City of Naples

Basin 4 Stormwater Analysis Final Report

October 30, 2020

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Quality information

Prepared by	Checked by	Verified by	Approved by
Amy Eason, PE Senior Project Manager	Karen Brandon, PE Project Director	Peter May, PE Lead Verifier	Amy Eason, PE Senior Project Manager

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Prepared for:

City of Naples

Prepared by:

Amy Eason
Senior Project Manager
T: 561-684-3375
E: amy.eason@aecom.com

AECOM
2090 Palm Beach Lakes Boulevard
West Palm Beach, FL 33409
aecom.com

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Executive Summary

As part of the City's previously completed 2018 Stormwater Master Plan Update, Basin 4 was identified to evaluate the current level of service and develop proposed projects to achieve the desired level of service. The study area consists of the north 218 acres of Basin 4, which is identified as the Aqualane Shores Neighborhood. This area was developed in the 1950's, which was prior to today's stormwater regulations. The current system is lacking a connected swale or pipe system to adequately convey stormwater and is being further stressed by redevelopment within the area with landowners redeveloping lots with more impervious area and resulting in less storage available to the overall system. Furthermore, the area is stressed by higher tides and future climate conditions. The goal of the study is to evaluate the current level of service, which is no flooding of the crown of road during the 5-year, 1-hour storm event; assess the area for an increased level of service; and plan for future climate conditions in order to provide a resilient system.

Currently, the system does not adequately provide the current level of service, however, today's level of service was established after the system was already built. The evaluation shows that with upsized discharge structures, connected swales and pipe systems, and increased elevation of roadways, the proposed system can handle not only the current level of service at the 5-year, 1-hour storm event, but can be designed to handle the 10-year, 1-hour and the 10-year, 24-hour storm events.

In evaluating the system, certain policy decisions were explored. These policy decisions included:

- Level of service of the system
- Water quality storage on individual lots
- Sea level rise projections

Each of these potential policies were examined to provide information to aid in planning of future stormwater systems throughout the City. Council along with staff may look at each of these evaluations to help guide proposed stormwater projects within the City.

As the proposed system is designed, many variables affect the cost of the system. These variables include swale and pipe placement, existing utilities, easement restrictions, and property improvements such as irrigation systems, landscaping, and roof overhangs that will need to be examined once a more detailed design begins.

Other considerations that impact the proposed improvements and will need to be addressed in detail design are the use of water quality treatment facilities. These facilities impact the headloss for the system and may result in increased pipe sizes, additional pipe connections, and increase the elevation of the roadways. Not all these variables could be evaluated during this study, however, must be addressed in order to permit the system.

Introduction

In August 2018, the City of Naples finalized its update to the Stormwater Master Plan. The plan update took a comprehensive approach of evaluating the City's stormwater program as a whole and was developed to be consistent with the City's stormwater mission *"to protect people and property against flood by maintaining and improving the public stormwater management system, while protecting and restoring ecological systems that work naturally to improve water quality and the environment and quality of life for residents and visitors."*

As part of the original 2007 Stormwater Master Plan and subsequent update in 2018, the City authorize in December 2019 a study to examine the north 218 acres of Basin 4. This study evaluated Basin 4's ability to manage potential sea-level rise through anticipated climate change and augment the City's effort to protect vulnerable assets. The City's goal is to increase the current level of service for drainage that states there shall be no flooding of the crown of road during the 5-year, 1-hour storm event (or 2.9 inches of rainfall within 1 hour); and to plan for future climate conditions in order to provide a resilient system.

Basin 4 consists of approximately 1,174 acres of land in total and is bordered by the Gulf of Mexico to the west, Basin 3 to the north, and Naples Bay to the east and south. Due to the complaints within this basin, especially in the Aqualane Shores neighborhood, the study is focusing on the north area of Basin 4. Therefore, the study area is generally bounded by 15th Avenue S to the north, Naples Bay to the east, 21st Avenue S to the south, and the Gulf of Mexico to the west and consists of approximately 208 acres. ***Figure 1*** shows the study area limits in relation to the entire Basin 4 area.

The area was originally developed in the 1950s. ***Figure 2*** shows an aerial of the area from 1953. This aerial shows how the canals were being constructed and shows the two existing lakes, Lake 13 and Lake 25, within the study area. Like most older communities, the drainage system consisted of roadside swales connected to culverts that directly discharged into Naples Bay.

Today, this area consists of beach front estates and single-family residential uses. There is one planned unit of development within the study area, Palmer Estates, which has its own stormwater management system that drains into the study area at Gordon Drive. Over time, lots have been redeveloped, which has reduced valuable storage within the basin through:

- Increased building pad elevations to abide with Federal Emergency Management Agency (FEMA) Floodplain maps or new building codes
- Filling in swales for aesthetics
- Increasing impervious areas by increasing building sizes and driveways

Figure 1. Basin 4 Study Area

Figure 2. 1953 Aerial

With redevelopment, the City has taken a proactive approach to monitoring water quality within Naples Bay, implementing water quality treatment devices, and introducing policy where parcels must retain 0.5-inches of runoff from the property minus the roof area onsite to help with treatment and storage.

Data Collection

In order to conduct the study, existing data from existing resources provided by the City of Naples was gathered. This data consisted of the geographic information system (GIS) data from the City's database, as-built drawings of redeveloped lots, existing South Florida Water Management District (SFWMD) permit information, geotechnical data, as well as reviewing data that was supplied in the 2018 Stormwater Master Plan Update. In addition, a topographic survey was obtained on structures that required more detail for the purpose of developing a hydrologic and hydraulic model. A field visit was conducted to verify data that was obtained.

Existing Facilities

Figure 3 contains the data within the City's GIS database. There was limited information provided in the GIS database. The database provided general location of facilities, however, did not include a complete listing of pipe sizes, locations, and invert elevations. As a result, a limited survey was conducted to support the basin assessment. ***Appendix A*** contains the survey information that was obtained. Since some data was provided by the City, the surveyor did not obtain all data within the basin. ***Appendix A*** shows both the information that was provided by the City and the surveyor. The surveyor provided the following services:

- Located all drainage structures within the basin assessment area where additional information was needed to supplement the City's GIS database and record drawings. Information gathered included structure type, top elevation, bottom elevation, pipe inverts, and pipe material type.
- Centerline of the roadway elevation taken every 100 feet.
- Located finished floors on five (5) structures

The survey information was referenced to the Florida State Plane Coordinate System (NAD83/11) and the North American Vertical Datum of 1988 (NAVD88) from the Florida Permanent Reference Network (FPRN RTK GPS).

Topography

Topographic information for the study area was obtained from two sources. The first source was from the Florida International University (FIU) Interactive Hurricane Impact Assessment Internet Mapping and Data Retrieval website, http://digir.fiu.edu/Lidar/. The Light Detection and Ranging (LIDAR) Project Survey was acquired from the Florida Division of Emergency Management. To collect the break lines, the LIDAR data was used as the main source data set in addition to orthophotography. Orthophoto imagery for the area within Collier County was from imagery collected and developed. All imagery for Collier County is dated 2007 with a 0.5-foot pixel resolution. Any elevations smaller than this accuracy had to be processed. The latest LIDAR (2020) was not available for this study. ***Figure 4*** illustrates the topographic information for the area. Elevations range from 1 feet to 10 feet NAVD. These elevations range from swale inverts to the building pads.

Figure 3. Existing Facilities Map

The second source of topographic information was obtained by the redevelopment that has occurred since 2007. ***Figure 5*** shows the parcels that have been redeveloped since 2007. Approximately 81 parcels out of a total of 444 parcels have been redeveloped. ***Appendix B*** contains the record plans provided by the City for these parcels as well as the contour map of the 2007 LIDAR information.

Geotechnical Information

Limited geotechnical exploration was conducted within the basin assessment area. Two (2) falling-head open-hole exfiltration tests in accordance with South Florida Water Management District (SFWMD) standards were performed to obtain the soil hydraulic conductivity values for proposed exfiltration trench, if needed.

In addition, in order to determine the groundwater elevation for the exfiltration trench for the master stormwater system, shallow and deep borings were performed. Two (2) auger borings were performed to a depth of ten feet below grade to determine seasonal high-water elevations and to explore the shallow soil stratigraphy. Also, one (1) auger boring was performed to a depth of 20 feet.

The groundwater table was encountered at depths approximately 3.5 to 5 feet below the existing ground surface. The groundwater table will fluctuate seasonally depending upon local rainfall and other site specific and/or local influences such as tidal events and in place artificial drainage. Brief ponding of stormwater occurs across the site after heavy rains. The estimated seasonal high groundwater table is approximately 2 to 3 feet above the level encountered within the test borings. These estimates are consistent with the control elevation of the one (1) SFWMD Permit found within the area for Little Harbor, which is located on the south edge of the study area. The control elevation was 1.3 feet NAVD (2.6 feet NGVD).

Lastly, two (2) borings were conducted within the road to determine the structural properties of the existing road system in order to develop cost estimates during the planning phase for the potential of raising roadways. These asphalt cores were taken along 21st Avenue S. and 17th Avenue S. An average asphalt thickness of 2-5/8 inches were found along with 8 to 10 inches of limerock for the base material.

Appendix C contains the geotechnical information as well as the soil survey for the area. The subsurface soil conditions encountered at the site generally consist of fine to medium grained sands (SP) and silty sand (SM) to the boring termination depths.

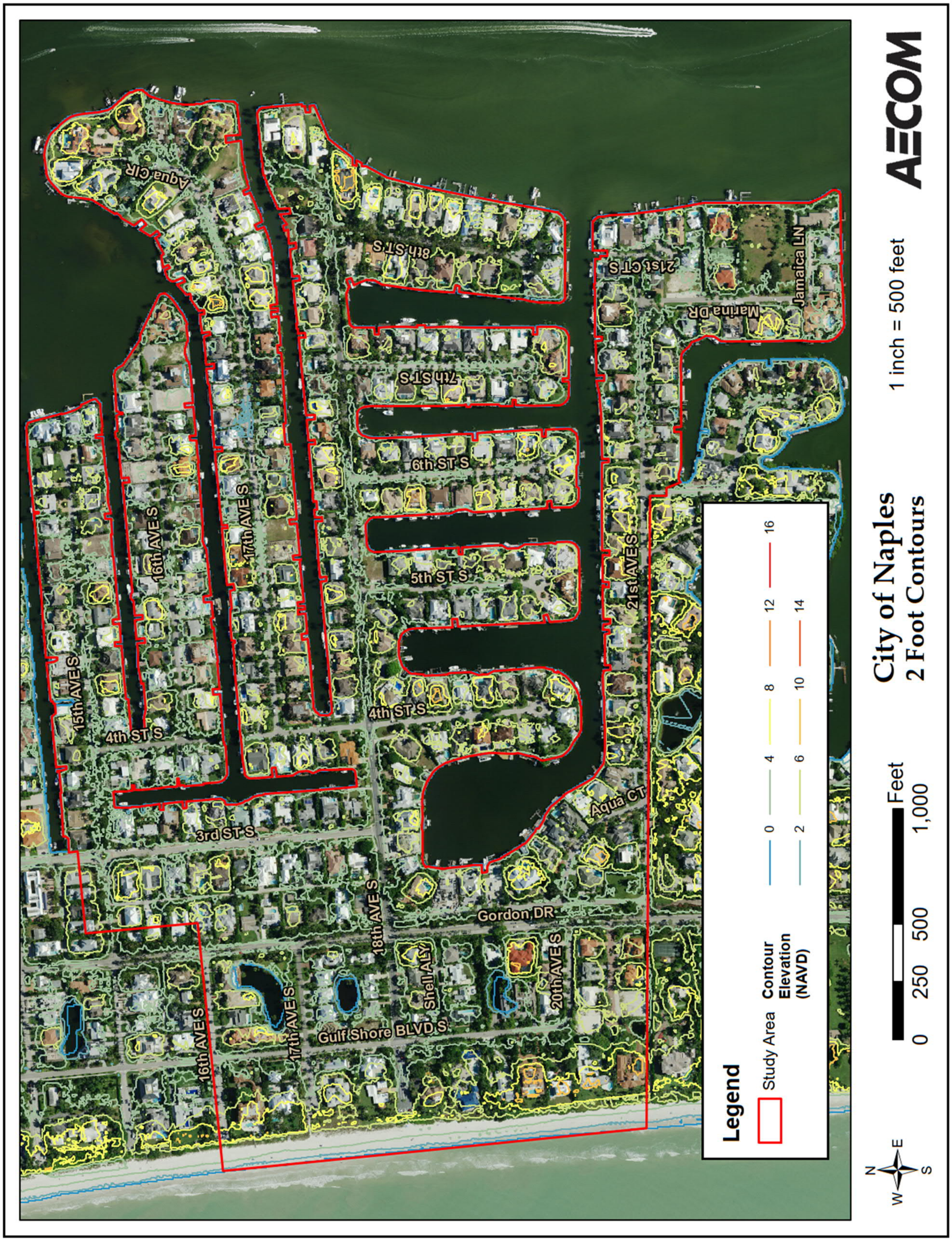

Figure 4. 2007 LIDAR Information

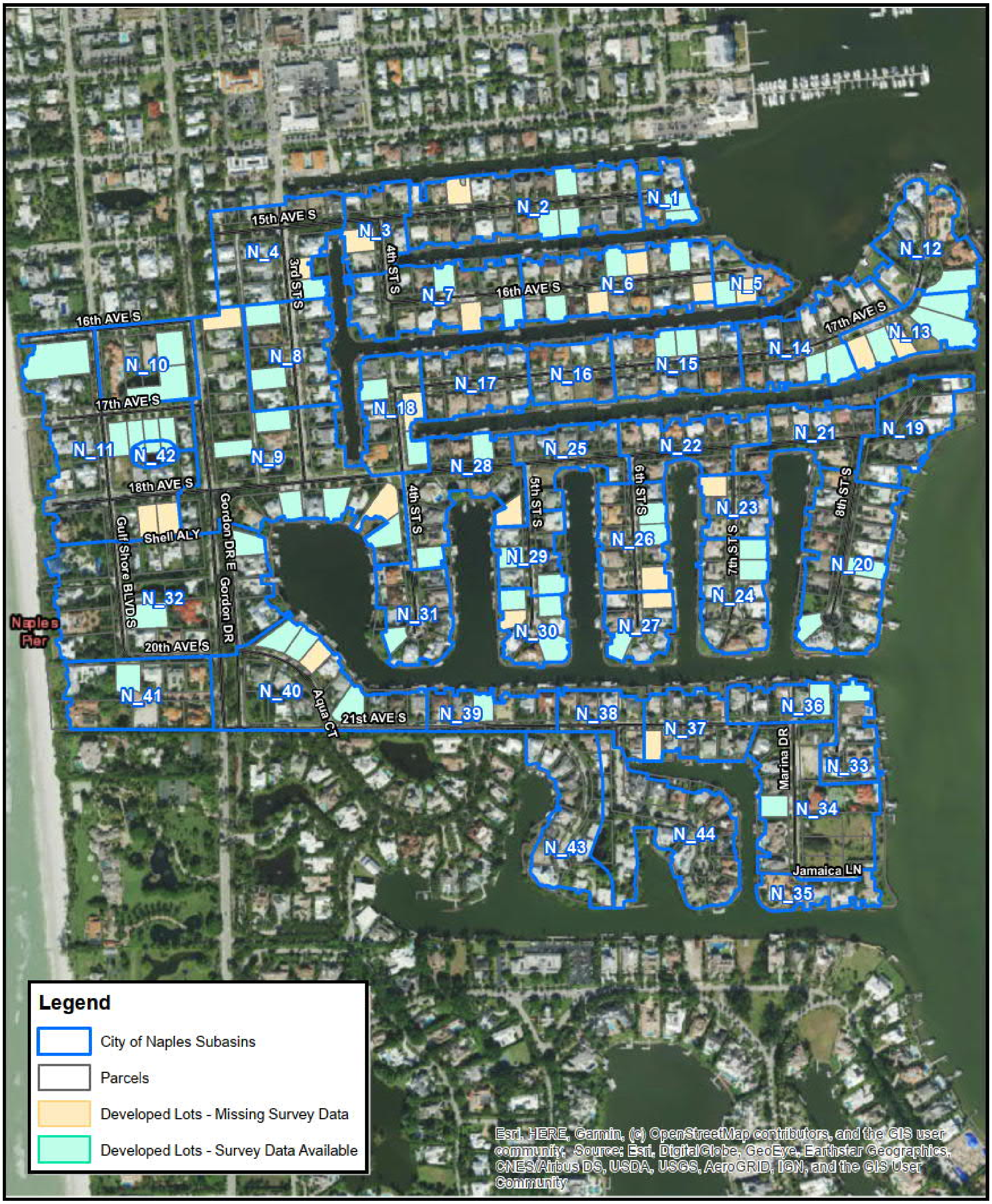

Figure 5. Parcels Redeveloped Since 2007

Existing Permits

There are no existing SFWMD Permits within the assessment area. There was one SFWMD permit along the south boundary of the assessment area noted as Little Harbor. In addition to the one SFWMD Permit, there were six (6) Florida Department of Environmental Protection (FDEP) Environmental Resource Permits (ERP) for boat docks.

Tidal Information

For this assessment, tide information for Naples Bay is provided by NOAA Station 8725100. ***Figure 6*** shows the different elevations that can be used for the report. For the design of the system the Mean High-Water (MHW) Elevation of 0.35 feet NAVD is used. This elevation is consistent for stormwater infrastructure design as well as for boat docks.

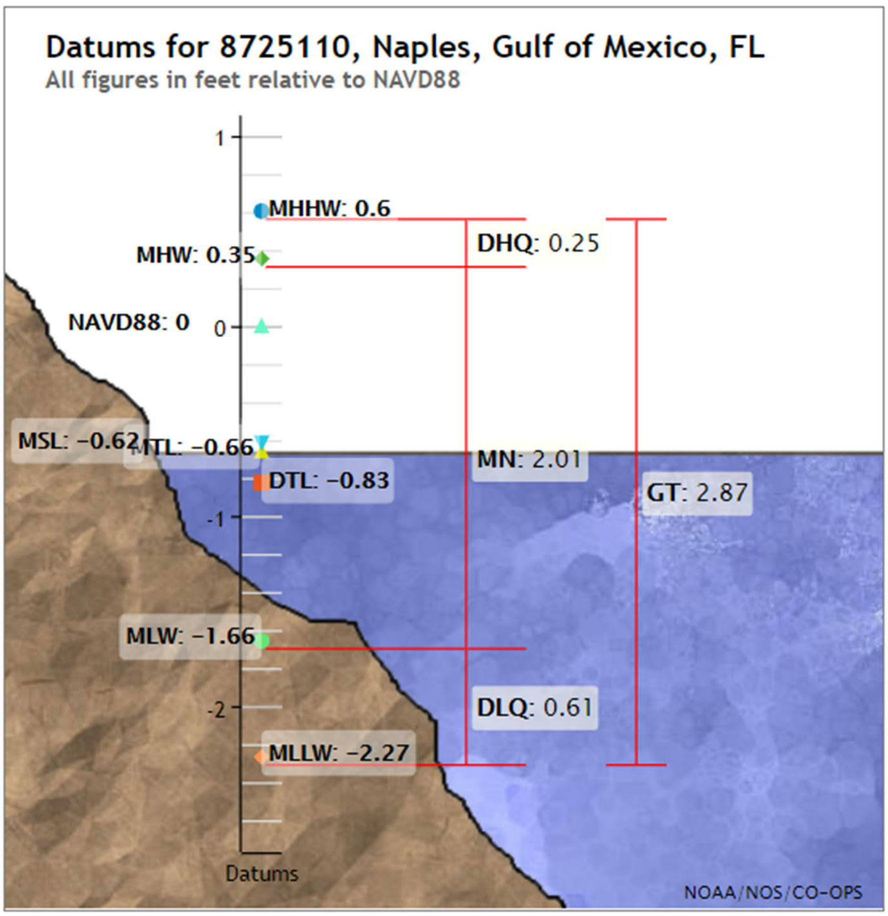

Figure 6. Datum for Station 8725110

Existing Conditions Analysis

The first step in the basin assessment is to examine the existing level of service of the system. The study area was divided into basins. These basins were determined based on existing outfalls and topographic information. After the basins were delineated, then assumptions were developed for the main elements of the hydrologic and hydraulic model. The modeling of the system for this basin assessment was conducted in Streamline Technologies Advanced Interconnected Pond Routing Version (ICPR) 4 software. Due to the use of the 2007 LIDAR, the model was setup as a 1-Dimensional model. The following assumptions were developed for each of the model components.

Assumptions

Curve Number

The curve number was determined from the existing single-family residential land use. Based on a review of the available aerial information, the basins were subdivided into three groups, and a curve number was calculated based on a representative sample of basins and then the resultant curve number was applied to the respective group. The curve number of 80 was calculated for a group of 44 basins located along the northeast portion of the study area; the curve number of 84.7 was calculated for a small group of three (3) basins located at the northwest portion of the study area; and a curve number of 80.6 was calculated for a single basin located at the southwest corner of the study area. ***Figure 7*** shows the curve number areas.

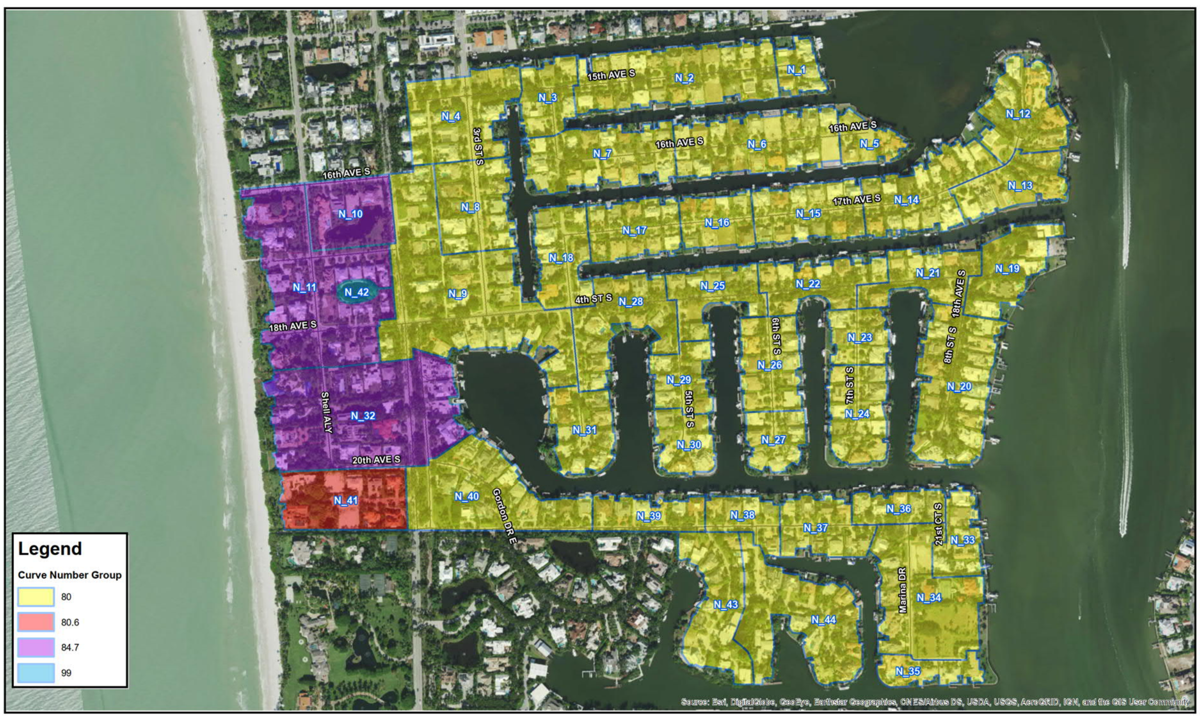

Figure 7. Curve Number Map

Stage-Storage

Stage-storage for each basin was developed using ICPR 2-Dimensional features. The 2007 LIDAR was downloaded into the model software along with the basin delineations. The software developed the stage storage curves for the basin. In order to get an accurate level of confidence in the storage of the basins, the waterfront homes were adjusted to have no storage from the pool decks or the mid yard to the waterfront. The back of lots were causing artificial storage in the basins at low elevations due to the processing of the LIDAR next to the waterway.

In order to account for the parcels that have been redeveloped since 2007, the stage storage for those parcels were subtracted from the basin and new stage-storage curves were developed based on the as-built information provided by the City for those homes. The new stage-storage was then added back to the total basin stage-storage.

Tideflex Valves

There are 3 existing Tideflex valves in the system. These valves were modeled as positive flow only. All other outfalls in the existing conditions is assuming two-way flow.

Warning Stages

Since the level of service is determined by no flooding of the crown of road, the warning stage for each basin is set at the minimum crown of road within the basin. The crown of road was obtained by reviewing two sources. The first source was the topographic survey that was obtained for this project. The crown of road elevation was taken at every 100 feet. This information was compared to the survey information of the parcels that have been developed since 2007. The lower elevation of the two sources was used. There are two (2) basins that drain into existing lakes and do not have roads that are affected by the drainage. Those basins are Basin 10 and Basin 42.

Rainfall Distribution

For the production runs used to evaluate the existing level of service, ***Table 1*** shows the rainfall used for each storm event along with the distribution curve.

Table 1. Rainfall Distribution

Storm Event	Rainfall Amount (inches)	Distribution Curve
5-year, 1-Hour	2.9	FDOT-1
10-year, 1-Hour	3.2	FDOT-1
10-year, 1-Day	7.4	SCSIII-24
25-year, 3-Day	11.5	SFWMD-72
100-year, 3-Day	15.5	SFWMD-72

Tailwater

The tailwater elevation used for the existing conditions analysis is the mean high-water elevation of 0.35 feet NAVD.

Analysis

The model was developed utilizing the above assumptions. Although the system has connected pipes, the model utilized the connections in between basins and did not model every junction and every pipe in the system. That type of analysis is typically completed during detailed design of a system. Also, the connections consisted of not only the pipe connection but also an overland weir connection represented by the existing road cross section at the basin line. These connections were added to assume that if the water level in one basin rises, it will not be restricted by the basin area and could flow to the next basin.

In addition, the hydrology of the basins was loaded on the upstream side of the pipe links. This produces a more conservative result and examines the headloss through the outfall pipes.

The basins also included the entire area of waterfront homes since each parcel has the right to drain toward the rights-of-way. Only the storage in the back of lots was removed, which also provides a more conservative approach.

Calibration

After building the model, a calibration simulation was completed. The City provided photos of a rain event that occurred on June 6, 2020. The area received approximately 1.96 inches in 5 hours. In order to calibrate the model, NEXRAD data for the day was obtained through SFWMD and was applied to the model. ***Figure 8*** is a photo taken at 164 17th Avenue S.

Figure 8. 164th 17th Avenue S

This photo was taken in Basin 11. Basin 10 is on the north side of the road but mainly drains into Lake 25, which is a privately owned lake. The centerline of the roadway is at elevation 2.6 feet NAVD. There is approximately 1 to 2 inches of water on the roadway, which equates to elevation 2.68 to 2.78. The model result was 2.68 feet NAVD. The model results are within range of the calibration event.

Figure 9 shows a photo in Basin 12 at 999 17th Avenue South. This photo shows approximately 1 inch of water at the pipe. The pipe invert is 2.63 feet NAVD, which equates to the water level at 2.71 feet NAVD. The maximum stage was 2.56 feet in the model. The model does not simulate this 8-inch diameter pipe. The flow for this basin is 1.8 cfs. When considering the headloss of the smaller diameter pipe, the calibration elevations are within range of the model.

Figure 9. 999 17th Avenue S.

Figure 10 shows a photo 685 17th Avenue S in Basin 15. The throat of the catch basin is at elevation 1.1 feet NAVD and the grate is at 1.6 feet NAVD. The water elevation for the storm event is a little over 1.6 feet NAVD. The model result is 1.3 feet NAVD, which is 3.6 inches difference. This is still within the tolerance range for the model.

In previous model runs, the calibration elevation in the model had been 1.56 feet NAVD which is closer to the calibration rain event. The previous model runs did not have a connecting weir. This connecting weir was added so that the basins do not function as individual holding areas but allow water to move in between basins. This basin is not using the weir connection which is why the calibration elevation is higher.

Overall, the existing conditions model is consistent with the calibration rainfall event. Differences between 1 to 4 inches are within a tolerable range and therefore, there is confidence in the model with some exceptions.

Figure 10. 685 17th Avenue S.

Results

After the calibration of the model, production runs were completed for the various storm events to evaluate the existing level of service. The model input reports and results are in ***Appendix E***. ***Table 2*** summarizes the results of the production runs and compares the elevations to the warning stage (existing minimum crown of road). ***Figures 13*** through ***17*** illustrate the areas of flooding for each storm event. When flooding is shown on a lot, this does not mean that there is flooding occurring on the house. The LIDAR information used to generate the maps is from 2007 and does not represent redevelopment that has occurred. In addition, the LIDAR is accurate to 0.5 feet. Additional processing of the information was completed in order to show results less than 0.5 feet.

For the existing level of service, 35 basins out of 44 have exceedances for the crown of road for the 5-year, 1-hour storm event. Based on the site visit and the model results, the following was observed throughout the neighborhood.

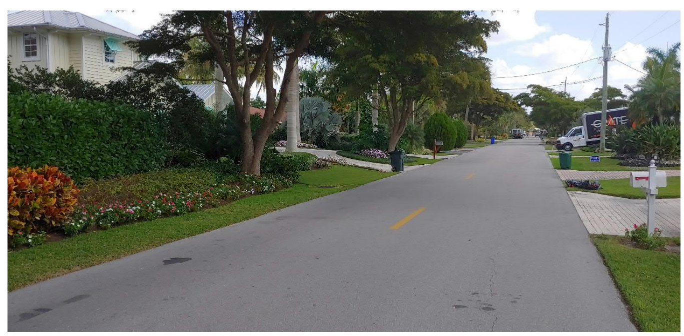

Figure 11. Typical Road Cross Section

- Swales have been filled in ***(Figure 11)***
- Building pad elevations have increased due to new regulations
- Increased impervious areas due to buildings and driveways increasing in footprint
- Conveyance systems have disappeared and are not connected
- Existing pipe outfalls are too small (8-inch to 12-inch pipes in most areas)

- Catch basins have been installed to alleviate local flooding ***(Figure 12)***. Catch basins are at grade in some areas making it hard for runoff to get to them.
- Driveways blocking flow

Figure 12. Catch Basin with No Swale

Table 2. Existing Conditions Results

Basin Name	Min. Crown of Road [ft]	5-Year, 1-Hour Maximum Stage [ft]	10-yr, 1-hour Maximum Stage [ft]	10-Year, 1-Day Maximum Stage [ft]	25-Year, 3-Day Maximum Stage [ft]	100-Year, 3-Day Maximum Stage [ft]
N_1	3.8	3.0	3.1	3.5	3.8	4.1
N_2	2.8	3.0	3.1	3.5	3.8	4.1
N_3	3.2	3.0	3.1	3.5	3.8	4.1
N_4	3.0	3.4	3.5	3.7	4.1	4.5
N_5	2.3	3.2	3.3	3.7	3.9	4.2
N_6	1.7	3.2	3.3	3.7	3.9	4.2
N_7	3.0	3.2	3.3	3.7	3.9	4.2
N_8	2.8	3.4	3.5	3.7	4.1	4.5
N_9	2.8	3.4	3.5	3.8	4.2	4.6
N_10	2.9*	2.8	3.1	3.8	4.2	4.6
N_11	2.6	3.6	3.7	4.2	4.5	5.0
N_12	3.7	4.1	4.2	4.6	4.9	5.3
N_13	3.5	4.1	4.2	4.6	4.9	5.3
N_14	3.5	3.1	3.2	3.6	3.9	4.4
N_15	1.6	3.1	3.2	3.6	3.9	4.4
N_16	2.3	3.1	3.2	3.6	3.9	4.4
N_17	3.4	3.1	3.2	3.6	3.9	4.4
N_18	3.4	3.1	3.2	3.6	3.9	4.4
N_19	3.3	3.8	3.9	4.1	4.3	4.6
N_20	4.1	3.8	3.9	4.1	4.4	4.6
N_21	2.9	3.7	3.9	4.1	4.3	4.6
N_22	2.9	3.7	3.9	4.1	4.3	4.6
N_23	3.4	3.7	3.9	4.1	4.3	4.6
N_24	3.5	3.7	3.9	4.1	4.4	4.6
N_25	3.0	3.7	3.9	4.1	4.3	4.6
N_26	3.0	3.7	3.9	4.1	4.3	4.6
N_27	3.7	3.7	3.9	4.1	4.3	4.6
N_28	3.5	3.7	3.9	4.1	4.3	4.6
N_29	3.8	3.7	3.9	4.1	4.3	4.6
N_30	3.5	3.7	3.9	4.1	4.3	4.6
N_31	4.5	3.7	3.9	4.1	4.3	4.6
N_32	2.7	3.6	3.7	4.3	4.7	5.1
N_33	2.8	3.6	3.7	4.1	4.4	4.7
N_34	2.7	3.6	3.7	4.1	4.4	4.7
N_35	3.0	3.6	3.7	4.1	4.4	4.7
N_36	2.3	3.6	3.7	4.1	4.4	4.7
N_37	3.5	3.6	3.7	4.1	4.4	4.7
N_38	3.5	3.6	3.7	4.1	4.4	4.7
N_39	3.8	3.6	3.7	4.1	4.4	4.7
N_40	3.0	3.6	3.7	4.1	4.4	4.7
N_41	3.9	3.7	3.7	4.3	4.7	5.1
N_42	3*	2.9	3.1	4.0	4.4	4.8
N_44	3.5	3.7	3.9	4.1	4.4	4.7

(shaded) - denotes basin exceeds the minimum crown of road elevation for the corresponding rainfall event.

* - warning stage is minimum top of bank of lank

Figure 13. Flood Map for 5-Year, 1-Hour Storm Event

Figure 14. Flood Map for 10-Year, 1-Hour Storm Event

Figure 15. Flood Map for 10-Year, 1-Day Storm Event

Figure 16. Flood Map for 25-Year, 3-Day Storm Event

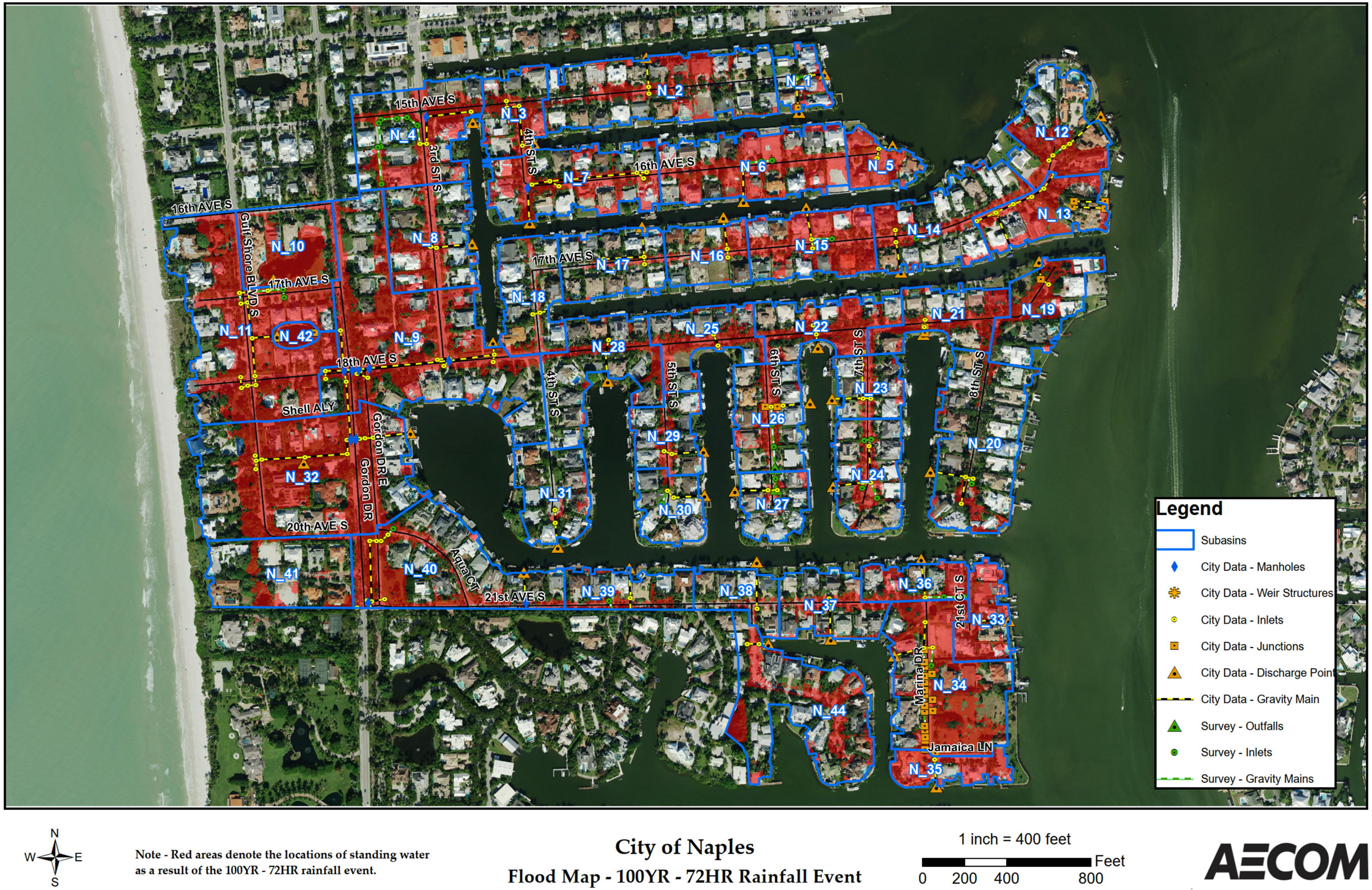

Figure 17. Flood Map for 100-Year, 3-Day Storm Event

Proposed Analysis

In developing infrastructure to meet the current level of service and to evaluate the proposed system for an improved level of service, storage, capacity, and conveyance need to be increased. Also, a stormwater system needs to be resilient, be easy to operate and maintain, and provide water quality treatment to satisfy permitting requirements.

Due to the impacts that certain assumptions make on a system, three (3) scenarios were developed in order to determine how those assumptions effect the infrastructure decisions needed to meet certain level of service. In order to develop the infrastructure needed for the scenarios, certain assumptions were made to account for future conditions. These assumptions are sea level rise and stage-storage.

Assumptions

Sea Level Rise

In June 2020, the City finalized its Climate Change Vulnerability Assessment document. This document examined the climate change science and mapped the potential sea level rise to analyze which assets would be vulnerable to future effects of climate change. Based on the projections of the Naples NOAA Sea Level Rise Trends at Station #8725110, sea levels may be between 9.8 inches to 40.6 inches higher by mid-century, and 15.4 to 100.4 inches higher by end-of-century. The sea level rise projections for Naples are shown in ***Figure 18***.

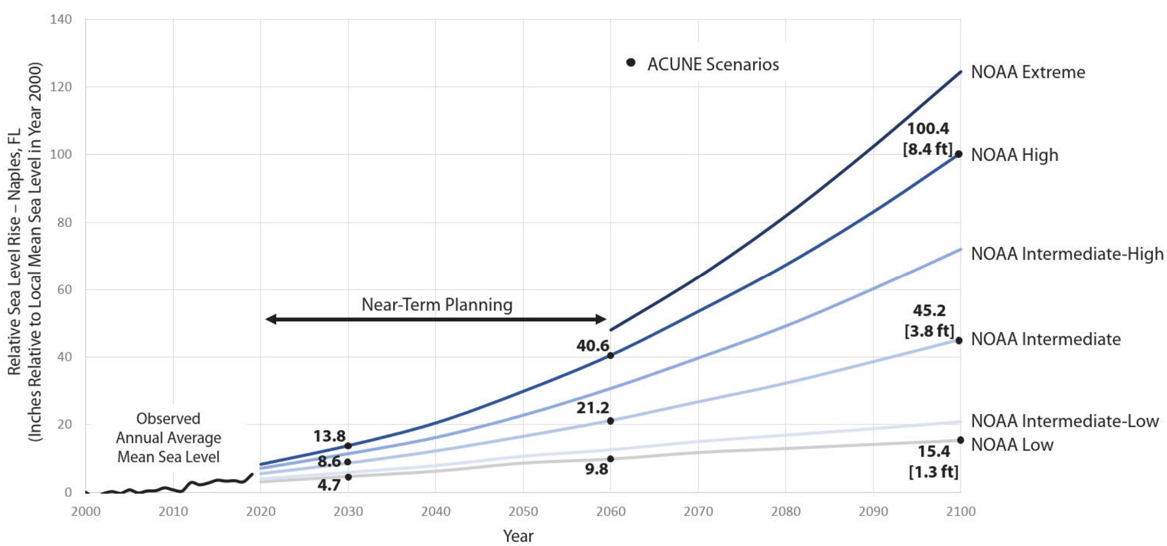

Figure 18. Naples Sea Level Rise Projections

Coastal communities are implementing sea level rise projections in their stormwater management systems to protect their facilities from the impact of future sea level rise and to reduce their vulnerability. When utilizing the projections, the first item to consider is the useful life of the facility. Typically for stormwater facilities, the planning period is 30 years which would be from the time the facilities are constructed. Since it takes time to construct the facilities, the projections for the year 2060 are used. The second item to consider is which projection to choose. Municipalities throughout Florida have used different projections. Some municipalities are more conservative. For example, the Southeast Florida Regional Climate Change Compact, which consists of Monroe County, Miami-Dade County, Broward County, and Palm Beach County, is utilizing the NOAA Intermediate-High projections. Collier County is utilizing the NOAA Intermediate at 21.2 inches for Year 2060.

The current Mean High Water (MHW) Level is at 0.35 feet NAVD. For design, the sea level rise projection is applied to the MHW level. The lowest existing road elevation for the study area is 1.56 feet NAVD. When applying the NOAA Intermediate High at 30 inches to the MHW, the tailwater for the study would be 2.85 feet NAVD. If the tailwater exceeds the 1.56 feet NAVD, then a pumped system would be needed for the design since water will not be able to discharge by gravity.

To evaluate a gravity system, the tailwater could not exceed 1.56 feet NAVD since this is the lowest road elevation in the system. If 1.56 feet is used as the highest tailwater, then this would equate to 14.5 inches of sea level rise projection. For the NOAA High, Intermediate-High, Intermediate, Intermediate-Low, and Low projections, 14.5 inches would be reached in years 2030, 2035, 2045, 2065, and 2095, respectively.

The rate of sea level change is unknown, but the current rate published on the NOAA website for the Naples Gulf Station is 3.02 millimeters per year (mm/yr)with a 95% confidence interval of +/- 0.45 mm/yr based on monthly mean sea level data from 1965 to 2019 which is equivalent to a change of 0.99 feet in 100 years. The recent Climate Vulnerability Assessment report published in June 2020 stated that the rate was 2.85 mm/yr. This rate continues to change with new data being published.

This assessment evaluated both a pump scenario at the 30 inches of sea level rise (2.85 feet NAVD) and a gravity scenario at the 14.5 inches of sea level rise (1.56 feet NAVD) to examine the differences in cost and constructability of these types of infrastructure with the varied tailwater elevations.

Stage-Storage

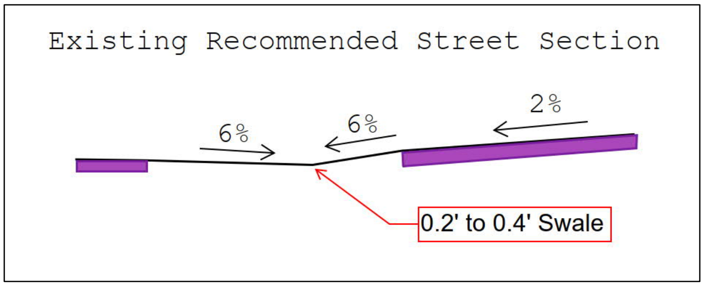

Figure 19. Existing Standard Swale

For the proposed scenarios, three assumptions were developed to represent future stage-storage assumptions. The first assumption in stage-storage is to consider how future redevelopment will impact the system. The stage-storage assumption for the redeveloped properties were applied to the remaining parcels within the study area. These assumptions included raising building pads and yards in accordance with similar grading that has been occurring within the study area. By applying these stage-storage assumptions, storage was reduced.

The second assumption for the improvements in the area was to add swales to the study area. Since the area is low, storage is needed below the road elevation to allow for the system to not only convey the drainage but to provide water quality treatment that will be necessary to permit the system. ***Figure 19*** represents the City's current standard for swales, which is 0.2 feet to 0.4 feet deep from the edge of pavement. These swales currently do not exist within the entire study area. For the three scenarios, ***Figure 20*** was used to represent deeper and wider swales to provide additional storage at the lower elevations. This storage assumption was applied to all the scenarios.

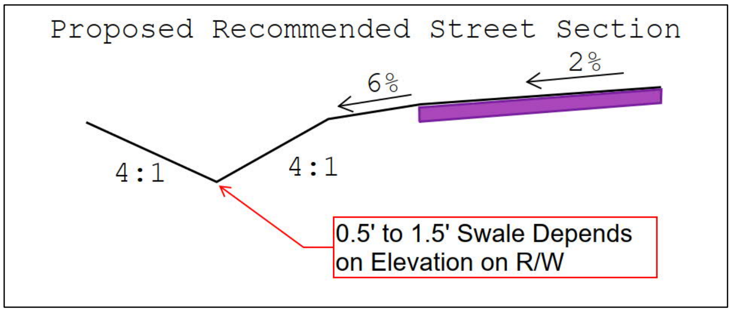

Figure 20. Proposed Standard Swale

The last assumption that was used was to increase the City's current policy for onsite retention. The current policy requires redevelopment to retain 0.5 inches of runoff from the parcel minus the roof areas. To gain more storage for the system, it is recommended to modify this policy to 1-inch of runoff over the impervious area for the entire parcel. The percent impervious for this study is 75%. In addition, the storage was assumed to start at elevation 2.5 feet NAVD, which is approximately 1 foot higher than the seasonal high groundwater table. This storage assumption was applied to all the scenarios.

Scenario 1 - Pump System

On August 14, 2020, City staff and AECOM met to review the results of the existing conditions modeling analysis and to determine the parameters of the first scenario. The parameters that were agreed upon were:

- Analyze a system to meet the 10-year, 1-day storm event level of service for no flooding of the road crown and the 25-year, 3-day storm event for no flooding of the road crown
- Use the NOAA Intermediate-High for sea level rise which is 30 inches. This equates to a tailwater elevation of 2.85 feet NAVD
- Do not include the 0.5 inches of runoff minus the roof area in the stage-storage assumptions
- Connected pipe system
- Add swales with 1.5 feet of depth to the road rights-of-way per ***Figure 20***
- Tideflex valves on all outfalls
- Utilize certain areas that may become available for pump stations
- Add a control structure to Lake 13

Figure 21 illustrates the concept plan that will provide a 10-year, 1-Day level of service of no flooding of the crown of road. This plan contains eleven (11) pump stations throughout the study area with a connected pipe system that ranges from 30-inches to 96-inches in diameter. The outfalls at the pump station have pipe sizes 72-inches to 132-inches in diameter in order to lower the velocity to 1.5 feet per second in the canals.

Although raising roads was not originally contemplated as an improvement for this scenario, the results of the modeling show that roads would need to be raised.

This concept was presented to City staff, but due to the larger diameter pipes and the amount of area needed to build the pump stations, new parameters were discussed for the next scenario.

The 25-year, 3-day level of service for no flooding of the crown of road appeared to not be feasible due to the needed infrastructure for the 10-year, 1-day scenario. ***Appendix F*** contains the modelling input and results for this scenario.

Figure 21. Scenario 1 Concept Plan

Scenario 2 – Gravity System for 10-year, 1-Hour Storm Event

After presenting Scenario 1, City staff and AECOM met on September 11, 2020 to discuss the parameters and the level of service storm event. In developing Scenario 1, it was noticed that the sea level rise projection needed to be re-evaluated and that a gravity system was desirable. In order to develop a gravity system, the tailwater needed to remain at the lowest road elevation. In addition, more storage was needed to be considered. Therefore, the following parameters were used for the Scenario 2:

- Use the 10-year, 1-Hour Storm Event for the level of service for no flooding of the crown of road
- Use a tailwater elevation of 1.56 feet NAVD. This would translate to 14.5 inches of sea level rise
- Add 1-inch of storage at elevation 2.5 feet NAVD for each basin given the assumption that every redeveloped lot in the future would need to store 1-inch over the impervious area (assuming 75% of the lot would be impervious)
- Assume that all pipes will have backflow prevention
- Provide a control structure for Lake 13
- Due to the limitations of a 15-feet easement between lots, use a maximum 48-inch diameter pipe for constructability
- Upsize existing outfalls up to a 48-inch diameter pipe in order to meet level of service
- Connect pipes where needed to maintain a maximum 48-inch diameter pipe
- Raise roads up to 1 feet before considering a pump station
- Add swales with 1.5 feet of depth to the road rights-of-way per ***Figure 20***

Figure 22 illustrates the concept plan that will provide a 10-year, 1-hour level of service of no flooding of the crown of road for a gravity system. For this scenario Basin N_1, which is located at the east end of 15th Avenue S, did not require any improvements. All the existing outfalls required upsizing and three (3) road segments are required to be raised:

- Gulf Shore Boulevard S. from Shell Alley to 17th Avenue S. needs to be raised 0.55 feet
- 17th Avenue S. from Gulf Shore Boulevard S. to Gordon Drive needs to be raise 0.55 feet
- Gordon Drive from Aqua Court to Shell Alley needs to be raised 0.30 feet

Appendix G contains the modelling input and results for this scenario.

Figure 22. Scenario 2 Concept Plan

Scenario 3 – Gravity System for 10-year, 1-Day Storm Event

After reviewing Scenario 2 results, the City requested to perform the same analysis on the 10-year, 1-Day storm event for a level of service of no flooding of the crown of the road to determine if a higher level of service could be achieved with the same concept. The same parameters that were used for Scenario 2 were applied to Scenario 3.

Figure 23 illustrates the concept plan that will provide a 10-year, 1-Day level of service with no flooding of the crown of road for a gravity system. For this scenario some of the pipe sizes had to increase to accommodate the larger storm event. All the existing outfalls required upsizing and five (5) road segments needed to be raised:

- Gulf Shore Boulevard S. from Shell Alley to 16th Avenue S. needs to be raised 0.80 feet
- 17th Avenue S. from Gulf Shore Boulevard S. to Gordon Drive needs to be raise 0.80 feet
- Gordon Drive from Aqua Court to Shell Alley needs to be raised 0.52 feet
- 16th Avenue S from the east end of the road to approximately 1,088 feet west of the east end of 16th Avenue S needs to be raised 0.15 feet
- Approximately 605 feet of 17th Avenue S in the mid-block section of the road west of 4th Street S needs to be raised 0.1 feet

Appendix H contains the modelling input and results for this scenario.

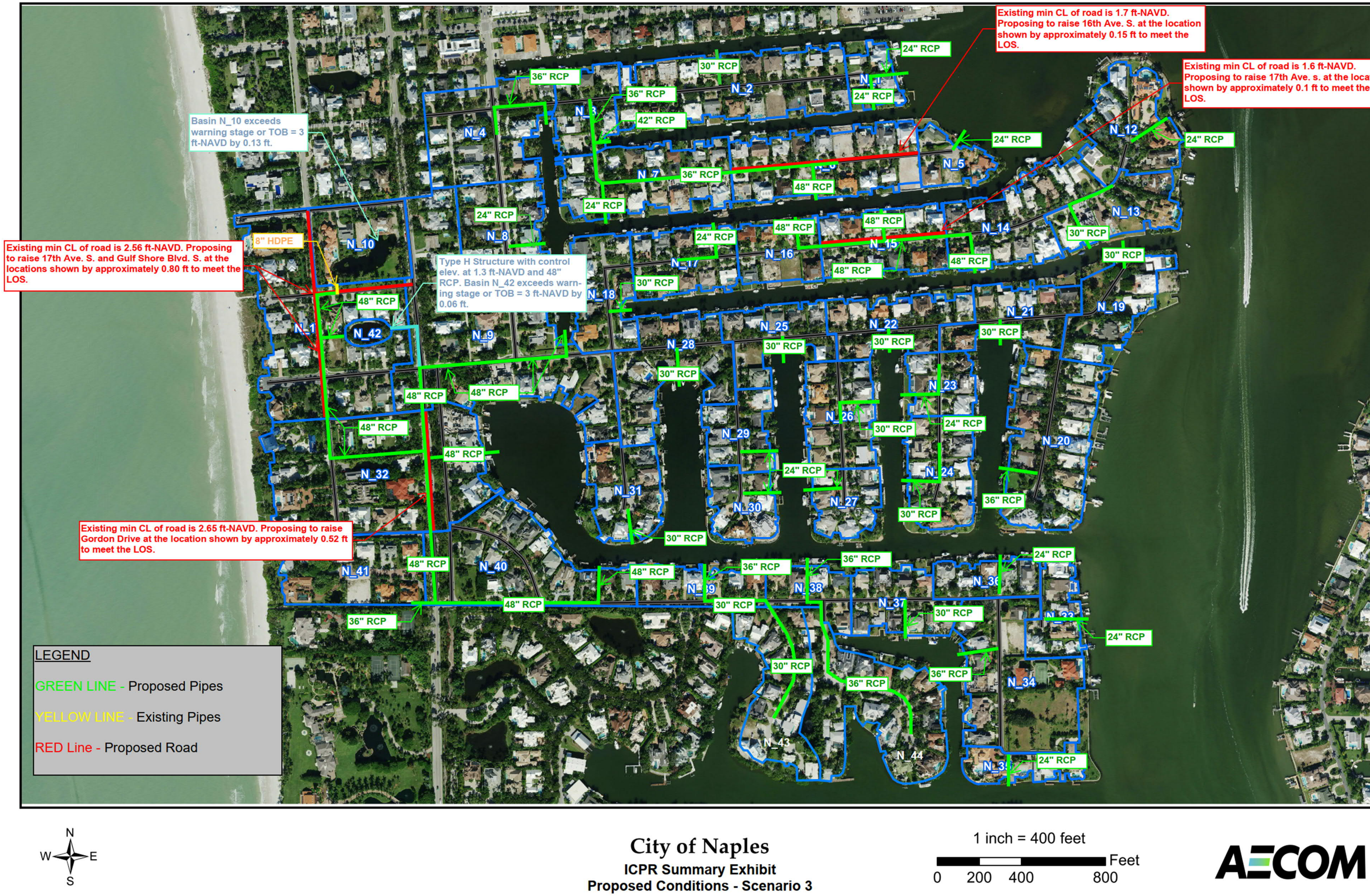

Figure 23. Scenario 3 Concept Plan

Cost Estimates

Cost estimates were prepared for each scenario to aid in determining the best scenario for the City. These detailed engineer's estimates of probable cost for each scenario are located in ***Appendix I.***

Each scenario was prepared to examine different varying elements. For instance, Scenario 1 aids in evaluating how a higher sea level rise projection effects the cost and constructability of the project. Another comparison is the cost between preparing a project for a higher level of service. A higher level of service increases the costs of the project.

These costs represent one direction or decision avenue and have not been valued engineered. As detailed design occurs other items may impact the design due to site specific conditions. Some unknown items that may impact the costs are:

- Types of water quality structures
- Whether curb and gutter will be needed on roads due to elevation issues
- Existing private irrigation systems
- Landscaping within the rights-of-way
- Existing Utilities
- Depending on the choice of water quality structures, the headloss across these types of structures could increase and therefore, planned pipe sizes may need to be increased or roads may need to be raised
- Existing drainage easements between lots

Scenario 1 – Pump Stations

This cost estimate includes a connected pipe system with swales to add more storage. This system would include catch basins located in the swale system which would be supplemented with some curb and gutter in areas where swales may not be constructed due to elevation constraints.

In order to meet the 10-year, 1-day storm event level of service for no flooding on the centerline of the roadways, approximately eleven (11) pump stations are needed. These stations would be equipped with 20,000 gallon per minute (gpm) pumps. Some stations would require 2 or 3 pumps depending on the discharge rate. Each station would have a trash rack structure and a water quality treatment device such as a Stormceptor or baffle box to address water quality treatment. In addition, the pumps would discharge in a larger diameter pipe or dissipater box where the velocity is reduced before entering the canal system.

Approximately 6,500 linear feet (LF) of roadway will need to be raised in order to meet the level of service.

The engineer's estimate of probable construction cost for this scenario is approximately $62.2 million.

Scenarios 2 and 3 – Gravity System

This cost estimate includes a connected swale system to main outfalls. The swales provide additional storage and water quality treatment as well as convey the stormwater to the main outfalls. The existing 39 outfalls in the basin are proposed to be modified with increased diameter pipe. The pipes range from 24-inches to 48-inches in diameter. Each outfall would be equipped with a Tideflex valve and a water quality control structure would be located within the right-of-way or drainage easement before discharging into the canals.

For Scenario 2, only 37 outfalls would be modified and approximately 2010 LF of roadways would need to be raised in order to meet the 10-year, 1-hour storm event level of service. The engineer's estimate of probable construction cost for this scenario is approximately $48.3 million.

For Scenario 3, all 39 outfalls in the basin would be modified and approximately 3,515 LF of roadways would need to be raise in order to meet the 10-year, 1-day storm event level of service. The engineer's estimate of probable construction cost for this scenario is approximately $52 million.

Permitting

Stormwater improvements under this assessment would be considered a retrofit. A stormwater retrofit project is typically proposed by a municipality to provide new or additional treatment or attenuation, or improved flood control to an existing stormwater management system. Stormwater retrofit projects shall not be proposed or implemented for the purpose of providing the water quality treatment or flood control needed to serve new development or redevelopment. This project would be considered a modification of an existing stormwater management system. Although redevelopment is mentioned in this analysis, redevelopment in the sense of permitting is typically a new land use and a major change in the system. Redevelopment is being considered in this assessment as a factor of safety should landowners continue to modify their lots. The City's existing codes and regulations restrict certain development within a certain land use.

Under the Environmental Resource Permit Applicant's Handbook Volume II for use within the geographic limits of the SFWMD, Effective May 22, 2016, an applicant for a stormwater quantity project must provide reasonable assurance that the retrofit project will reduce existing flooding problems in such a way that it does not cause any of the following:

1. A net reduction in water quality treatment provided by the existing stormwater management system or systems;
2. Increased discharges of untreated stormwater entering adjacent or receiving waters;

If the applicant has conducted, and the Agency has approved, an analysis that provides reasonable assurance that the stormwater quantity retrofit project will comply with the above, the project will be presumed to comply with the requirements in Part III of the SFWMD Permit Applicant's Handbook.

In addition, the applicant for any stormwater retrofit project must design, construct, operate, and maintain the project so that it:

1. Will not cause or contribute to a water quality violation;
2. Does not reduce stormwater treatment capacity or increase discharges of untreated stormwater. Where existing ambient water quality does not meet water quality standards the applicant must demonstrate that the proposed activities will not cause or contribute to a water quality violation. If the proposed activities will contribute to the existing violation, measures shall be proposed that will provide a net improvement of the water quality in the receiving waters for those parameters that do not meet standards.
3. Does not cause any adverse water quality impacts in receiving waters; or
4. Will not cause or contribute to increased flooding of adjacent lands or cause new adverse water quantity impacts to receiving waters.

Therefore, during detailed design, the project will need to provide an analysis that the increased discharge would not impact water quality to the downstream system. Furthermore, an environmental assessment will be needed at the discharge points to ensure that there are no impacts to resources at the discharge points.

Water Quality

As mentioned in the permitting section of this report, water quality treatment needs to be included in the detailed design of this project. Currently, water quality treatment is not provided by the existing system. The designer of the system will need to evaluate the existing discharge of pollutants into Naples Bay versus the treated increased discharge of the proposed system. ***Table 3*** summarizes the existing versus the proposed discharge rates for each of the scenarios at the level of service that each scenario is trying to achieve.

Table 3. Peak Discharge Rates

Scenario	Storm Event	Existing Outflow (cfs)	Proposed Outflow (cfs)
1	10-year, 1-day	261.24	771.11
2	10-year, 1-hour	212.74	660.72
3	10-year, 1-day	261.24	724.83

Although these are peak discharge rates, this aids in understanding the amount of water that will need to be treated.

Currently, all three scenarios have considered water quality treatment through the following methods:

- Swales
- Inlet Filters
- Extra retention of redeveloped parcels
- Stormwater Pollutant Removal Vaults (Baffle boxes or Stormceptors)
- Control Structure in Lake 13

Other treatment devices that may be considered are:

- Exfiltration trenches
- Rain Gardens

As the sea level rises, the groundwater table will also rise which will decrease the capacity of some of these treatment systems.

These water quality devices are currently not in the current model. When detailed design occurs and treatment solutions are selected, the designer will need to consider the potential of additional headloss through the system which causes the pipes to increase in size and additional roads to rise due to the low topography in some areas of the study area.

Design Considerations

Water Quality

As discussed in the previous section, the designer will need to treat the stormwater discharge to at a minimum the pre-existing condition. This would entail calculating the existing pollutant loading to the system and adding water quality treatment devices to achieve the desired loading. The designer will need to carefully balance the impact that the treatment device may have on headloss to the system to minimize the cost of the system.

In addition, the designer will need to add pipe connections to the treatment facilities and ensure that the entire system is conveyed. To minimize the amount of treatment facilities, the designer could provide a piped system of several basins into one treatment device. This could result in an increased cost of pipes however, could minimize the number of outfalls that would need to be modified.

Conveyance System

Driveways currently block the current conveyance system. Connections should be made by connecting swales with driveway culverts or bubble up catch basins where water can cross under driveways.

Another consideration would be to provide a curb and gutter system. This would be an increased cost to the project, but it would ensure that the stormwater would be directed to the water quality treatment devices and the outfalls. Another approach would be to minimize the number of outfalls that need to be modified by connecting the basins with one main pipe to a centralize outfall. As basins are connected and outfalls are reduced, pipe sizes will increase, but the need to reconstruct sea wall will be decreased.

Swale Construction

The geometry of the swale construction is dependent on the elevation of the road, the elevation of the right-of-way, and the groundwater table. The depth of the swale will depend on those restraints. Should the elevation along the right-of-way be lower than the edge of pavement, the City may need to consider drainage easements along property lines to mitigate flooding in yards and to add necessary storage for water quality treatment.

The swales need to be connected properly with driveway culverts so that the water can be directed to the outfalls.

Raising Roads

Similar to the swales, as roadways are being raised, storage could be lost in swales since the minimum design slopes would need to be kept and the elevations at the rights-of-way are fixed.

In addition, consideration will need to be made for lots that are lower than the proposed raised road. In those areas, mitigation for drainage can occur through connections with catch basins in yards to a piped system and an easement may be needed for the encroachment of drainage on private property.

Future Sea Level Rise Projections

If sea level rises above 1.56 feet NAVD, a pumped system will need to be considered. As the system is being designed, the designer could keep in mind the potential that a pump station might be needed and to plan for the potential placement of a pump stations in the future within the City's rights-of-way or drainage easement.

Although this system examined sea level rise at an elevation of 1.56 feet NAVD, the maximum observed tide occurred at elevation 4.62 feet NAVD in 2017 and the average maximum monthly water level for the past 10 years has been 1.62 feet NAVD. Therefore, the system currently experiences tailwater in exceedance of 1.56 feet NAVD but that does not become an issue unless a storm occurs during those higher water levels.

With the installation of Tideflex valves, the higher water levels will be prevented from backing into the system.

Summary

Basin 4's system is clearly impacted by rising water levels, reduced conveyance capacity, reduced storage, and increased impervious area. Although the basin has faced these changes in its stormwater management system, it is possible to achieve no flooding of the crown of road for both the 10-year, 1-hour and 10-year, 1-day storm event through the design of both a pumped and gravity system.
Clearly, the existing infrastructure needs to be improved through increased storage, increased conveyance capacity, and drainage infrastructure connections. With those improvements in mind, the City should consider implementing a policy to design stormwater infrastructure to a fixed sea level rise projection with infrastructure lifespan in mind, a policy to improve storage on individual lots, a change in its current right-of-way handbook to implement deeper swales, and to re-evaluate the requirements of sea wall heights to combat sea level rise.
The cost of the proposed systems is dependent on the sea level rise projection, the level of service criteria, storage in the system, and water quality treatment. When the system is being designed, the City should implement a value engineering analysis on the design due to the co-dependency of the variables.

The results of this study were presented to the City Council on October 19, 2020. After hearing the results of the study, Council agreed that storage needs to be added to the basin by reclaiming the swales and adding requirements for redevelopment to retain more stormwater within properties. In addition, Council generally agrees that the system should be designed for the lower projection of sea level rise and understands that at times, the system will be impacted by the tidal fluctuations since the tailwater may be higher than the lowest road elevation of the basin. They recognize that high tides occur for a short period of time and that if the peak storm occurs at the high tide, water may not be able to discharge. The Council agrees that backflow preventers should be installed on all the outfalls to prevent the tide from entering the system.

After reviewing the cost of the system and recognizing that the City would need to explore how the project would need to be funded, the City would like to implement components in phases to provide relief to the landowners sooner than waiting for the project to be designed, permitted, and constructed. The project could start with the reclamation of swales within the area and connecting the swales with the use of driveway culverts to the existing outfalls. Although the outfalls are undersized, the construction of these activities would provide immediate relief and would not require an extensive permitting process. The swales and the driveway culverts would need to be sized in order to obtain the maximum amount of storage and conveyance achievable within the existing rights-of-way.

The next phase of the project would involve a value engineering of design components in order to achieve the maximum level of service while keeping the cost low. This can be achieved by examining each basin individually through the results of this report and determining whether raising the road would be more cost beneficial to an outfall being increased in size versus a pipe conveyance network as explained in the report.

In conclusion, this study evaluated Basin 4's ability to manage potential sea-level rise through anticipated climate change and augmented the City's effort to protect vulnerable assets. The City's goal to increase the current level of service for drainage in this basin can be achieved with consideration of future climate conditions in order to provide a resilient system. This can be achieved in a phased approach that would be in line with the City's funding mechanisms.

Appendix A Survey

Appendix B Topographic Information

Appendix C Geotechnical Information

Appendix D Existing Permits

Appendix E Existing Conditions Analysis

Appendix F Scenario 1 Analysis

Appendix G Scenario 2 Analysis

Appendix H Scenario 3 Analysis

Appendix I Cost Estimates