionally, water quality improvements will be addressed in this Master Plan.

Broward County also requires that major redevelopment projects use a future groundwater elevation based on SLR projections. This would affect control elevations and soil storage assumptions. For Broward County and SFWMD regulations, SLR projections would not apply to projects that are anticipated in this Master Plan since they would not be considered "major redevelopment." The Master Plan, however, will consider SLR, regardless.

The United States Army Corps of Engineers (USACE) will also be a regulatory entity for environmental permitting in regard to activities on, in or over Waters of the State. A 'Nationwide' permit would be required for modified or new outfall pipes into the river. USACE would be reviewing such projects for environmental impacts to sea grass and marine life in the river. It will need to be demonstrated that erosive velocities will not occur and that water quality will not be degraded.

4.3.2 Federal Emergency Management Agency Flood Hazard

Finished floor elevations of new buildings within the City must be set at or above Federal Emergency Management Agency's (FEMA) Flood Hazard stages which are depicted on **Figure 4-5** and based on a 100-year storm event and a storm surge elevation of approximately 4.5 feet, North American Vertical Datum of 1988 (NAVD88) in the Middle River in the vicinity of the City.

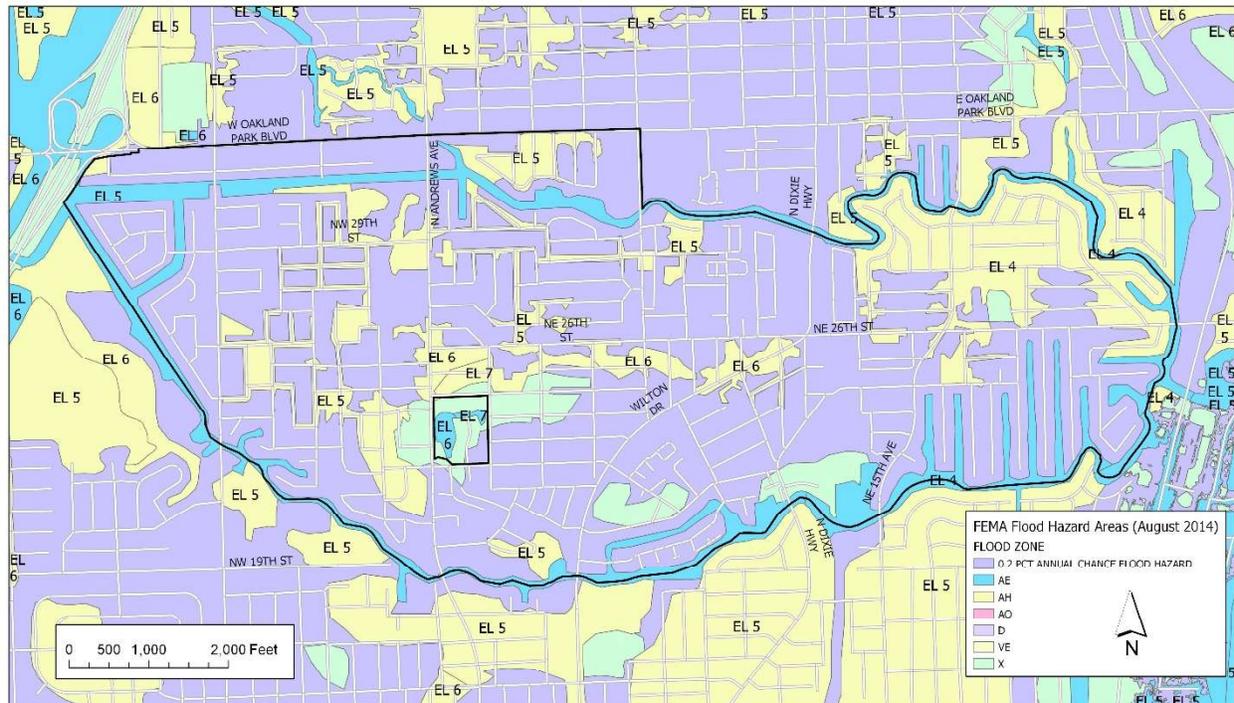


Figure 4-5: FEMA Flood Hazard Areas

4.3.3 National Pollutant Discharge Elimination System (NPDES) Program

The Environmental Protection Agency (EPA) was mandated by the United States Congress through Section 405 of the Water Quality Act of 1987 to manage the National Pollutant Discharge Elimination System (NPDES) Program for stormwater discharges from Municipal Separate Storm Systems (MS4s). In the State of Florida, EPA has delegated the NPDES Permit Program regulation to the Florida Department of Environmental Protection (FDEP).

The City of Wilton Manors is one of the twenty-nine entities authorized for stormwater discharge under the comprehensive Broward County NPDES MS4 permit (Permit Number FLS000016-003). This permit is currently in its fourth cycle with each cycle consisting of approximately 5 years. The City is authorized to discharge to Waters of the State per the approved stormwater management programs, effluent limitations, monitoring requirements, and other provisions as set forth in this permit. This permit is administered by FDEP and requires the City to perform record keeping on the maintenance and operation of the existing stormwater management system through annual NPDES Reporting.

The NPDES Program requires that the City implement a Stormwater Management Plan designed to reduce the discharge of pollutants into water bodies. The following outlines the specific enforceable sections of the Broward County NPDES MS4 permit (Permit Number FLS000016-003) that co-permittees are required to report on annually and the associated required inspection and maintenance activities:

Structural Controls and Stormwater Collection System Operation:

Permittees must provide an inventory of all structural controls, stormwater collection and conveyance systems, and outfalls. Additionally, all permittees must have Standard Operating Procedures (SOPs) for Structural Control Inspections. **Table 4-1** outlines the specific structural controls, stormwater collection and conveyance systems, and outfalls that the City currently owns and maintains. The City is required to report inspection and maintenance activity at the frequencies shown to comply with the NPDES Permit Conditions.

Table 4-1: NPDES Inspections & Maintenance Requirements

Type of Structure	Required Inspection Frequency	Possible Inspection Activities	Maintenance Frequency
Exfiltration Trench	New = Annually the first 2 years of operation; Existing (Good Condition) = Once every 3 years; Existing (Poor Condition) = Annually until chronic problems are corrected	i.e. Inspection for sediment, oil, and grit accumulation; Inspection for storage volume recovery	As needed based on inspection to assure proper operation
Grass Treatment Swales (Dry)	New = Annually the first 2 years of operation; Existing (Good Condition) = Once every 3 years; Existing (Poor Condition) = Annually until chronic problems are corrected	i.e. Inspect for storage volume recovery within 72 hrs; Inspect for debris, litter or sediment accumulation; Inspect for obstructions (parking, filling excavation, etc.)	As needed based on inspection to assure proper operation
Pollution Control Boxes; Weirs	Quarterly – unless historic clean out operation records demonstrated that a more or less frequent schedule is appropriate	i.e. Inspect sediment, vegetation and debris accumulation; Inspect absorbent materials to determine if replacement is needed	As needed based on inspection to assure proper operation
Pump Stations	Semi-annually or more frequently as needed	i.e. Inspect for proper pump operation; Inspect inlets and bar screens for debris	As needed based on inspection to assure proper operation
Pipes / Culverts	Inspect a minimum of 10% of the total number of structures each year. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years).	i.e. Visual inspections for structural deficiencies and/or sediment or litter accumulation; Televising; Lamping	As needed based on inspection to assure proper operation
Inlets, Catch Basins, Ditches, Conveyance Swales, & Other Stormwater Conveyances	Inspect a minimum of 10% of the total number of structures each year. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years).	i.e. Inspect for sediment and litter accumulation; Inspect for erosion	As needed based on inspection to assure proper operation

Areas of New Development and Significant Redevelopment:

Permittees are required to adhere to a comprehensive master plan to reduce the discharge of pollutants. As part of this planning effort, permittees must maintain documentation of new development or significant redevelopment.

Roadways:

Permittees must maintain all public roads, rights-of-way, and maintenance yards / shops to reduce the discharge of pollutants into the MS4. Each permittee is required to have a Litter Control Program SOP that governs trash collection and maintenance of the public rights-of-way. This SOP may include a street sweeping program, which is encouraged as a Best Management Practice (BMP) for municipalities that own curb and gutter.

Flood Control Projects:

Permittees are required to review, evaluate, and track proposed flood control projects within the MS4. All proposed flood control projects must include stormwater treatment.

Municipal Waste Treatment, Storage and Disposal Facilities:

Permittees must monitor known facilities that handle municipal waste that are not covered by another NPDES stormwater permit. The monitoring program should be implemented and evaluated regularly for effectiveness in reducing pollutants in stormwater discharges from these facilities.

Pesticides, Herbicides, and Fertilizer Application:

Permittees are advised to adopt an Ordinance or SOP related to pesticide, herbicide and fertilizer application practices. Florida Department of Agriculture & Consumer Sciences (FDACS) licenses along with Green Industry BMP Training is required for applicators of pesticides, herbicides and fertilizers. Additionally, permittees must implement a public education / outreach program to encourage citizens to reduce their use of pesticides, herbicides and fertilizers. This public program may be in conjunction with other local permittees.

Illicit Discharges and Improper Disposal:

Permittees are required to be proactive and adopt the necessary SOP's and Ordinances to detect and eliminate illicit discharges and improper disposal into the MS4. All appropriate personnel must have the required annual training to identify and report potential illicit discharges, illegal connections and dumping into the MS4. The following are the only non-stormwater discharges that are allowed into the MS4:

- Water line flushing
- Landscaping irrigation
- Diverted stream flows
- Uncontaminated ground water infiltration to separate storm sewers
- Uncontaminated pumped ground water
- Discharges from potable water sources
- Foundation drains

- Air conditioning condensate
- Irrigation water
- Springs
- Water from crawl space pumps
- Footing drains
- Lawn watering
- Individual residential car washing
- Flows from riparian habitats and wetlands
- Dechlorinated swimming pool discharges
- Street wash waters
- Discharges or flows from emergency firefighting activities
- Reclaimed water line flushing authorized pursuant to a permit issuance under Rule 62-610 F.A.C.
- Flows from uncontaminated roof drains

All permittees are required to have a spill response and prevention SOP in place in case of hazardous and non-hazardous material spills. All appropriate personnel must have the necessary spill response training. Additionally, permittees must implement a public education / outreach program to encourage citizens to identify and report suspected illicit discharges and how to properly dispose of oils, toxics and house hazardous waste. This public program may be in conjunction with other local permittees.

Permittees are required to monitor and implement activities to reduce/eliminate sanitary sewer overflows (SSO) and infiltration & inflow (I&I) into the MS4.

Industrial & High-Risk Runoff:

Permittees must maintain an inventory of high-risk facilities within the MS4 and perform recorded inspections of these facilities. High-risk facilities include operating municipal landfills; hazardous waste treatment, storage, disposal and recovery (HWTSDR) facilities; EPCRA Title III, Section 313 facilities (TRI); and facilities deemed as high-risk by the permittee.

Construction Site Runoff:

Permittees are required to create and implement a SOP for construction site inspections of both private and public construction sites. This SOP outlines the required use and maintenance of appropriate stormwater best management practices to reduce pollutants discharge to the MS4 during construction. All construction sites that meet ERP and Construction General Permit (CGP) requirements must be logged, inspected and confirmed coverage for both requirements. Pre-, during and Post-inspections are required for all active construction sites that meet ERP and CGP requirements. Permittees are required to have the necessary codes and ordinances in place to enforce action if best management practices are not being adhered to at active construction sites. All permittee construction site inspectors, plan reviewers, and site operators are required to have the necessary FDEP Stormwater Inspector training and annual training.

TMDL Status Report:

As defined by FDEP, “a Total Maximum Daily Load (TMDL) is a scientific determination of the maximum amount of a given pollutant that a surface water can absorb and still meet the water quality standards that protect human health and aquatic life.” Surface water bodies that exceed FDEP-specified TMDL’s are classified as impaired. Permittees that discharge to an impaired waterbody with a known total maximum daily load (TMDL) must include a prioritized TMDL list along with the monitoring and implementation schedule. In the subsequent reporting years, monitoring data summaries including estimated load reductions along with proposed revisions to the Stormwater Management Plan (SWMP) are required to address the TMDL.

Specific Year Reporting Requirements:

Year 1 Only = Permittee must submit an updated inventory and map of all known major outfalls with the Annual Report.

Year 2 Only = Permittee must provide a summary review and evaluation of current codes and regulations to reduce stormwater from development with the Annual Report.

Year 2 Only = Permittee must include a copy of the adopted Florida-friendly fertilizer ordinance if required with the Annual Report.

Year 3 Only = Permittee must provide estimates of pollutant loading and event mean concentrations for each major outfall or watershed with the Annual Report.

Year 4 Only = Permittee must submit a follow-up report to the Year 2 code and regulation review. Additionally, if total annual pollutant loadings have not decreased over the past 2 permit cycles then revisions to the SWMP are required to be submitted with the Annual Report.

Cycle 4 – New Requirements:

As part of the Cycle 4 NPDES Permit, each permittee is required to submit an assessment program for review and approval by FDEP during Year 1. The Assessment Program is intended to assist each individual permittee in evaluating the effectiveness of its stormwater management program in reducing stormwater pollutant loadings. FDEP has reviewed all Assessment Programs during Year 1 and permittees are responsible for implementing their respective programs once approved. In the Cycle 4, Year 4 Permit, each MS4 permittee must evaluate their Assessment Program and recommend any needed revisions.

The Assessment Program can be broken down in the following three (3) implementation plans:

- Water Quality Monitoring Plan
- Pollutant Loading Estimate Plan
- Evaluation / Action Plan

City of Wilton Manors NPDES Cycle 4 Permit Program:

The City of Wilton Manors entered into an interlocal agreement with Broward County on July 18, 2017, which defines the City as a “co-permittee” and Broward County as the “lead-permittee” of NPDES Permit Cycle 4 (Permit #FLS000016-004). Through the interlocal agreement, Broward County is responsible for managing and performing certain technical tasks necessary to determine compliance with the applicable portions of Parts III and V of the NPDES MS4 permit for all co-permittees. The City of Wilton Manors is currently in the third year of the Cycle 4 permit. As outlined in the aforementioned permit requirements section, the City completes an annual report utilizing both in-house and information provided by Broward County.

In addition to the standard reporting required of all permittees, the City is also required to report on the TMDL process that is currently on-going for the C-13 East (Middle River) Canal (WBID 3274). The C-13 East (Middle River) Canal (WBID 3274) has been deemed impaired by FDEP for fecal coliform and the City's stormwater system discharges to this surficial water body. The City has been coordinating with other local stakeholders during Years 1 and 2 of the reporting cycle to determine pollution sources and potential SWMP updates. As part of the Year 3 reporting, the City will submit a monitoring data summary and estimated load reductions. Based on this information, the City will submit a revised SWMP during the Year 4 reporting. Since the impairment of the C-13 East (Middle River) Canal is for fecal coliform, this planning document will review the proposed stormwater improvements in conjunction with the proposed sanitary sewer improvements as potential ways to reduce fecal coliform.

4.4 Stormwater Model Development

A flood routing model was developed to simulate the existing drainage systems using Inter-Connected Pond Routing version 4 (ICPR4) software. This model can simulate various storm events to verify the benefits of potential improvements while verifying the permitability of proposed systems. Specifically, flood stages and peak discharge rates cannot be increased. These criteria are evaluated for a 25-year, 3-day storm event. A 3-year, 1-day storm is used to evaluate the minimum LOS relative to street flooding.

4.4.1 Hydrology

No previous drainage studies were available from the City and it appears that a City-wide stormwater model has never been developed before with the exception of a countywide FEMA model used to determine the flood hazard areas. FEMA modeling, however, does not account for individual sub-basins and drainage infrastructure and is intended for purposes other than the stated goals of this Master Plan. Therefore, the datasets needed for a City-wide stormwater model needed to be created including sub-basin boundaries. Stormwater infrastructure, permits and topography were used to delineate the sub-basins. Many of the sub-basins correspond to the estimated contributing area of an existing outfall. Some sub-basins, however, are located further upstream and discharge through another sub-basin before discharging to the Middle River.

A GIS dataset of the stormwater infrastructure was provided by the City. Permit information was obtained from the SFWMD and Broward County. Permitted areas are a good indication of where sub-basin divides exist. Most permitted areas handle their own drainage and are required to have perimeter elevation up to the 25-year, 3-day storm peak stage. Topography also provides a crucial backdrop for sub-basin delineation. Light Detection and Ranging (LiDAR) data available from the Florida Division of Emergency Management (FDEM) was obtained. The information is in the form of rasters with elevations provided in every 5-foot by 5-foot cell. This dataset, however, is over 10 years old and some areas that have been redeveloped may not be accurately depicted.

Figure 4-6 shows the results of the sub-basin delineation along with the drainage infrastructure and existing LiDAR Topography. It should be noted that the area that is not in the City, but is surrounded by the City, known as Lazy Lake, was included in the hydrology of the model because it contributes runoff to portions of the City.

The majority of the soils within the project area are classified as Immokalee, which is defined as poorly drained with relatively low percolation rates. Other soils such as Arents, Matlatcha and Udorthents also exist that are considered somewhat poorly drained. The only well drained soil, Dade, corresponds to the highest elevations within the City as seen in **Figure 4-7**. Soils are important for hydrology because they indicate the potential stormwater absorption capacity. Stormwater that is in excess of that capacity will become runoff and will enter the drainage infrastructure or sheet-flow to low lying areas. A Curve Number (CN) is developed to be used in the model to represent the soils ability to store water. The depth to the wet season water table also affects the volume of potential soil storage. The water table elevation ranges from 1.0 feet, NAVD to 2.0 feet, NAVD based on Broward County water table maps and existing permits within the City. **Table 4-2** shows the curve numbers SFWMD recommends for various types of soils per the depth to the water table for compacted soils.

Table 4-2: SFWMD Recommended Curve Numbers

Depth to W.T.	Well Drained	Somewhat Drained	Poorly Drained
1'	96	96	96
2'	84	84	86
3'	67	71	75
4'	55	60	66

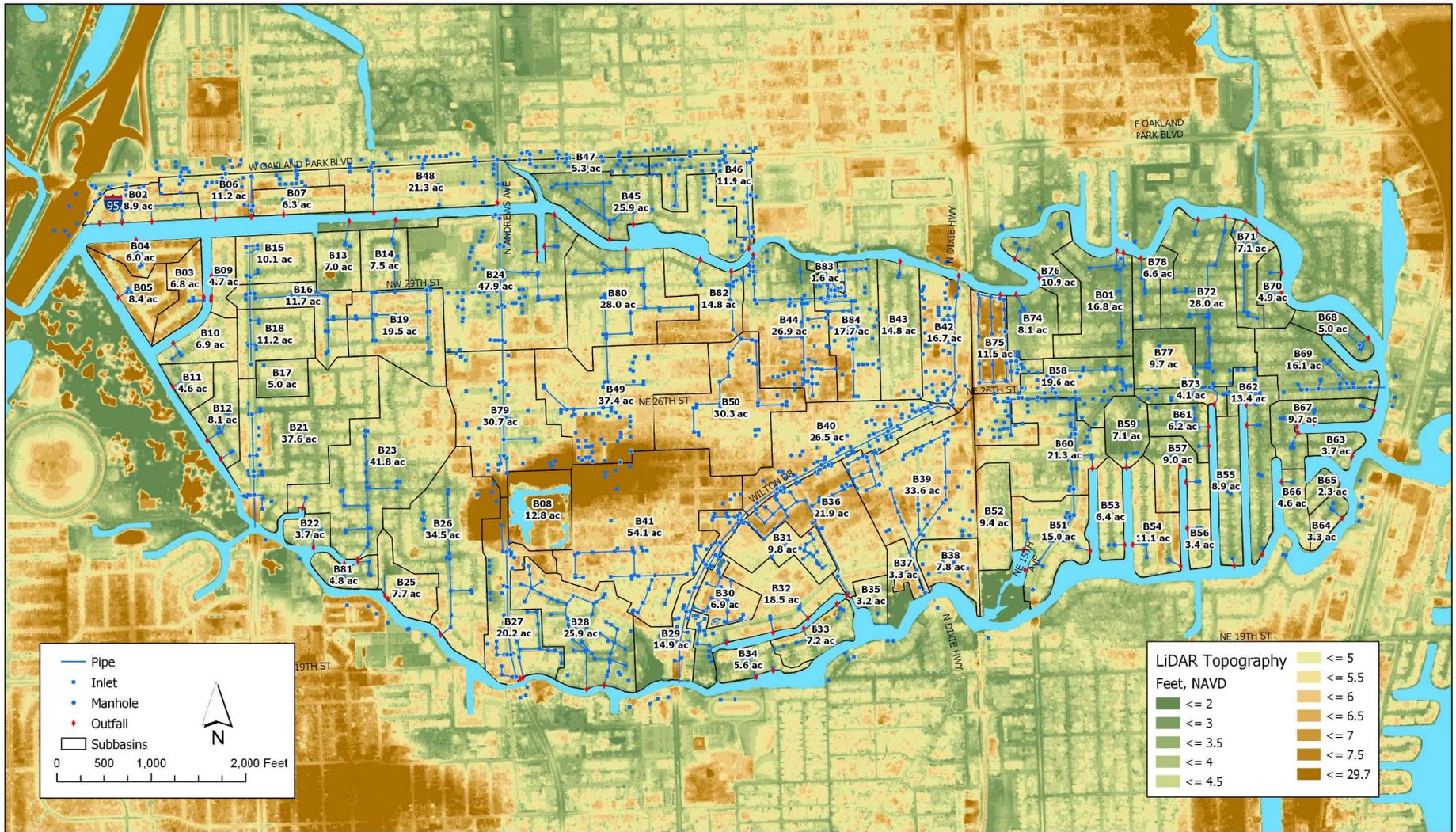


Figure 4-6: Sub-basin Delineation

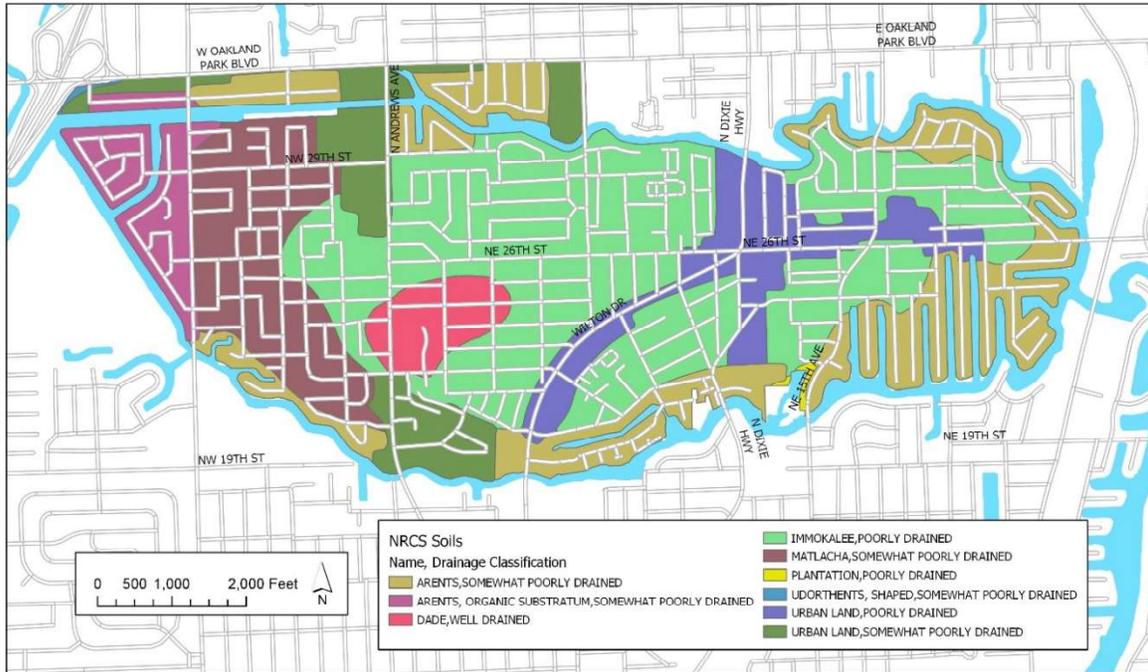


Figure 4-7: NRCS Soils with Drainage Classifications

To develop curve numbers, a GIS dataset was created for the depth to the water table by subtracting the groundwater elevation from the LiDAR topography. The depths were then spatially intersected with the soil hydrologic classifications and curve numbers were assigned to the intersected polygons based on the values in *Table 4-2*. *Figure 4-8* shows the resulting curve numbers throughout the City based on the soils and depths to the water table.

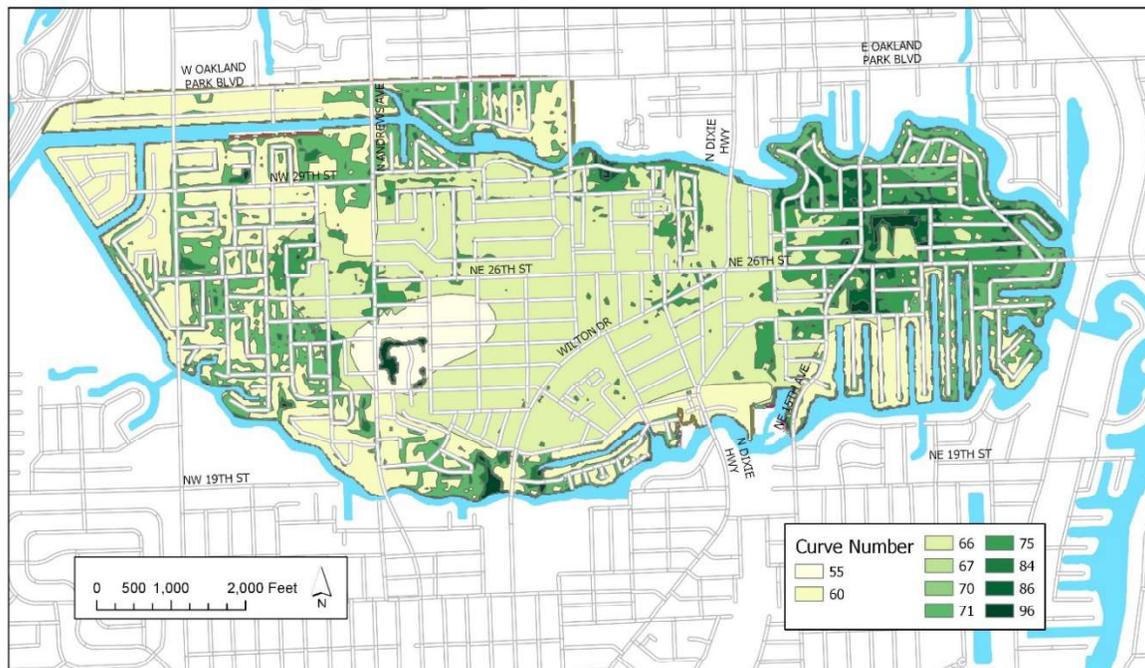


Figure 4-8: Curve Numbers Based on Soil Type and Adjusted by Depth to Water Table

These values were used throughout the City and are adjusted in the ICPR model by impervious percentage values that were applied based on land use. **Table 4-3** shows the percentages of impervious area that were assumed for each land use. Land use within the City is a mix of single-family residential, commercial, parks, industrial and institutional. A land use map was provided by the City. This map was updated and converted to the Florida Land Cover and Classification System (FLUCCS) to match established land use characteristic. Road rights-of-ways were also added to the dataset because these areas are an important feature in terms of drainage by providing conveyance. **Figure 4-9** shows the existing land uses within the City.

Table 4-3: Land Use Assumptions

Land Use	Impervious	Manning's Equation Roughness Coefficient
Channelized Waterways, Canals	100%	0.01
Commercial and Services	90%	0.05
Educational Facilities	70%	0.02
Fixed Single Family Units	40%	0.15
Institutional	70%	0.02
Multiple Dwelling Units	70%	0.05
Other Light Industry	90%	0.02
Parks and Zoos	25%	0.15
Reservoirs	100%	0.01
Roads and Highways	85%	0.01
Shopping Centers	90%	0.05
Upland Hardwood Forests	0%	0.50

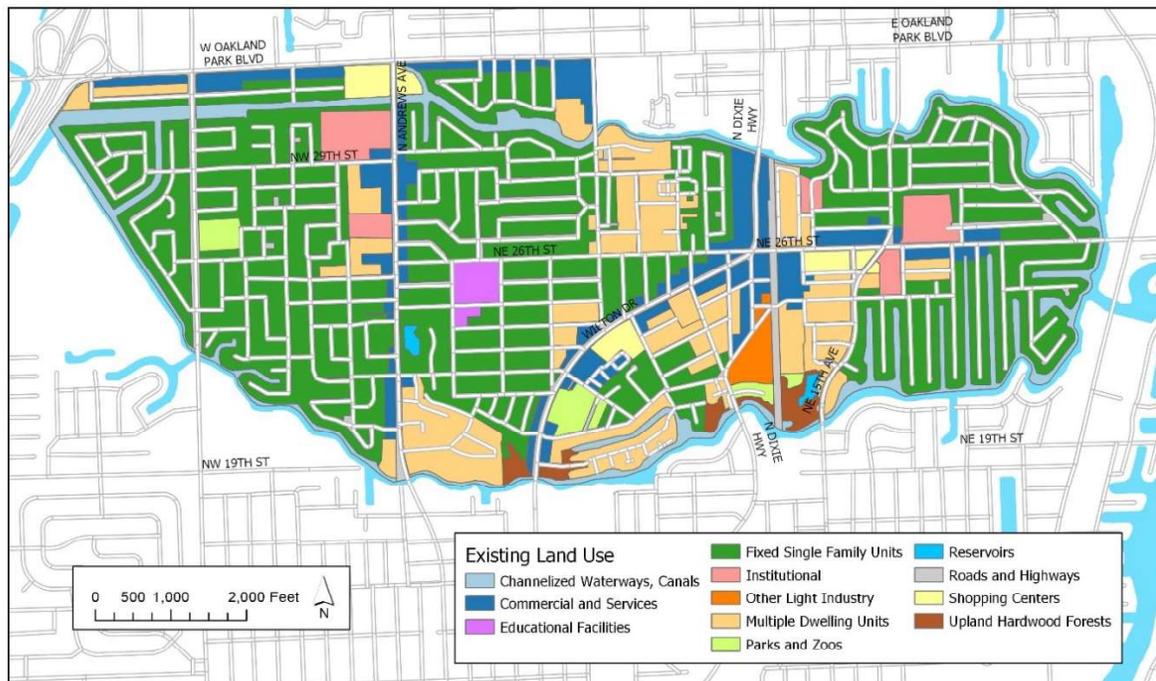


Figure 4-9: Existing Land Use

Time of Concentration (Tc) values were also calculated for each sub-basin based on travel distances, slopes and types of surfaces. Tc is the time it takes for runoff to travel from the far end of the sub-basin to the outfall and includes two components – sheet flow and concentrated flow. Sheet flow is assumed to occur within the first 300 feet of rainfall contacting a surface and is determined using Manning’s kinematic formula which applies roughness coefficients depending on the surface. The assumed Manning’s roughness coefficients for each land use are shown in **Table 4-3**. The concentrated flow calculation uses formulas derived in the United States Department of Agriculture Urban Hydrology for Small Watersheds TR-55 document for determining velocity which can be converted to time based on the length of travel.

A GIS model was created to develop the input data needed for the above calculations by using digitized flow paths intersected with land use (for the roughness coefficients) and LiDAR (for average slopes). The travel time for each intersected segment was calculated depending on whether the flow was sheet flow or concentrated flow and summed per sub-basin.

Another GIS model was used to create datasets needed for each sub-basin that provide the acreages of each land use and soil combination with the sub-basin. The model intersects the sub-basins, land uses and soils to create polygons of unique combinations which can be summarized. Since the soils dataset was modified to account for the depths to the water table, those depths are also factored in the unique combinations.

The Tc values and the land use/soil combination tables for the 84 sub-basins can be found in the model input data in **Appendix C**.

4.4.2 Hydraulics

The primary drainage features used to convey stormwater during a smaller storm event is an existing network of drainage culverts that collect runoff via inlets and transport the water to the North or South Fork of the Middle River. The systems are dispersed throughout the City with various pipe sizes that generally increase in size as the systems get closer to the outfalls. To simulate each system, an equivalent pipe size was calculated that matched the hydraulic characteristics of the multiple sized pipes that exist in series. This was not necessary in all locations. Some sub-basins simply include only one pipe that was put directly into the model.

Unfortunately, the GIS data for the stormwater pipes did not include invert elevations of the pipes and several pipe sizes were missing. Upstream and downstream pipe sizes were used to interpolate the missing sizes. For modeling purposes, invert elevations were assumed based on engineering judgement. For example, a cover of at least two (2) feet was maintained over the crown of the pipes at the upstream end of the systems and a minimum slope of 0.2% was used for downstream elevations. Since most of these systems become fully submerged during storm events, a full flow condition would occur regardless of the elevations, provided that they are set within the appropriate range.

In addition to these inlets and pipes, larger storm events also rely on overland flow at the boundaries of the sub-basins. Overland flow occurs when the drainage infrastructure becomes overwhelmed by the amount of runoff. To simulate this in the model, several broad crested weirs were placed at sub-basin divides. The locations and “irregular” geometry for each weir

were determined by producing and reviewing profiles of the LiDAR information along the sub-basin boundaries.

Downstream boundary condition nodes were created to represent tidal conditions in the river. An average high tide elevation of 1.0 feet, NAVD88 was used based on a review of water level data recorded downstream of SFWMD's S-36 Structure located upstream of the City, west of Interstate I-95. **Figure 4-10** shows the maximum daily stages measured since 1985 to present day. Considering the proximity of the monitoring to the SFWMD structure, some of the spikes in the data may be due to releases of flow which may not have been experienced further downstream. However, the spikes could also be due to king tides. A statistical trend line was developed for the data which shows that the average high tide elevation has risen from 0.5 feet, NAVD88 in 1985 to 1.0 feet, NAVD88 today. For the model boundary condition, elevations ranging from 1.0 to -1.0 feet, NAVD88 were used with 12-hour separations to simulate tidal conditions. The timing of the high tide was correlated with the theoretical peak of the storm events that were modeled to consider a worst case situation.

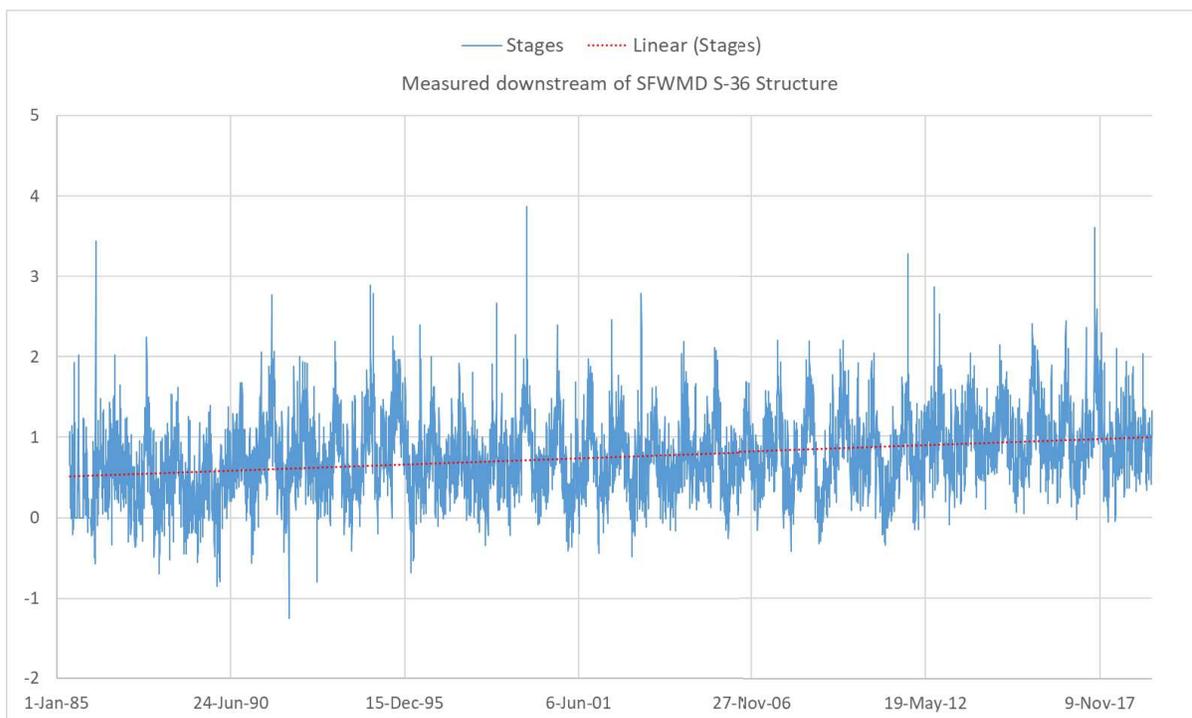


Figure 4-10: Daily Maximum Stages in the C-13 Canal (Middle River)

Stage-Area relationships were also developed for each sub-basin by utilizing GIS functions that can tabulate the number of raster cells within the LiDAR dataset that correspond to specific elevations within each sub-basin. The stage vs. area tables were entered into the ICPR model as storage nodes and they are used in the model to determine the flood elevation based on the peak runoff volume that occurs in the simulation.

The equivalent pipes, overflow weirs and stage-area tables can be found in the model input in **Appendix C**.

4.5 Model Results for Existing Conditions

The existing conditions model was run for a 3-year, 1-day; 5-year, 1-day; 10-year, 1-day; 25-year, 3-day and 100-year, 3-day storm events. After a review of the initial results, additional sheet flow between sub-basins was incorporated into the model by adding more broad-crested weirs at locations where it was apparent that such flow could occur.

The flooding that residents reported in their questionnaires matched the results in some locations, but did not in other locations. This is common because the model cannot pick up all types of flooding that can occur. There are many depressed areas where water becomes trapped and cannot make its way to an inlet or outfall. For example, *Figure 4-11* shows an area of trapped runoff next to Lift Station No. 10 on NE 26th Drive. This is an example of poor surface grading and does not reflect on the ability of the subsurface infrastructure to handle the stormwater. The



Figure 4-11: Example of Trapped Runoff

The model assumes that all runoff can get to the storage node which is linked to offsite areas via pipes and/or overflow weirs. It is also possible that the residents have correctly attributed the problems to clogs in the pipelines. These areas where flooding is reported but not verified by the model represent areas where closed circuit television (CCTV) inspection should be considered for further investigation of the existing piped system.

Figure 4-12 through 4-16 show the spatial extent and depths of flooding during the modeled storm events. The flood stage elevations per sub-basin are provided in *Table 4-4*.

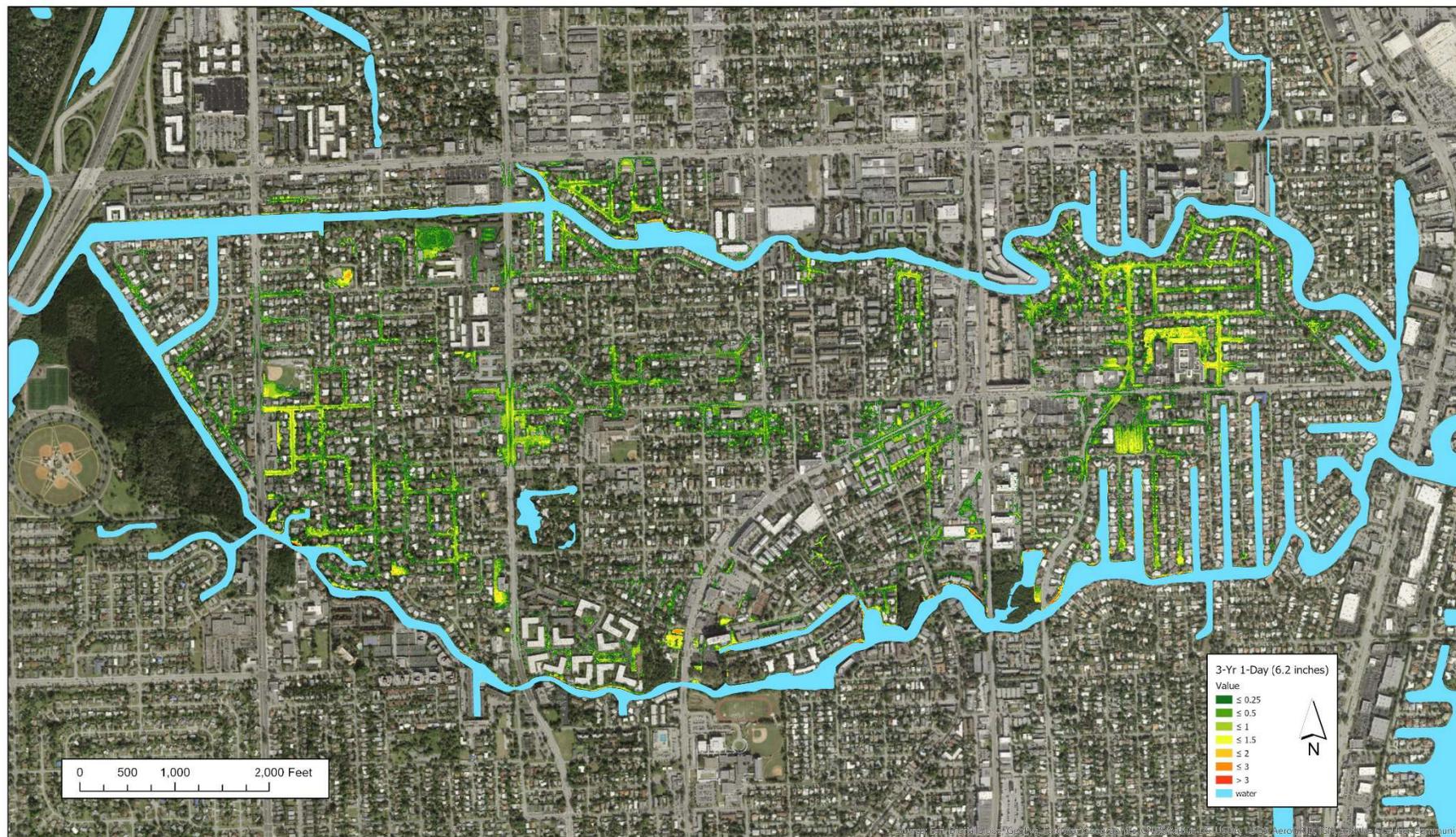


Figure 4-12: Flood Depths for Existing Conditions during 3-Year, 1-Day Storm Event

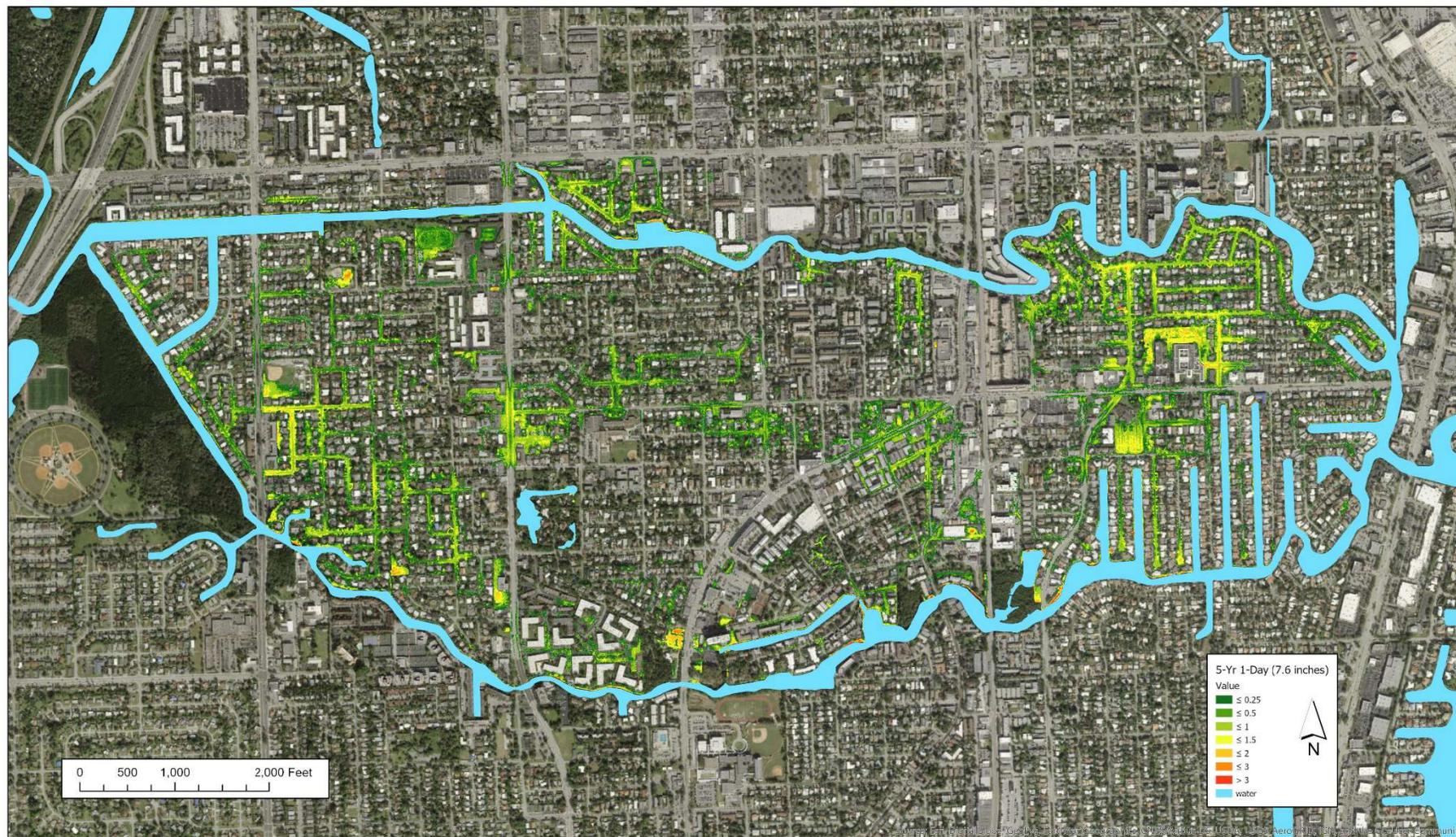


Figure 4-13: Flood Depths for Existing Conditions during 5-Year, 1-Day Storm Event

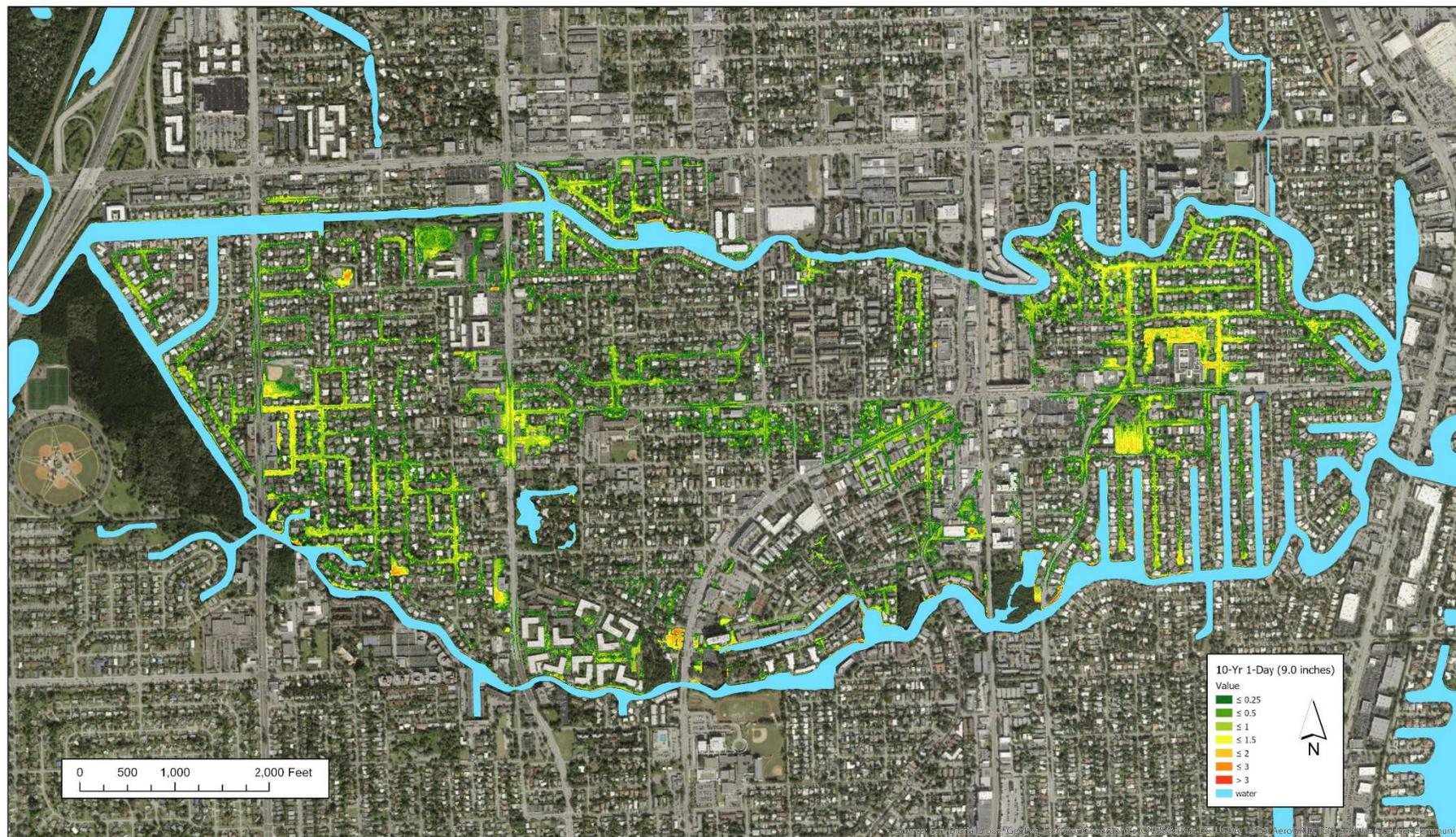


Figure 4-14: Flood Depths for Existing Conditions during 10-Year, 1-Day Storm Event

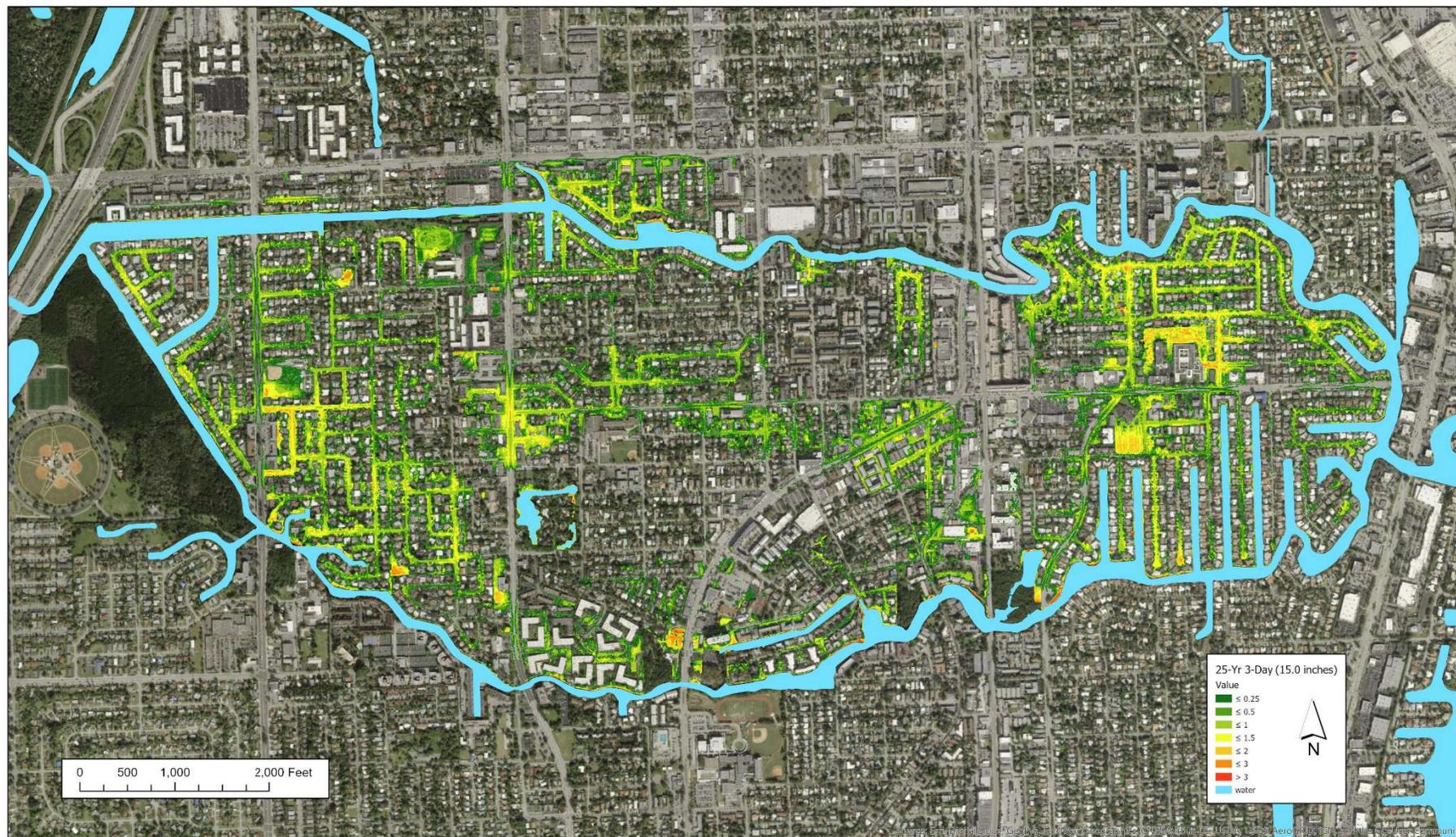


Figure 4-15: Flood Depths for Existing Conditions during 25-Year, 3-Day Storm Event

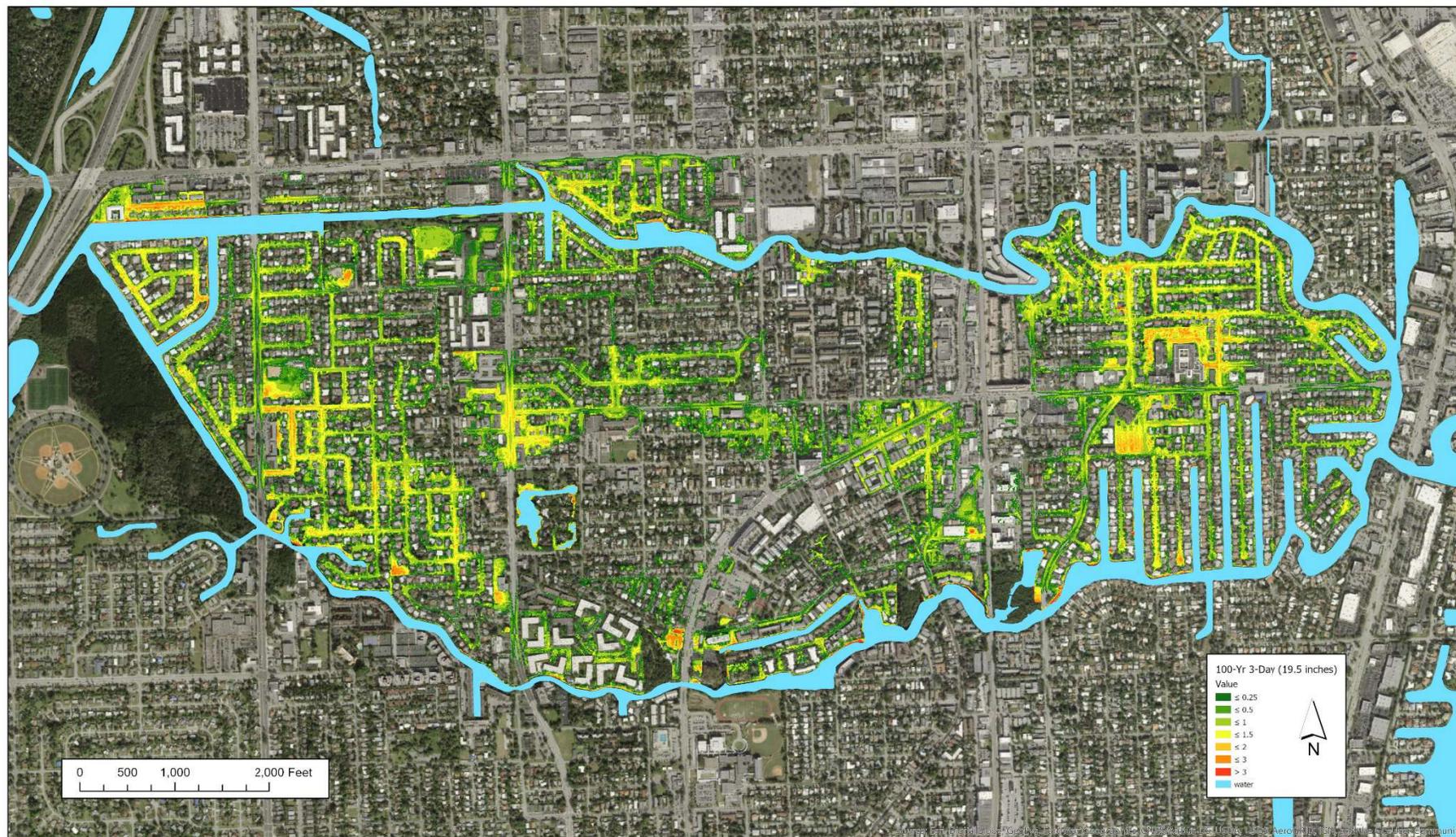


Figure 4-16: Flood Depths for Existing Conditions during 100-Year, 3-Day Storm Event

Table 4-4: Peak Flood Elevations for Existing Conditions in Feet, NAVD88

Basin	3Yr1D	5Yr1D	10Yr1D	25Yr3D	100Yr3D	Basin	3Yr1D	5Yr1D	10Yr1D	25Yr3D	100Yr3D
B01	3.02	3.16	3.27	3.43	3.59	B44	2.27	2.41	2.53	2.73	3.12
B02	2.76	2.90	3.02	3.25	3.48	B45	3.30	3.40	3.49	3.69	3.88
B03	2.72	2.83	2.92	3.11	3.26	B46	1.51	2.43	3.34	3.66	3.87
B04	4.38	4.69	4.91	5.28	5.63	B47	3.36	3.42	3.51	3.69	3.88
B05	4.77	5.00	5.19	5.54	5.89	B48	3.36	3.45	3.52	3.64	3.75
B06	2.26	2.95	3.34	3.66	3.86	B49	4.71	4.82	4.91	5.10	5.29
B07	3.84	4.10	4.24	4.40	4.54	B50	5.22	5.29	5.35	5.45	5.53
B08	2.69	3.17	3.58	4.82	5.54	B50	5.22	5.29	5.35	5.45	5.53
B09	2.46	2.98	3.44	4.00	4.26	B51	3.52	3.74	3.91	4.18	4.37
B10	3.56	3.68	3.81	4.06	4.27	B52	3.44	3.50	3.55	3.64	3.71
B11	3.56	3.67	3.81	4.06	4.26	B53	3.58	3.71	3.79	3.92	4.04
B12	3.46	3.66	3.80	4.05	4.26	B54	1.00	1.00	1.00	2.89	3.71
B13	3.26	3.37	3.45	3.61	3.76	B55	2.81	3.08	3.26	3.52	3.71
B14	2.88	3.09	3.27	3.56	3.84	B56	2.22	2.93	3.32	3.80	4.07
B15	3.09	3.45	3.75	4.03	4.25	B57	2.91	3.14	3.29	3.51	3.72
B16	3.52	3.68	3.81	4.05	4.24	B58	3.29	3.36	3.42	3.51	3.69
B17	3.52	3.68	3.81	4.05	4.26	B59	2.91	3.13	3.30	3.51	3.72
B18	3.58	3.72	3.84	4.06	4.27	B60	3.30	3.37	3.43	3.52	3.72
B19	3.90	3.97	4.03	4.12	4.26	B61	2.90	3.12	3.27	3.48	3.69
B20	3.52	3.68	3.81	4.05	4.25	B62	2.13	2.23	2.30	2.45	2.65
B21	3.52	3.67	3.81	4.05	4.25	B63	2.27	2.47	2.65	3.03	3.25
B22	3.48	3.62	3.75	3.98	4.15	B64	2.28	2.61	2.87	3.29	3.60
B23	3.51	3.67	3.80	4.04	4.24	B65	1.56	1.87	2.16	2.66	3.01
B24	3.40	3.51	3.59	3.72	3.85	B66	2.48	2.58	2.76	3.05	3.26
B25	3.17	3.58	3.75	4.00	4.21	B67	2.17	2.53	2.77	3.05	3.26
B26	3.52	3.67	3.80	4.05	4.25	B68	2.48	2.74	2.91	3.13	3.32
B27	3.82	3.92	4.01	4.15	4.29	B69	2.48	2.72	2.89	3.12	3.32
B28	3.27	3.39	3.46	3.57	3.66	B70	2.69	2.95	3.09	3.28	3.46
B29	3.82	4.10	4.28	4.50	4.68	B71	2.98	3.13	3.24	3.41	3.57
B30	4.89	4.93	4.97	5.04	5.09	B72	2.99	3.14	3.26	3.43	3.60
B31	4.40	4.42	4.45	4.49	4.54	B73	2.96	3.13	3.27	3.45	3.64
B32	3.59	3.74	3.86	4.07	4.30	B74	3.01	3.14	3.23	3.37	3.50
B33	2.16	2.51	2.77	3.13	3.34	B75	3.51	3.56	3.61	3.69	3.78
B34	1.99	2.36	2.64	3.07	3.43	B76	3.00	3.13	3.23	3.37	3.51
B35	3.58	3.66	3.73	3.83	3.92	B77	2.99	3.15	3.27	3.43	3.61
B36	4.05	4.15	4.23	4.38	4.51	B78	2.99	3.15	3.27	3.43	3.60
B37	4.25	4.31	4.36	4.48	4.59	B79	4.63	4.78	4.90	5.10	5.30
B38	4.22	4.35	4.49	4.73	4.97	B80	3.46	3.56	3.63	3.77	3.90
B39	4.16	4.33	4.48	4.73	4.97	B81	3.27	3.35	3.43	3.59	3.72
B40	4.78	4.91	5.01	5.15	5.31	B82	3.32	3.42	3.48	3.59	3.68
B41	4.59	4.65	4.70	4.79	4.86	B83	2.27	2.46	2.54	2.74	2.90
B42	3.72	3.82	3.92	4.07	4.21	B84	2.67	2.74	2.79	2.89	2.97
B43	3.67	3.80	3.90	4.05	4.19	B85	3.89	3.96	4.01	4.1	4.26

3Yr1D = 3-Year, 1-Day Storm

5Yr1D = 5-Year, 1-Day Storm

10Yr1D = 10-Year, 1-Day Storm

25Yr1D = 25-Year, 3-Day Storm

100Yr1D = 100-Year, 3-Day Storm

4.6 Future Conditions

4.6.1 Future Land Use

Future land use was provided as a GIS dataset by the City to reflect changes that the City anticipates may occur in the next 25 years. This dataset was edited to match the naming conventions used for the existing land use dataset. The biggest potential change would occur along the railroad tracks to consider the possibility that a new train station may be built in the future and would support related businesses. A new land use was added called Transit Oriented Corridor to represent the new usage. In regard to the hydrologic attributes of the new land use, the characteristic of the land use would be considered similar to Other Light Industrial. **Figure 4-17** shows the reconciled future land use within the City as well as Lazy Lake which is hydrologically connected to the City.

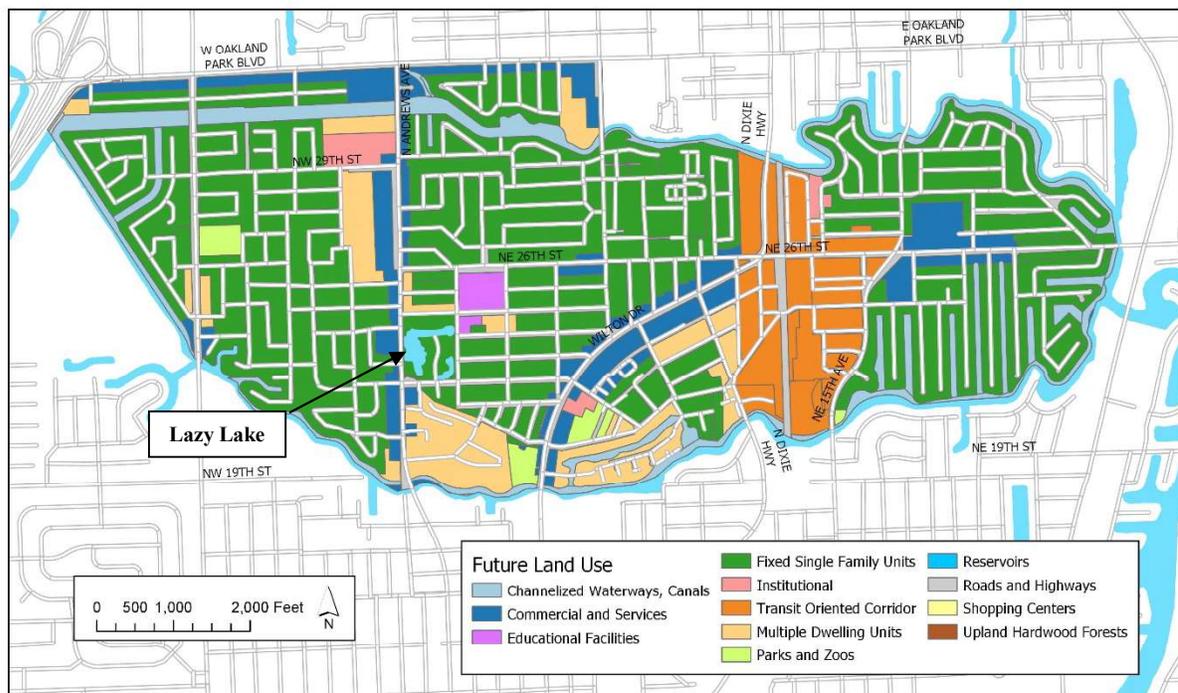


Figure 4-17: Future Land Use

4.6.2 Sea Level of Rise

Sea Level Rise (SLR) events consist of storm surges, king tides and the effects of climate change, all of which can have adverse impacts on gravity-based drainage systems. The City is especially vulnerable to SLR because it is virtually surrounded by tidal waters. The effects can force water up into low lying areas while also impeding the discharge of stormwater that would normally need to occur.

The Unified Sea Level Projection was published in October 2015 by the Southeast Florida Regional Climate Change Compact (SEFRCCC) with regional projections for the period from 1992 through 2100 based on projections and scientific literature released since 2011. This publication is being used by local municipalities for SLR planning purposes. The unified projections include three global mean curves that were regionally adapted to account for observed acceleration in SLR in South Florida as shown in **Figure 4-18**. The three curves consist of an adjusted “National Oceanic and Atmospheric Administration (NOAA) High” curve, USACE “High” curve (same as the “NOAA Intermediate-High”), and the median of the Intergovernmental Panel on Climate Change Fifth Assessment Report Representative Concentration Pathway 8.5 scenario (i.e. “IPCC AR5 Median” curve). The “USACE Intermediate”, which is equivalent to the “NOAA Intermediate-Low” curve, was also included to reflect the projection based on a significant reduction in greenhouse gas emissions, which is not likely given the current emission trends. The “USACE Intermediate/ NOAA Intermediate-Low” curve is not part of SEFRCCC’s recommendations.

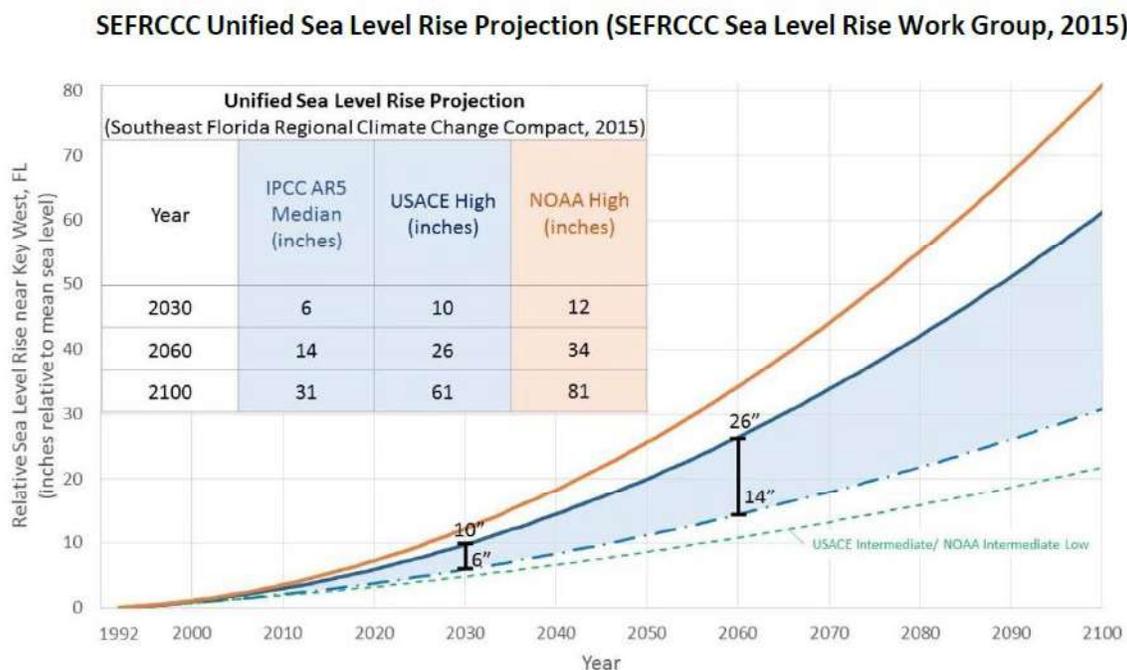


Figure 4-18: Sea Level Rise Projections

A Climate Leadership Summit was held in Key West in late 2019 where it was reported that predictions may be rising 3”-5”. These predictions have not yet been officially adopted. For this Master Plan, the 2060 USACE High prediction was used. According to the graph in **Figure 4-18**, the change in sea level between 1992 and 2060 is 26 inches for that prediction. The graph shown in **Figure 4-10** indicates that the average high tide elevation in 1992 was 0.6 feet, NAVD88. This corresponds to a 2060 average high tide elevation of 2.8 feet, NAVD88. The model was modified to reflect a sea level rise of 1.8 feet over current average high tide elevation.

In addition to sea level rise, king tides can raise the normal high tides. King tides occur once or twice every year when the orbits and alignment of the Earth, moon, and sun combine. **Figure 4-10** was used to determine the average high tide elevations over time, but also shows peak stages due to king tides as regular spikes in the data. Like the average high tide, king tides have also risen by approximately 6-inches since 1985 and appear to add approximately 1.5-feet to the normal high tide. In 2060, the combined sea level rise and king tide would result in a high tide that peaks at elevation 4.3 feet, NAVD88. This elevation is higher than many of the streets within the City. **Figure 4-19** shows the inundation that would occur in 2060 with unabated SLR during a king tide event. The light blue lines in the figure represent the existing drainage pipes which can exasperate the problem by allowing the rising tides to enter the streets.

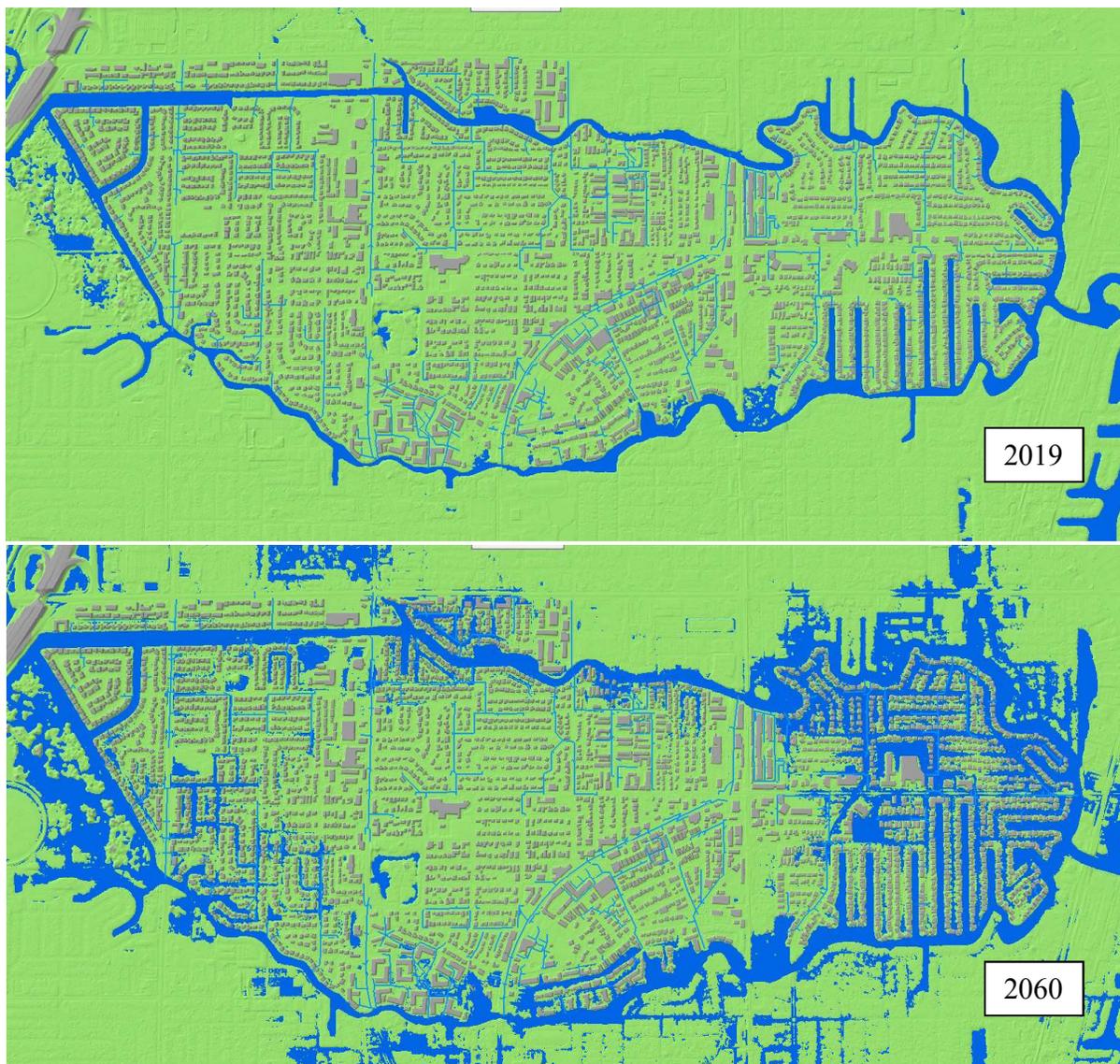


Figure 4-19: Sea Level Rise Flooding with King Tides

The most common line of defense against SLR is to prevent tidal waters from entering into the stormwater conveyance systems by installing check valves in vulnerable areas. An analysis was performed to determine where such valves will be needed and the priority of their installation by examining the areas of inundation incrementally. There are several types of valves that are used for this purpose including flap gates, “duck-bill” valves and inline check valves. Considering maintenance requirements and low head losses, inline check valves are recommended because they can be installed in upstream inlets (as opposed the outlets in the River), they are resistant to barnacle growth and operate with low pressure. Steel or cast iron flap gates, however, should be considered for any future pump stations because of the pressures involved in the designs and need to keep marine life out of the pipes. The results of the analysis show that 61 of the 80 outfalls owned by the City will need to have valves installed, see **Figure 4-20**. The City has indicated that they have already begun the process of installing valves on all of City-owned and County-owned outfall pipes. Four priority phases were developed to assist the City in determining where to begin the installations.

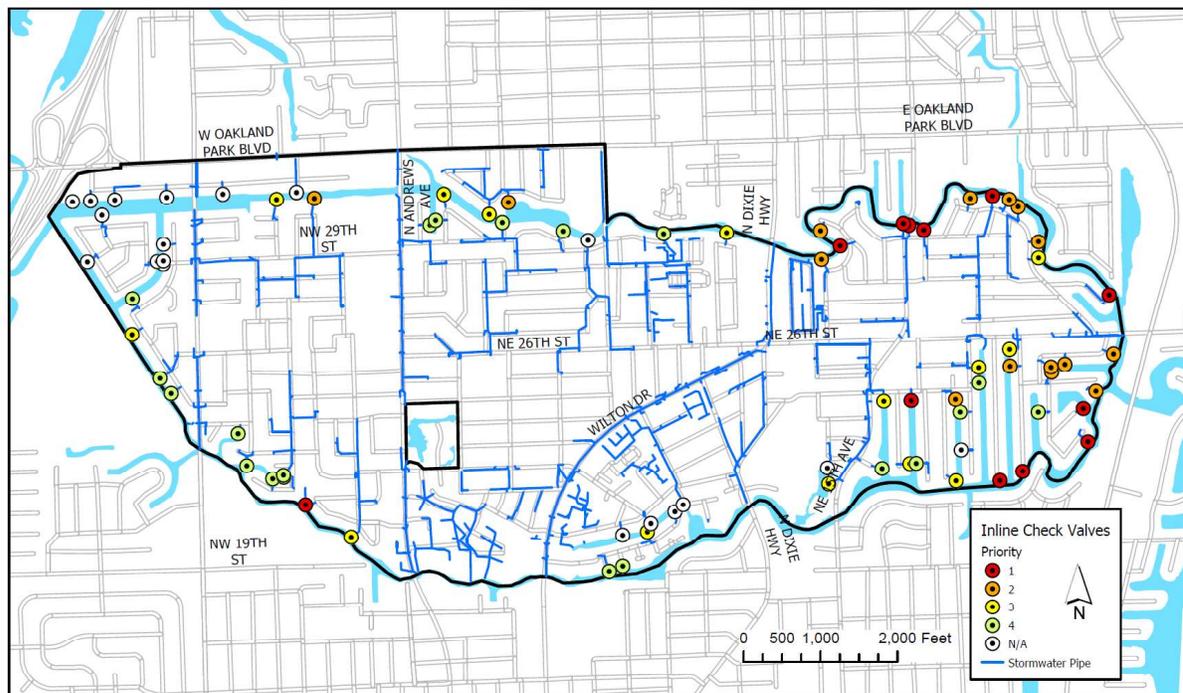


Figure 4-20: Recommended Locations and Phasing of Discharge Check Valves

4.6.3 Model Revisions for Future Conditions

To simulate storm events with the future changes due to land use and SLR, a new model scenario was created in ICPR by copying the existing conditions scenario and modifying the following parameters:

- Depth to water table
- Soil Curve Number

- Land use/soil combinations
- Boundary conditions – stage vs. time

Other parameters such as stage-storage and impervious assumptions were unchanged. The rainfall amounts and intensities also remained the same for comparison purposes. It is important to note that these changes to the model do not include measures to offset the impacts of SLR. This future conditions model was created to illustrate what may occur if no actions are taken. The model does not include a king tide condition considering the frequency of these events and likelihood of occurring during a major storm event. It is, however, possible. The results of the analysis of the future conditions is discussed in **Section 4.7**. Although in most cases, the pre vs. post peak discharge rates for the 25-year, 3-day storm can be maintained some individual projects may exceed the existing rates and will need to be addressed when the detailed design of each system is performed.

4.7 Level of Service

LOS refers to a standard that is applied to a feature for that feature to remain in service. As applied to roadways, it refers to a flood level associated with a theoretical storm event with the intent of setting the crown of the road above the peak flood elevation of the storm. For new roads, this is usually achieved by establishing municipal codes and ordinances that describe the design requirements. For existing roads built before standards were established, the LOS is a goal more than a requirement and is usually set using a less intense storm event such as a 3-year, 1-day event for practical reasons. For the City, the 3-year, 1-day storm event contributes 6.2 inches of rain distributed over a 24 hour period with the most intense portion of the rain occurring midway through the storm.

A LOS assessment for roads involves determining the lengths of road crowns that are below the peak stage of the 3-year, 1-day storm. This was determined by creating a dataset of City-owned roads by deleting County, State and private roads from the original dataset which was obtained from Broward County. The dataset was further modified by realigning the roadway lines with the centers of the roads as shown on recent aerial photography. This was necessary because many of the lines in the original dataset did not correspond to the crowns of the roads which is where the assessment needs to occur.

The corrected roads were then rasterized into 5-foot by 5-foot cells and overlaid onto the LiDAR raster to determine the estimated road crown elevations at 5-foot intervals. This result was then subtracted from the 3-year, 1-day flood stages that vary by sub-basin. Positive values from this calculation represented depths of flooding over the road crowns. These depths were then coded based on the severity of the flooding. Depths up to 6 inches were assigned a severity factor of 1, depth between 6 and 12 inches were assigned a factor of 2 and depths above 12 inches were assigned a factor of 3. **Figures 4-21 and 4-22** shows the locations of road crowns that would be expected to flood and the severity of the flooding for the existing and future conditions (SLR with no improvements), respectively.

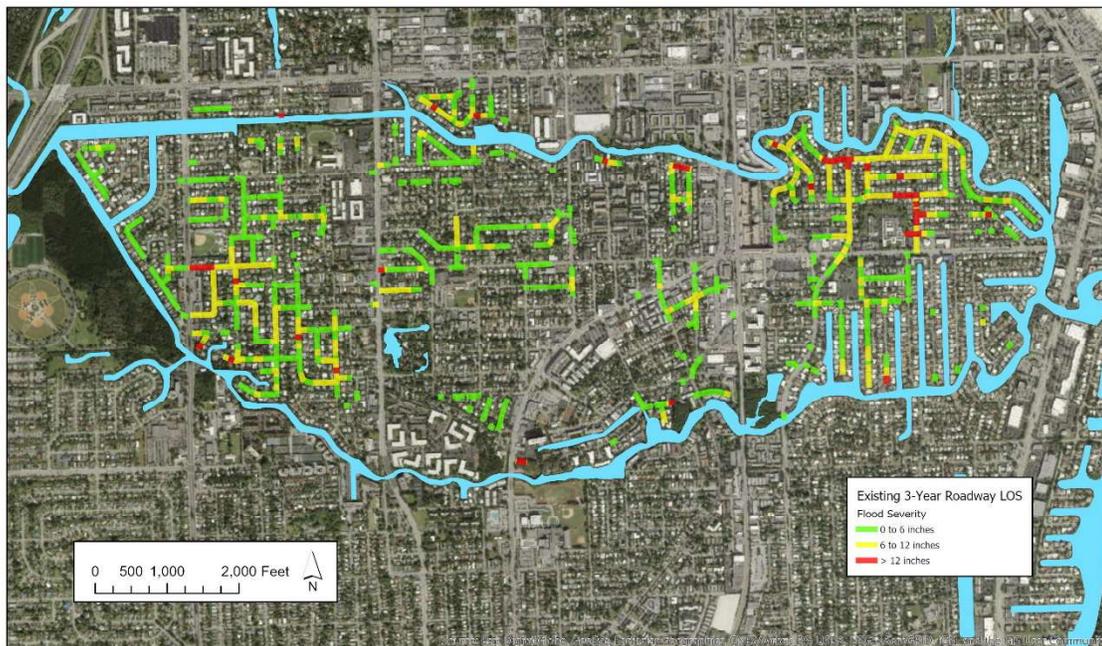


Figure 4-21: Existing 3-Year Roadway LOS Assessment

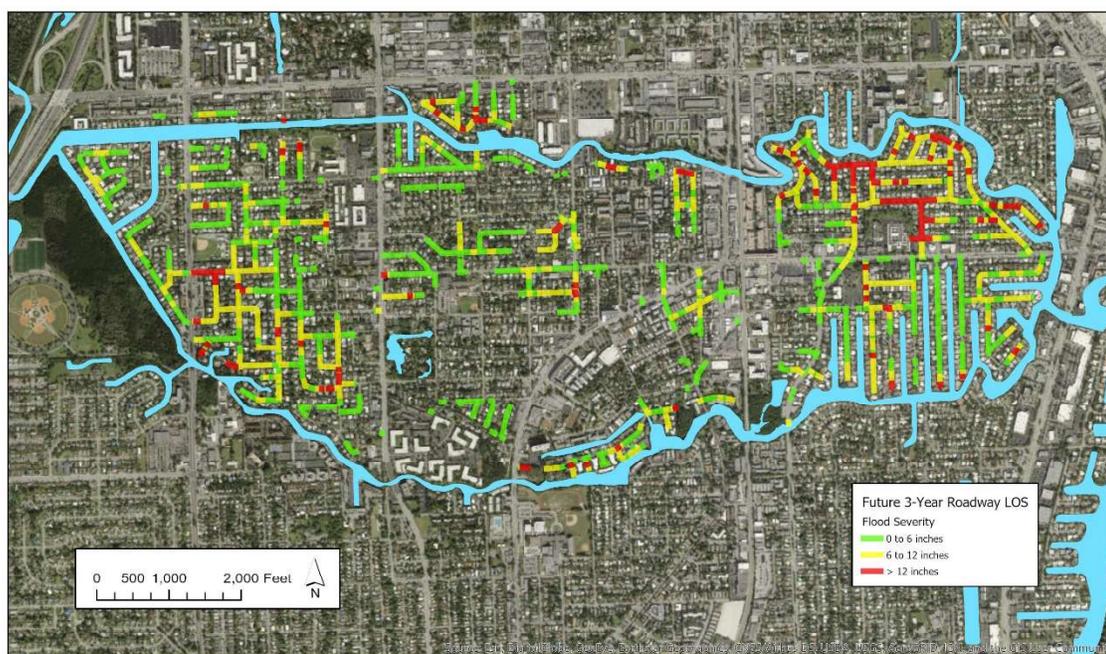


Figure 4-22: Future 3-Year Roadway LOS Assessment

An overall LOS score was determined by multiplying the roadway lengths by the severity factors, subtracting that product from the total length of roads and then dividing by the total length of roads. This approach is similar, though scaled down, with Miami-Dade's Department of Regulatory and Economic Resources (DRER) procedures and provides a weighted score based on severity with consideration of the fact that roads with more severe flooding would be

impassible. The goal for developing improvement projects is to increase this score as much as possible with the most effective solutions. The impacted roads are summarized in **Table 4-5** including the LOS score for City roads for existing and future conditions, respectively. As expected, there is a drop in the LOS under future conditions because of the effects of SLR.

Table 4-5: Roadway LOS Score for Existing and Future Conditions (without Improvements)

Existing Roadway LOS			Future Roadway LOS		
Severity	Miles	Weighted	Severity	Miles	Weighted
1	7.80	7.80	1	9.81	9.81
2	2.39	4.78	2	4.96	9.92
3	0.22	0.66	3	0.76	2.28
Total Weighted		13.24	Total Weighted		22.01
Total Roads (mi)		35.68	Total Roads (mi)		35.68
LOS Score		0.628	LOS Score		0.383

4.8 Stormwater System Recommended Improvements

The proposed stormwater improvements were modeled to provide the City both short-term and long-term proposed improvements. The proposed short-term improvements are anticipated to be implemented in the next 10-years of the City's CIP budget. The proposed long-term improvements address future SLR implications for the City and are anticipated to be implemented by 2060. This goes beyond the 20-year long-term projections used for the water and sanitary utilities because any stormwater improvements planned for the next 20 years need to also consider what will happen beyond that time.

It should be noted that culverts, inlets and stormwater facilities can have a life span from 50 to 100 years and that it would be inefficient to install facilities if there is a possibility that they could be obsolete in a much shorter timeframe. By planning for the short-term and long-term improvements at the time, it is possible to coordinate those improvements so that the short-term improvements can be functional into the future. For example, if a future pipe is planned in the same location as a short-term recommended pipe, but is larger than the short-term pipe, the short-term pipe can be increased in size so that it can also be used in the long-term.

The analyses performed for both the short-term and long-term improvements are outlined below. The results from each analysis along with the associated cost estimates are included in **Section 6**.

4.8.1 10-Year CIP Stormwater Improvements

For the City's 10-Year (short-term) CIP budgetary projects, locations for proposed stormwater improvements were chosen based on the severity of the flooding with the goal of reducing flooding and increasing the LOS score for the City's roadways. As described in **Section 4.7**, a 3-Year, 1-Day storm event was modeled for the proposed short-term improvements in order to increase the City's LOS of the roadways. A 25-Year, 3-Day storm event was also implemented for the proposed short-term improvements in order to compare the pre- and post-stormwater

discharge in order to confirm that the proposed improvements will meet permitting requirements.

The 3-Year, 1-Day storm event was modeled for the City's existing stormwater system, see *Figure 4-21*. The areas shown in red and yellow were the focus of the proposed short-term improvements. The proposed short-term improvements consist of selective upsizing of the City's existing piped stormwater system, addition of new piped systems, and addition of water quality improvements (swales and exfiltration trench). The 3-Year, 1-Day storm event was modeled for the proposed stormwater improvements and the results are shown in *Figure 4-22*. The proposed improvements were modeled as a complete system and the improvements that were most effective at alleviating the flooding in the public rights-of-way were selected. The two (2) figures are shown side-by-side to provide a comparison of the existing LOS and the proposed roadway LOS following installation of the proposed short-term stormwater improvements. As shown in the figures, the proposed improvements target and decrease the amount of flooding within City roadways which experience greater than 12 inches of flooding and provide relief to many roadways which currently experience between 6 to 12 inches of flooding. Through installation of the proposed short-term stormwater improvements, the City's roadway LOS score increased from 0.628 to 0.745, which is approximately a 19% increase in LOS, see *Table 4-6*. *Figure 4-23* and *Figure 4-24* provide a side-by-side comparison of the City's existing roadway LOS vs. the proposed roadway LOS.

Table 4-6: Roadway LOS Score for Existing and Proposed 10-Year CIP Improvements

Existing Roadway LOS			Proposed Roadway LOS		
Severity	Miles	Weighted	Severity	Miles	Weighted
1	7.80	7.80	1	7.14	7.14
2	2.39	4.78	2	0.93	1.86
3	0.22	0.66	3	0.04	0.11
Total Weighted		13.24	Total Weighted		9.11
Total Roads (mi)		35.68	Total Roads (mi)		35.68
LOS Score		0.628	LOS Score		0.745

The proposed short-term improvements are summarized and prioritized into CIP projects in *Table 4-7* and depicted in *Figure 4-25* below. The prioritization ranking of the projects is based on the severity of the existing roadway flooding as shown in *Figure 4-23*. In addition to the proposed short-term improvements identified by the model, the Priority 1 and Priority 2 discharge check valves are recommended in the 10-Year CIP projects as described in *Section 4.6.2*. The discharge check valves will provide improvements to the negative effects of king tides that the City is already experiencing.

The proposed improvements for each project are described in further detail in *Section 6* and include conceptual cost estimates for each project. The conceptual construction cost estimate includes the cost for detailed design and construction engineering and inspection for the project. The construction cost information is preliminary in nature. These costs are based upon comparisons of previous and current similar types of work and materials underway in the

Southeast Florida area. All costs developed herein are in 2019 dollars and do not include land acquisitions or easements.

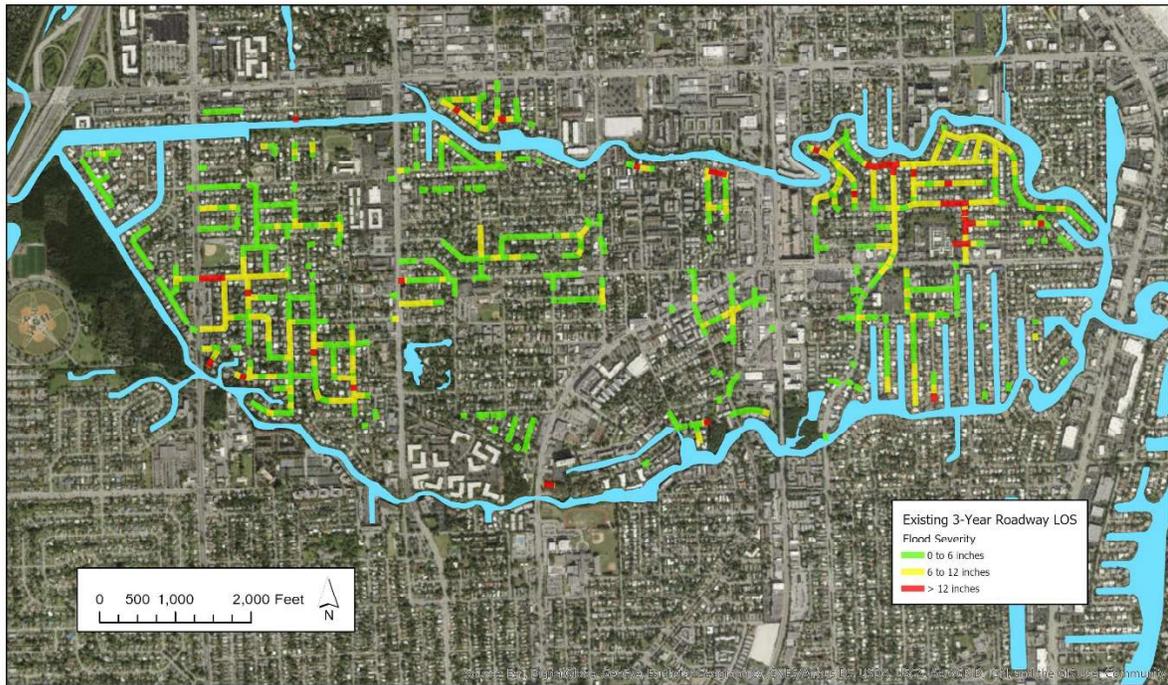


Figure 4-23: Existing Roadway LOS



Figure 4-24: Proposed Roadway LOS

Table 4-7: Proposed 10-Year Stormwater Capital Improvement Projects

Project # / Priority	Project Name
1	Coral Gardens Drive Outfalls & Stormwater System Improvements
2	NE 28 th Drive Outfall Improvements
3	NE 14 th Avenue Outfall Improvements
4	NW 24 th Street to NW 22 nd Street Stormwater System & Outfall Improvements
5	NW 3 rd Avenue Stormwater System & Outfall Improvements
6	NE 30 th Street Outfall Improvements
7	NE 28 th Drive Outfall Improvements
8	NE 7 th Terrace Stormwater System and Outfall
9	NE 17 th Avenue Stormwater Outfall Improvements
10	NE 27 th Drive Stormwater Exfiltration Trench
11	NW 25 th Street Stormwater Exfiltration Trench
12	NE 25 th Street & NE 8 th Terrace Stormwater Exfiltration Trench

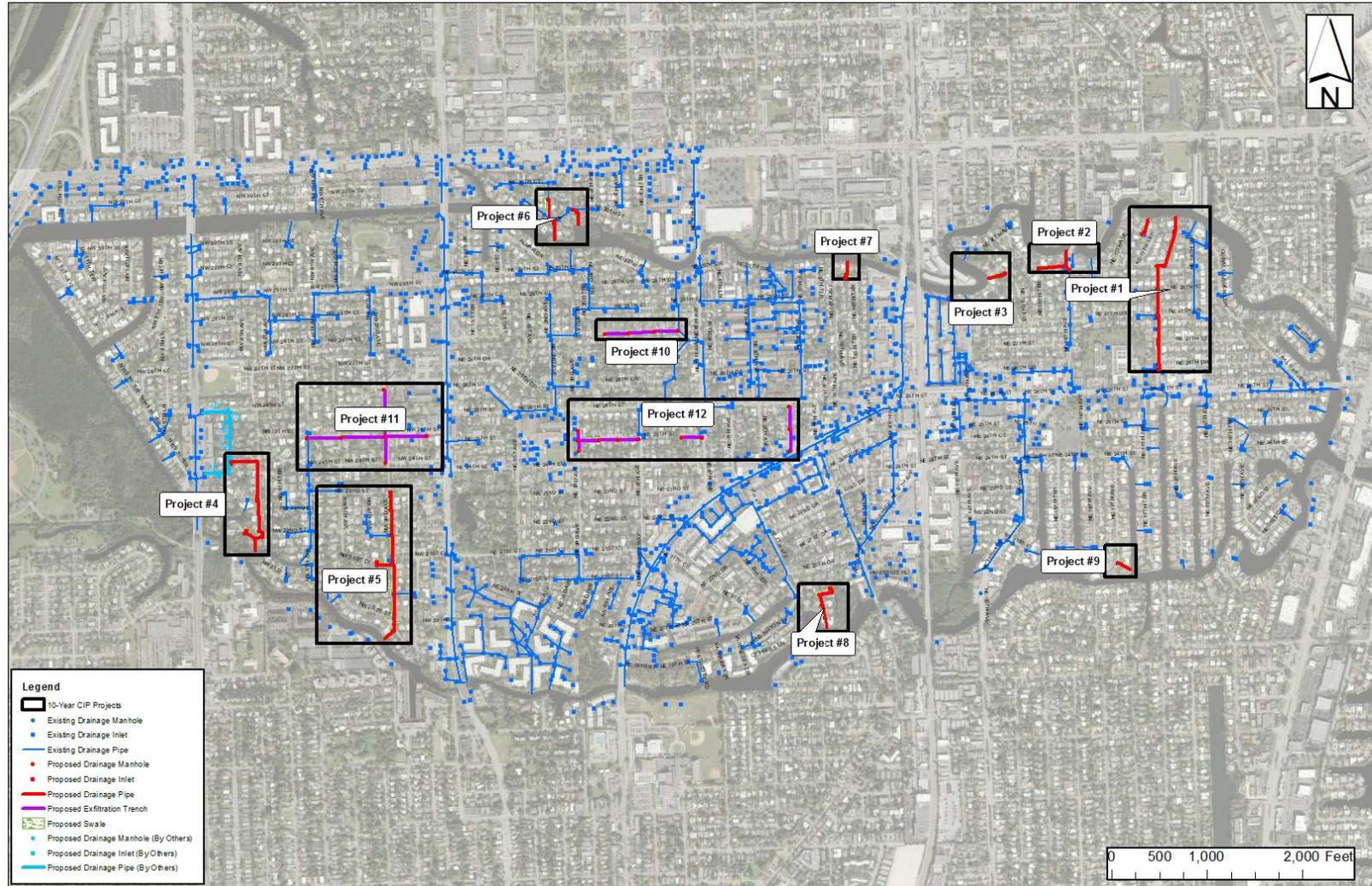


Figure 4-25: Proposed 10-Year Stormwater Capital Improvement Projects

4.8.2 Long-Term CIP Stormwater Improvements

For the City's long-term CIP budgetary projects, the results of the future land use and 2060 SLR modeling scenario, as well as the analysis of SLR with king tides were carefully reviewed to determine the best solutions for future conditions. Pumping is necessary to maintain water levels within the City during both dry and wet (rainfall) conditions. There are two (2) possible approaches in regards to pumping: 1) a regional single pump station facility located at the confluence of the North and South Forks of the Middle River near Federal Highway or 2) consolidation of drainage systems to a fixed number of pumping stations within the City.

The idea of a regional single pump station facility solution has been posed to the USACOE for inclusion in the South Atlantic Coastal Study which will assess impacts and potential solutions to SLR. It is not known yet whether the USACOE will consider the suggestion and if so, whether they will determine if the idea is viable. Such a facility would also benefit Oakland Park and parts of FTL, but there are several factors to consider. The structure would need to be able to handle all of the upstream flow from the C-13 Basin which passes through the Middle River. Large gates, pumps and (likely) a navigation lock would be needed. There will be environmental concerns as well, for wetlands connected to the River that depend on salinity concentrations.

Considering the uncertainty associated with the regional single pump station facility solution and the timing involved in getting such a facility built, the option of using multiple internal pump stations was considered for this Master Plan. It is recommended, however, that the City monitor the progress and results of the South Atlantic Coastal Study which is scheduled for completion in 2021.

The most effective approach for designing multiple internal pump stations is to consolidate drainage areas to reduce the number of stations and only locate the stations in areas where they will be needed. Pumped systems have to follow the same allowable discharge criteria as gravity systems and cannot exceed the current peak discharge rate for a 25-year, 3-day storm event. The advantage to a pumped system is that the peak discharge rate can be maintained at a constant rate whereas a gravity system only experiences the peak discharge rate when stormwater stages are at the corresponding head elevation to produce the peak discharge rate. Under this design storm event, there is a combination of pipe discharge and overland flow into the River. The pump stations need to be designed to consider both of these discharge components to provide an equal or better LOS for the City. For this analysis, overland flow from low lying sub-basins was assumed not to occur in the future. The presence of SLR and king tides will likely drive the need for higher seawalls or berms to prevent inflow from the River which will also prevent sheetflow offsite from occurring.

For pump stations to be effective, a conveyance system is needed to deliver the stormwater to the pump station without resulting in excessive head losses that can cause pump cavitation or force the pump to cycle on and off too frequently. In built-out urban areas such as Wilton Manors, the conveyance must be achieved using a network of culverts sized to provide an adequate flow capacity to the pump stations. The pipes also need to be installed at lower depths than a typical gravity system so that the pump station can take full advantage of its capabilities. Pumps, if sized with the correct total dynamic head, can pump water at very low elevations to areas of relatively high elevations. For example, despite the future SLR elevation of 2.8 feet, NAVD88 that is projected to occur in the Middle River by 2060, a pump station could potentially pump water as low as -4.0 feet, NAVD88 to allow water to be drawn towards it

during a storm event. Pump stations can also be used to maintain groundwater levels, whereby maintaining soil absorption for minor rain events and preserving the soils ability to capture and filter the first flush of runoff for water quality.

The pumps would be contained in underground wetwells within the road rights-of-way and would consist of electric submersible motors that are relatively quiet during operation. At least two (2) pumps would be needed at each station for redundancy purposes. Backup generators should be considered wherever feasible in case of a power failure. If a generator cannot be installed, the control panel should be equipped with a receptacle for a mobile generator. The City should purchase a sufficient number of mobile generators to serve the pump stations as needed.

Figure 4-26 shows the pumped drainage systems that were developed based on the modeling and SLR analyses. The Engineer's Opinion of Probable Construction Costs are summarized in *Section 6* for the pump stations. Inline check valves, as discussed in *Section 4.6.2*, were not included in the 10-year and 20-year CIPs because the City has already moved forward with purchasing and installing valves for all of their existing outfall pipes.

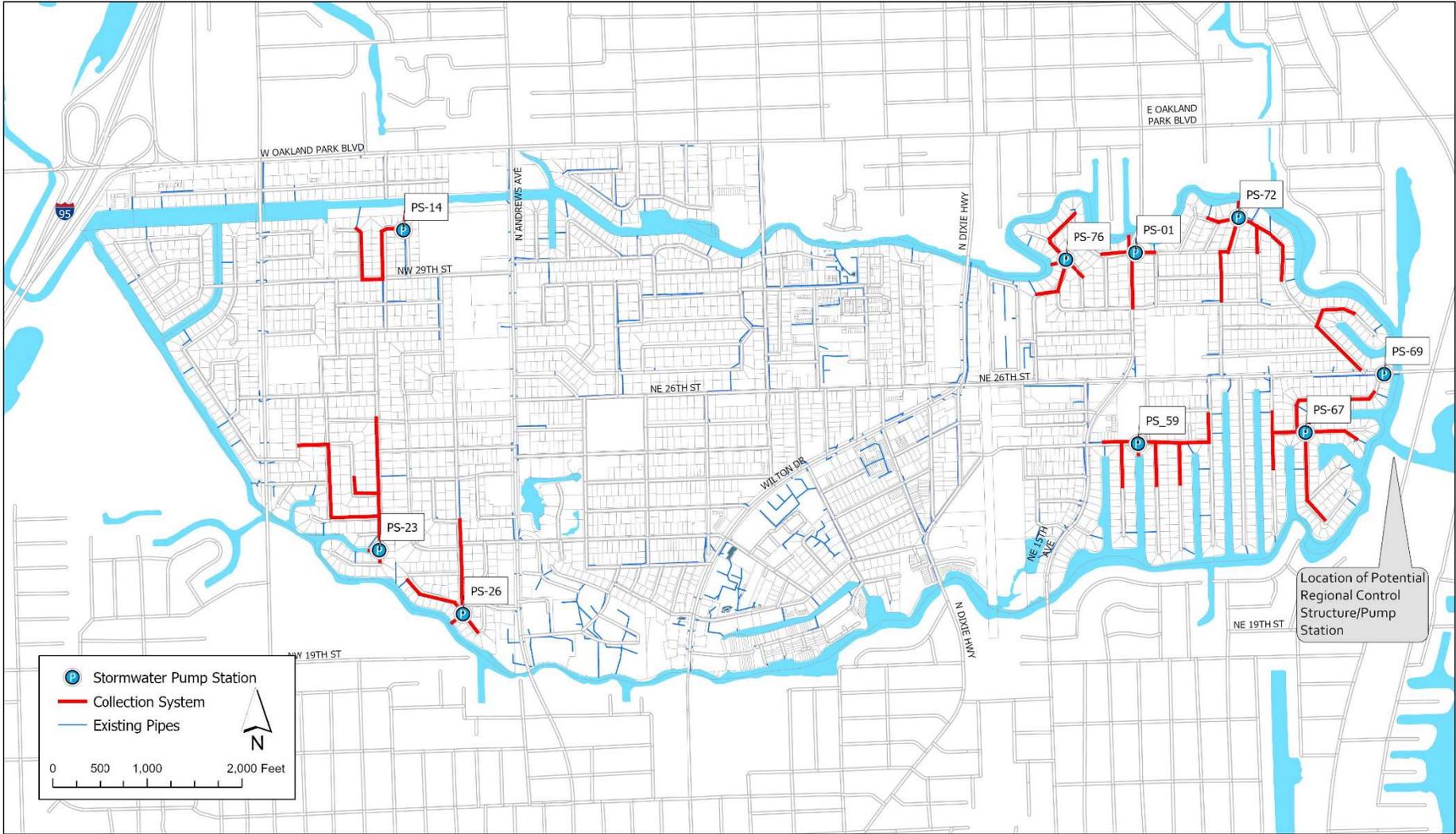


Figure 4-26: 20+ Year CIP Projects