Innovative approaches
Practical results
Outstanding service

WALNUT CREEK PUMP STATION BASIN STUDY

Prepared for:

Town of Cary

March 2021

Prepared by:

FREESE AND NICHOLS, INC.
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Raleigh, NC 27606
919-582-5850

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Prepared for:

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NORTH CAROLINA PROFESSIONAL SEAL 037633 ENGINEER BRIAN T. WHITE

03/11/2021

Prepared by:

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FNI Project No.: CYC20340

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

The Town of Cary (Town) is located in Wake County, North Carolina. Within the Town's Walnut Creek Pump Station Basin, the Town currently provides wastewater service to approximately 5,300 people and is anticipating tremendous growth due to redevelopment in the coming decades. Accommodating this growth in an efficient and cost-effective manner, while also focusing on the maintenance of existing wastewater system assets, was the focus of the *Walnut Creek Pump Station Basin Study* project. This report has been prepared to provide the Town of Cary with a planning tool to serve as a guide for improvements to the wastewater infrastructure through 2050.

The major elements of the scope of this project included:

- Wastewater Flow Monitoring Data Analysis
- Population and Flow Projections
- Design Storm Analysis and Selection
- Wastewater System Model Development and Calibration
- Wastewater System Capacity Analyses
- Capital Improvements Plan (CIP) and Report

2.0 EXISTING WASTEWATER COLLECTION SYSTEM

The Walnut Creek Pump Station Basin (Basin) service area encompasses approximately 1,600 acres. The Basin wastewater collection system network consists of roughly 1,147 manholes and 216,000 linear feet of gravity sewer main ranging in size from 6-inches to 30-inches. The Walnut Creek Pump Station (PS) which serves the Basin is a triplex PS with a design capacity of 3.93 MGD for one pump and a design capacity of 5.80 MGD for two pumps. The pump station was recently a part of another study, *Pump Station Assessments and Recommendations* by FNI, that included extensive testing and condition assessment. The testing on the Walnut Creek PS was performed by Kimley Horn. Initial testing was performed on July 16, 2019, and a second test evaluation was conducted on January 30, 2020. The theoretical pump station capacity based on results from the draw down testing is 4.18 MGD.

3.0 WASTEWATER FLOW MONITORING

The Town has a contract with Frazier Engineering to install, maintain and provide monthly data analysis for 33 permanent flow monitoring and 7 permanent rain gauge locations systemwide. FNI was provided with multiple years of monitoring and rainfall data from the Town's permanent monitor within the Basin to use for analysis and calibration. As a part of this project, FNI contracted with Vieux and Associates, who provided Gauge Adjusted Radar Rainfall (GARR) data to provide more granular rainfall data across the system. The flow monitoring and rainfall data were used to characterize dry and wet weather flows within the Basin and to calibrate the wastewater hydraulic model. The data was also utilized to evaluate inflow and infiltration (I/I) throughout the collection system.

4.0 POPULATION AND FLOW PROJECTIONS

Population and land use are important elements in the analysis of the wastewater collection system. Wastewater flows depend on the residential population and commercial development served by the system. Residential population and non-residential flow projections for the existing (2020), 2025, 2030, 2040, and 2050 planning periods were developed by interpolating between 2050 projected flows and 2020 water meter billing meter data provided by the Town of Cary, which was scaled during dry weather calibration. The projected average day dry weather flows and peak wet weather flows for each planning year for the Basin are shown in **Table ES-1.**

Table ES-1: Walnut Creek Basin Flow Projections

Planning Year	Average Day Dry Weather Flow (MGD)	Peak Wet Weather Flow (MGD)
2020	0.82	6.62
2025	1.76	7.39
2030	2.24	7.66
2040	2.91	8.22
2050	3.32	8.55

5.0 MODEL DEVELOPMENT AND CALIBRATION

The hydraulic model for the Walnut Creek Pump Station Basin Study was developed using the Infoworks ICM® hydraulic modeling software by Innovyze. The model will be exported and provided to the Town in

Innovyze InfoSWMM hydraulic modeling software. The hydraulic model consists of approximately 594 gravity sewer main segments, 593 manholes, 2,192 catchments, and one outfall. The Town provided survey data for gravity sewer mains and manholes in areas where future growth is anticipated. The survey data provided determined which mains and manholes were included as active parts of the hydraulic model. All mains and manholes without survey information were pruned from the active network. The pruned portions of the network can be restored within the model in the future as survey data becomes available.

FNI calibrated the model to closely match the observed dry and wet weather flows based on the flow monitoring data recorded within the Basin. The dry and wet weather calibration results provide a high level of confidence that the model closely matches real world conditions and is suitable to use for hydraulic analyses and capital improvements plan (CIP) development.

6.0 WASTEWATER SYSTEM ANALYSES

Hydraulic analyses were conducted to identify deficiencies in the Basin existing wastewater collection system and establish capital improvements projects to address existing system deficiencies and accommodate the projected wastewater flows through 2050. A 5-year, 24-hour center-weighted storm was utilized as an *assessment storm* for the existing and future system analyses. A 5-year, 12-hour Soil Conservation Service (SCS) storm was utilized as a *design storm* for capital improvement project sizing. Various combinations of improvements and modifications were investigated to determine the most efficient approach to convey projected flows.

7.0 CAPITAL IMPROVEMENTS PLAN

A wastewater CIP was developed for the Basin. The recommended projects improve the system's ability to convey wastewater flows and provide the required conveyance capacity to serve the projected residential and commercial growth through 2050. All recommended infrastructure is sized to convey the projected 2050 peak wastewater flows (including I/I).

Capital costs were calculated for all recommended improvements and do not include individual service connections or subdivision lines. The costs are provided as estimates based on previous similar engineering experience in 2021 dollars and include allowances for engineering, surveying, mobilization, and contingencies. Costs do not include easements or land acquisition. A summary of the wastewater CIP costs is provided in **Table ES-2**.

Table ES-2: Walnut Creek Basin Wastewater CIP Summary

Project ID	Project Name	Cost
A	15-inch Durham Road Gravity Mains	$ 1,545,600
B	15-inch Urban Park Gravity Mains	$ 856,500
C	18/21/27-inch Cary Towne Boulevard Gravity Mains	$ 3,945,200
	TOTAL	**$ 5,119,100**

1.0 INTRODUCTION

The Town of Cary is located in Wake County, North Carolina. The Walnut Creek Pump Station Basin currently provides wastewater service to approximately 5,300 people. Due to anticipated redevelopment and growth in the Downtown and Eastern Cary Gateway special planning areas, the population within the wastewater service area is projected to increase to approximately 35,000 by 2050. Accommodating this growth in an efficient and cost-effective manner, while also focusing on the maintenance of existing wastewater system assets, was the focus of the *Walnut Creek Pump Station Basin Study*. This report has been prepared to provide the Town of Cary with a planning tool to serve as a guide for improvements to the wastewater infrastructure through 2050.

1.1 SCOPE OF WORK

The Town of Cary (Town) retained Freese and Nichols, Inc. (FNI) to develop the *Walnut Creek Pump Station Basin Study* (Project). The goal of the Project was to evaluate and analyze the Town of Cary's Walnut Creek Pump Station Basin wastewater collection system to measure existing (2020) performance, identify system deficiencies, and determine improvements needed to meet future conditions. Based on the system evaluations, a trigger-based Capital Improvements Plan (CIP) was developed to address system deficiencies through 2050 projected flows. The recommended improvements serve as the basis for the design, construction, and financing of infrastructure required to meet the Town's future system needs in the Walnut Creek Pump Station Basin.

The major elements of the scope of this project included:

- Wastewater Flow Monitoring Data Analysis
- Population and Wastewater Flow Projections
- Design Storm Analysis and Selection
- Wastewater System Model Development and Calibration
- Wastewater System Capacity Analyses
- Capital Improvements Plan (CIP) and Report

1.2 ABBREVIATIONS

Table 1-1: List of Abbreviations

Abbreviation	Full Nomenclature
ASCE	American Society of Civil Engineers
CIP	Capital Improvement Plan
CAMPO	Capital Area Metropolitan Planning Organization
d/D	Depth of Flow to Diameter Ratio
EPA	Environmental Protection Agency
FNI	Freese and Nichols, Inc.
gal/LF	Gallons per Linear Foot
GARR	Gauge Adjusted Radar Rainfall
GIS	Geographic Information System
gpm	Gallons per Minute
gpcd	Gallons per Capita per Day
gpd	Gallons per Day
HGL	Hydraulic Grade Line
IDF	Intensity-Duration-Frequency
I/I	Inflow and Infiltration
LF	Linear Feet
LS	Lift Station
MG	Million Gallons
MGD	Million Gallons per Day
mi	Miles
NCDEQ	North Carolina Department of Environmental Quality
NOAA	National Oceanic and Atmospheric Administration
RDII	Rainfall Derived Inflow and Infiltration
SCS	Soil Conservation Service
SSOAP	Sanitary Sewer Overflow Analysis Planning
WEF	Water Environment Federation

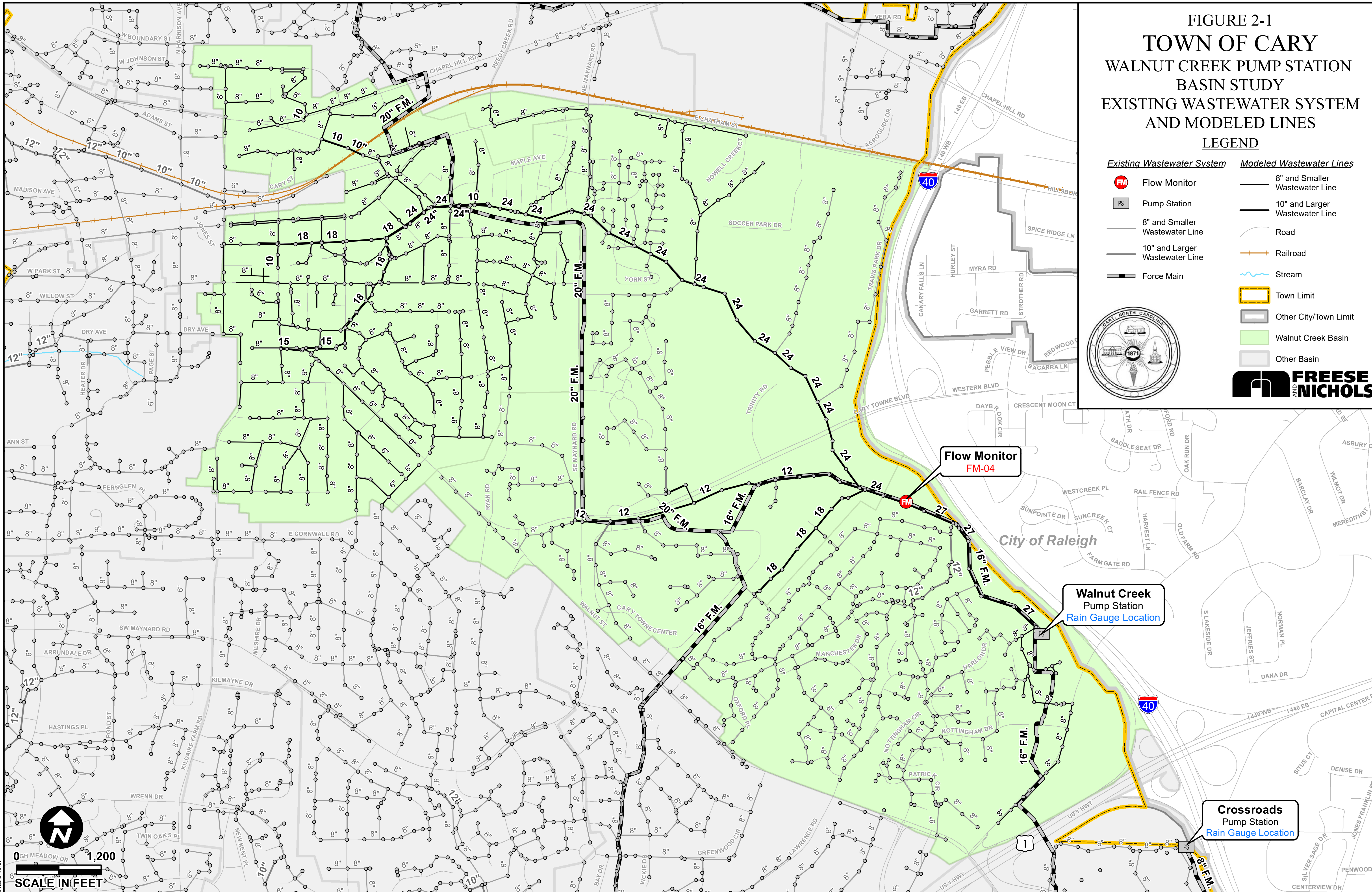
2.0 EXISTING WASTEWATER COLLECTION SYSTEM

The Walnut Creek Pump Station Basin (Basin) wastewater service area encompasses approximately 1,600 acres. The Basin wastewater collection system network consists of roughly 1,147 manholes and 216,000 linear feet of gravity sewer main ranging in size from 6-inches to 30-inches. **Table 2-1** provides a breakdown of the Basin-wide linear footage of gravity sewer main by diameter.

Table 2-1: Collection System Length by Diameter

Diameter (inches)	Length of Main (LF)	Length of Main (miles)	Percent of Total System
6	6,098	1.15	2.8 %
8	181,374	34.35	84.0 %
10	2,654	0.50	1.2 %
12	6,726	1.27	3.1 %
15	958	0.18	0.4 %
18	5,908	1.12	2.7 %
24	9,202	1.74	4.3 %
27	2,788	0.53	1.3 %
30	98	0.02	0.1 %
Unknown	76	0.01	< 0.1 %
Total	**215,905**	**40.89**	**100.0 %**

The wastewater collection system is primarily a gravity flow system that follows the major drainage features of the service area to the Walnut Creek Pump Station (PS) which serves the Basin with a design capacity of 3.93 MGD for one pump and a design capacity of 5.80 MGD for two pumps. The pump station was recently a part of another study, *Pump Station Assessments and Recommendations* by FNI, that included extensive testing and condition assessment. The testing on the Walnut Creek PS was performed by Kimley Horn. Initial testing was performed on July 16, 2019, and a second test evaluation was conducted on January 30, 2020. **Figure 2-1** shows a map of the existing wastewater collection system which uses symbology to differentiate the portion of the Basin included in the hydraulic model.



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Updated: Wednesday, March 10, 2021 3:28:41 PM
User Name: 03797

3.0 WASTEWATER FLOW MONITORING

The Town has a contract with Frazier Engineering to install, maintain and provide monthly data analysis for 33 permanent flow monitoring and 7 permanent rain gauge locations systemwide. There is a permanent flow monitoring location (FM-04) on the 24-inch gravity sewer main leading to the Walnut Creek PS. FNI utilized historical data from this monitor for model development and calibration.

3.1 DRY WEATHER PERFORMANCE

Dry weather flow conditions are characterized by evaluating flow monitor data observed during normal conditions, excluding wet weather events and the periods associated with the recovery from wet weather events. The average daily dry weather pattern is identified as a diurnal curve and results from the collective daily flows of residential, commercial, institutional, and industrial users. Land use within a particular area affects the shape of the diurnal pattern. Typical residential usage is characterized by peaks during the early morning and evening with valleys during the workday and night. Typical weekend patterns tend to have later morning peaks with limited mid-day valleys. A diurnal pattern was generated by reviewing all individual dry weather days, removing any days with unusual behavior, and exporting the average flow pattern of the remaining days. The dry weather period from May 4 through May 9, 2018, was utilized to perform dry weather calibration of the hydraulic model. The maximum flow depth observed at FM-04 during dry weather was 5.47 inches and the corresponding depth-to-diameter ratio (d/D) was 22.8%.

3.2 WET WEATHER PERFORMANCE

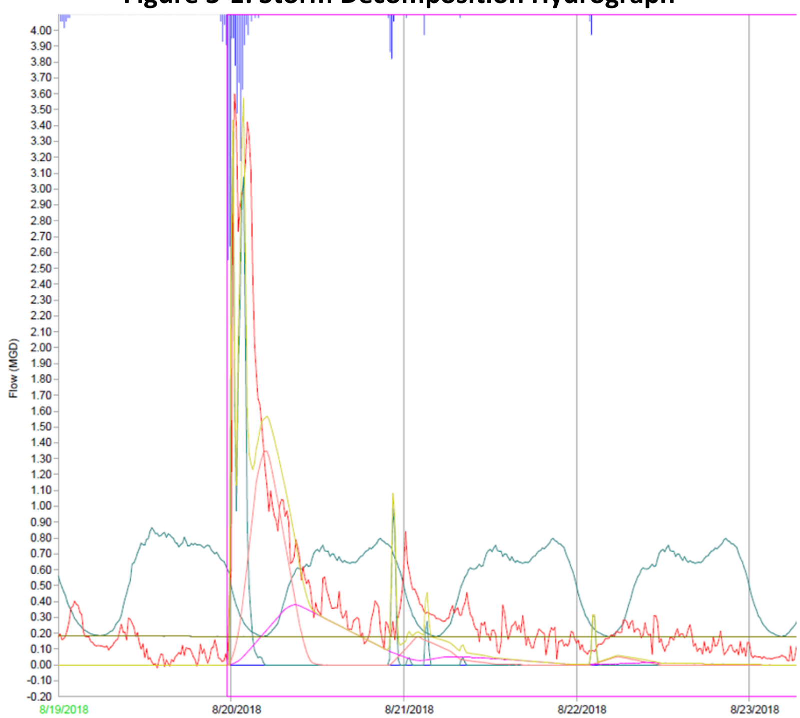
Wet weather flow conditions are characterized by evaluating flow monitor data observed during each storm event that occurred during the study period. A summary of evaluated rainfall events is provided in **Table 3-1**. Rainfall data was recorded by a gauge located at the Walnut Creek Pump Station.

Table 3-1: Rainfall Summary

Date	Duration (hours)	Average Intensity (inches/hour)	Depth (inches)
4/24/2017	34	0.24	8.18
6/16/2017	7	0.42	3.00
8/19/2018	5	0.45	2.30

A comparison of flow monitor data from the dry and wet weather periods is used to analyze the amount of rainfall derived inflow and infiltration (RDII) entering the system, which is calculated by subtracting the recorded flow during an average dry day in the study period from the measured flow during a rainfall event. A wet weather storm decomposition hydrograph is illustrated in **Figure 3-1** and shows the observed flow rate during a storm event (**green**) compared to the average dry day diurnal pattern (**teal**). The difference between the two is the RDII measured by the flow monitor (**red**) resulting from the rainfall (**blue**). The hydrograph compares the wet weather response to the diurnal pattern to determine the impact of the rain event on the collection system. The effects of the rain event are then measured during and following the rain event, and to the point where the flow pattern returns to the typical diurnal pattern, resulting in the calculated RDII for the observed storm event.

Figure 3-1: Storm Decomposition Hydrograph



3.3 FLOW MONITORING DATA

The average dry and peak wet weather flows and observed RDII at FM-04 are summarized in **Table 3-2**. RDII and wet weather to dry weather peaking factors were calculated from each of the three evaluated wet weather events. RDII values, normalized to the basin size, that are greater than six gallons per linear foot (gal/LF) are considered high. Medium RDII response is approximately four to six gal/LF, moderate RDII response ranges from two to four gal/LF, and low RDII values are typically anything less than two gal/LF. Based on the three events analyzed, the Basin response is generally in the medium to high RDII category. The August 18, 2018 event, which was selected for model calibration (as discussed in **Section 5.4**), had an RDII value of 5.79 gal/lf indicating a medium response. It should be noted that the April 23, 2017 event was a multi-day event, and the values shown below are not indicative of typical, single-day storm responses in the Basin.

Table 3-2: Summary of Flow Monitoring

Flow Monitor	Average Daily Dry Weather Flow (MGD)	Maximum Wet Weather Flow (MGD)	Wet Weather to Dry Weather Peaking Factor	RDII (MG)	Basin Size (LF)	Normalized RDII (gal/LF)
4/23/2017	0.70	5.15	7.36	3.65	215,905	16.90
6/16/2017	0.70	3.40	4.86	0.73	215,905	3.38
8/18/2018	0.70	4.12	5.89	1.25	215,905	5.79

A peaking factor is a simple ratio of the wet weather to dry weather flow recorded in the basin and does not account for basin size. Peaking factors are commonly used to estimate maximum flow rates based on average flow rate estimates and play a key role in sewer design. Peaking factors are typically inversely proportional to the population served and generally decrease as average dry weather flow increases. The RDII for the Basin was normalized by the total length of gravity sewer main in the Basin. Normalized RDII by linear footage can help illustrate if a metershed has higher levels of RDII or is simply in a basin that is relatively large or downstream of a basin with large flows.

The wet weather depth over diameter (d/D) ratio is used to assess wastewater pipe capacity during wet weather events. Wastewater collection systems are designed to flow under open channel flow conditions during dry weather and near full pipe capacity during wet weather. Typical recommendations for wet weather d/D ratios are less than 100%, so the pipe does not operate under surcharged conditions. **Table 3-3** shows the observed d/D ratio during the three historical events evaluated. The observed d/D ratios during these storms are less than the 100% recommendation, indicating that at the time of the events there was not a downstream flow restriction or insufficient capacity to accommodate the maximum observed wet weather flows at this location without surcharged conditions.

Table 3-3: Wet Weather Depth-to-Diameter Ratio

Rainfall Event	Main ID	Main Diameter (inches)	Maximum Wet Weather Recorded Depth (inches)	Wet Weather d/D
August 18,2018	SL77306002.1	24	13.4	56%
April 23, 2017	SL77306002.1	24	15.4	64%
June 16, 2017	SL77306002.1	24	12.0	50%

3.4 SUMMARY OF FLOW MONITORING ANALYSIS

The results of this analysis are based on data from the Town of Cary's permanent flow monitor (FM-04), and Gauge Adjusted Radar Rainfall (GARR) data provided by Vieux and Associates, which is discussed in further detail in **Section 5.4**. A detailed analysis of dry weather and wet weather periods was performed and included an evaluation of wet weather to dry weather peaking factors and RDII.

During dry weather conditions, the observed dry weather d/D ratio for the Walnut Creek flow monitor was within design criteria recommended by ASCE and WEF, indicating that there is sufficient capacity to accommodate existing dry weather flows at the monitoring location.

During peak wet weather events, flow monitoring results indicated medium to high RDII within the Basin. The Town has completed structural rehabilitation of critical, large-diameter interceptors in the Basin since the flow monitoring analysis period for this study. FNI was provided six months of post-rehabilitation flow monitoring data and it was determined to be an insufficient sample size, with not enough wet weather data to make a determination of whether I/I has decreased as a result of the structural rehab efforts. It was concluded from the six months of post rehab data that the system characteristics did not change significantly, and the initial hydraulic model calibration is appropriate to move forward with the Basin study.

The initial flow monitoring data indicates that across the three wet weather events analyzed, peaking factors ranged from 4.9 to 7.4. Flow increases at the flow monitor location occur quickly during wet weather events and gradually return to normal when the rain event ends. This behavior suggests traditional I/I sources.

4.0 POPULATION AND FLOW PROJECTIONS

Residential population projections for the buildout (2050) planning period were provided by the Town. Population values for the existing (2020), 2025, 2030, and 2040 planning periods were interpolated linearly from the 2050 values, except in locations where known developments with specific flow estimates and phasing were planned. Town staff provided flow projections for the following development projects: Chatham Walk Condos, Park Station Townes, Downtown Park, One Walker/One Walnut, Fenton, Urban Place, Rogers Building, Meridian East Chatham, Epic Games, Byrum St Flats, EcoLive Multifamily, Maynard Multifamily, and Triangle Apartments. The flow estimates for these developments were manually added to the model based on their anticipated completion dates. Per capita flow factors were derived from the Town's projections and were applied to the residential population projections to determine future base flows in the hydraulic model.

4.1 HISTORICAL WASTEWATER FLOWS

Wastewater flows in a municipal collection system vary by time of day, wastewater discharge source, and weather conditions. Annual average daily flow is defined as the total wastewater flow over a one-year period divided by the number of days in that year. Historical flow monitor data from the Walnut Creek Pump Station Basin is presented in **Table 4-1**.

Table 4-1: Historical Wastewater Flows

Year	Annual Average Day Flow (MGD)	Rainfall (inches)
2015	0.66	50.57
2016	0.65	45.66
2017	0.60	39.22
2018	0.63	49.63
2019	0.67	44.20
2020	0.66	64.43
Average	**0.67**	**48.95**

4.2 WASTEWATER FLOW PER CAPITA DEVELOPMENT

The dry weather flow data from the wastewater flow monitoring period was used to determine per capita flow rates and a typical diurnal pattern for the flow monitoring basin. FNI selected the period from May 4 to May 9, 2018, which had no observed rainfall for five days prior, to determine the diurnal pattern of the FM-04 basin. This period was selected to minimize potential influences from RDII. The existing residential and non-residential wastewater flows, scaled from geocoded winter water meter billing data, were utilized to develop current residential per capita and non-residential flow rates for the basin.

The existing per capita flow rates were held constant for the existing population in the future planning periods. FNI examined representative water meter data, as well as flow projections provided by the Town to estimate a residential per capita flow factor of 35 gallons per capita per day (gpcd), that was applied to all future population growth.

4.3 WASTEWATER FLOW PROJECTIONS

Future wastewater flow projections are based on the population and non-residential projections for the existing (2020), 2025, 2030, 2040, and 2050 planning periods. Future non-residential growth is captured by parcel-level flow projections provided by the Town, while future residential growth is captured by parcel-level population projections also provided by the Town. The population and flow projections are based on the Town's projections developed to support the Capital Area Metropolitan Planning Organization (CAMPO) 2050 Metropolitan Transportation Plan. The 35 gpcd per capita flow factor derived from calibration was applied to the population value for each parcel and combined with Town provided non-residential growth projections to calculate total future flow projections. **Table 4-2** summarizes average dry weather flows within the Basin for each planning period. FNI created mapping, included in **Appendix B**, to illustrate the distribution of growth throughout the Basin.

Table 4-2: Average Dry Weather Flow by Planning Year (MGD)

2020	2025	2030	2040	2050
0.82	1.76	2.24	2.91	3.32

5.0 MODEL DEVELOPMENT AND CALIBRATION

The hydraulic model for the Walnut Creek Pump Station Basin Study was developed using the Infoworks ICM® hydraulic modeling software by Innovyze. The model will be exported and provided to the Town in Innovyze InfoSWMM hydraulic modeling software. All gravity sewer mains in the basin were included in the model; however, only mains with survey information were utilized as active components of the hydraulic model. FNI built and calibrated the hydraulic wastewater model to serve as a basis for all future modeling scenarios and CIP development.

5.1 MODEL DEVELOPMENT

The hydraulic model consists of approximately 594 gravity sewer main segments, 593 manholes, 2,192 catchments, and one pump station. For the purposes of this study, the pump station was modeled as a free outfall. FNI reviewed the modeled wastewater network for proper connectivity.

The Town of Cary provided field survey data of gravity sewer mains and manholes in areas where future growth is anticipated. The survey data provided determined which mains and manholes were included as active parts of the hydraulic model. All mains and manholes without survey information were pruned from the active network. The pruned portions of the network can be restored within the model in the future as survey data becomes available.

5.1.1 Catchments

The hydraulic model stores hydrologic runoff information important to wet weather calibration in catchments. FNI generated catchments around all manholes in the system using parcel boundaries. Catchments are connected to the appropriate downstream manhole.

5.2 MODEL LOAD ALLOCATION

FNI allocated wastewater loads to the hydraulic model using factored data from the geocoded water customer billing account information. The billed water consumption for active water meters from January, February, November, and December 2018 was utilized due to low irrigation activity during winter months. Water meters were spatially allocated to the catchments where wastewater loading was applied.

5.3 DRY WEATHER CALIBRATION

The first step in the model calibration process was to select a dry weather period from the flow monitor data to calibrate the base flow in the model. Dry weather calibration is conducted so that the base flow in the hydraulic model closely matches observed dry weather flows. These dry weather flows represent residential, commercial, and groundwater flows during a period without any additional measurable I/I due to rainfall. A four-day period from May 4th through 8th, 2018, was selected to be used for dry weather calibration. The model was then calibrated to the recorded flow during the dry weather week by adjusting the per capita flows and diurnal flow profile for the basin. **Figure 5-1** displays the diurnal pattern generated for the Walnut Creek Pump Station Basin, derived from flow monitoring data. This diurnal pattern was applied to the hydraulic model. The base loading from the water meter billing data was then factored as necessary until the aggregate flows in the basin closely matched the observed flow monitor data.

The dry weather flows for the Walnut Creek Basin were adjusted until the flow at the monitoring location was calibrated to within 5% of the average flow, as per industry standards. On average, the model was calibrated to within 1% of observed system flows during dry weather calibration, with the modeled average flow being 386 gpm and the observed being 382 gpm. **Figure 5-2** shows the graph of model results for dry weather calibration. The results of the dry weather calibration provide a strong level of confidence that the model matches the recorded flows and system operations during dry weather periods.

Figure 5-1: Wastewater Profile Diurnal Pattern

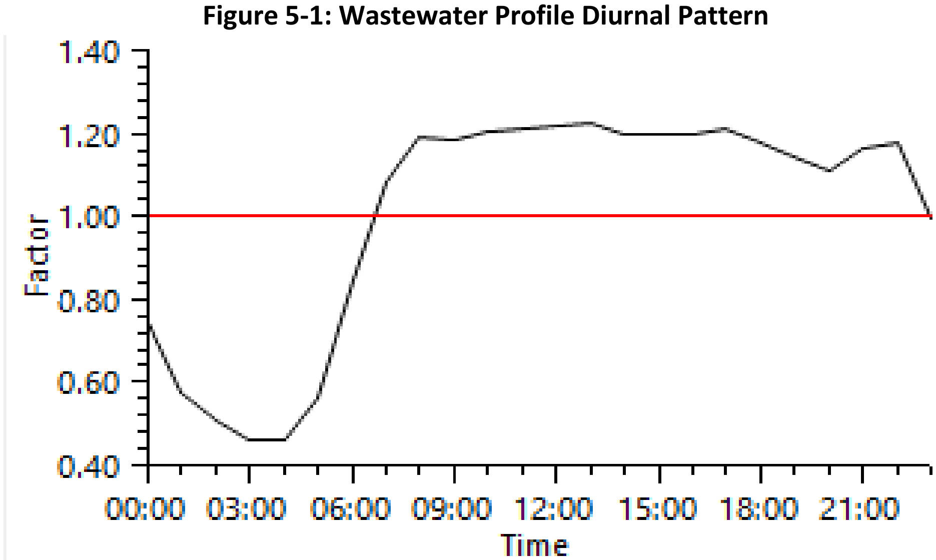
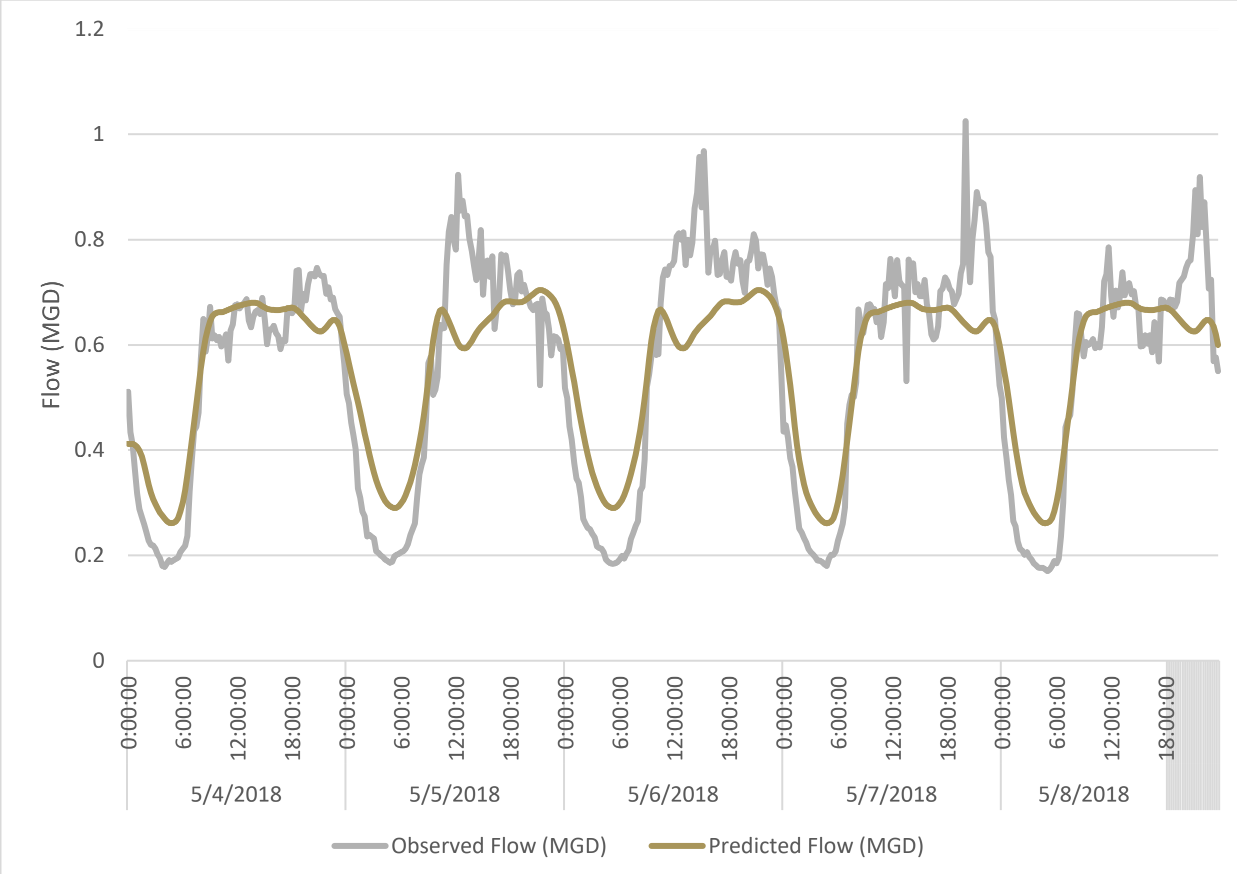


Figure 5-2: Dry Weather Flow Calibration Results



5.4 WET WEATHER CALIBRATION

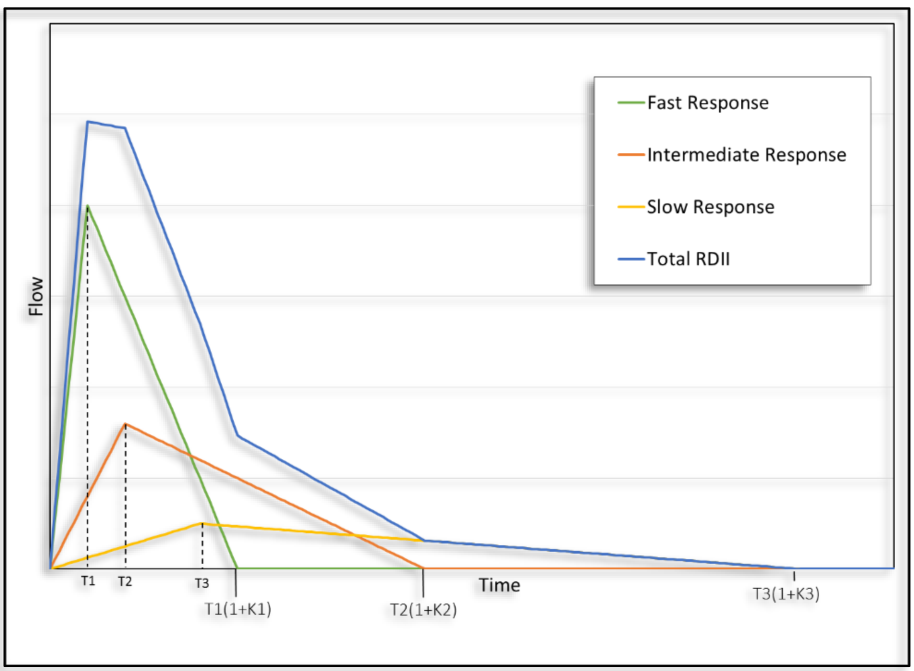
Recorded rainfall and flow monitoring data was examined in order to select rainfall events of varying magnitudes and peak intensities to facilitate wet weather calibration. The hydraulic model was calibrated to the August 18, 2018 rain event, which had a depth of 2.3 inches and a typical rainfall profile with one prominent initial peak. The wet weather calibration simulation extended over multiple days to verify that the model matched the preceding flows, the peak flow, and the return to average flows following the event. Wet weather calibration to specific recorded wet weather events provides confidence that the hydraulic model accurately simulates recorded system responses to wet weather events.

FNI modeled two additional storm events (June 16, 2017 and April 23, 2017), however these storms were not selected for calibration. The April 23, 2017 event was not selected because there was a smaller rain event that occurred eight hours before the main event, which significantly influenced system response. The June 16, 2017 event was not utilized for calibration because it had two distinct peaks in rainfall to which the system did not respond equivalently. Adjusting calibration parameters to fit this behavior would cause the system to respond unrealistically to more common storm events.

For each storm event modeled for wet weather calibration, FNI utilized GARR data provided by Vieux and Associates to load the model with spatially varying rainfall data. In a GARR pixel dataset, rainfall is reported spatially across grids one square kilometer in area, known as "pixels." Each pixel will have a unique ID and will typically have differences in rainfall as compared to neighboring pixels, which aids in understanding the spatial variation of rainfall across an area. The Vieux and Associates reports for each historical wet weather event can be found in **Appendices E-G**.

The RTK hydrograph method was utilized to model the RDII that entered the wastewater system during the observed rainfall event. The RTK method is the method utilized by the Environmental Protection Agency (EPA) in the Sanitary Sewer Overflow Analysis Planning (SSOAP) toolbox. The SSOAP toolbox was developed specifically for the quantification of RDII and assistance with capacity analysis and condition assessment of sanitary sewer systems. This method utilizes three hydrographs that each contain three parameters which are modified to achieve calibration: fraction of rainfall volume entering the system (R), the time to peak flow (T), and the ratio of time of recession to time to peak (K). The combination of the three component hydrographs forms the total response (I/I) that is observed in the wastewater system. An example RTK hydrograph is shown on **Figure 5-3**.

Figure 5-3: RTK Component Hydrographs



R1, T1, and K1 represent the fast response associated with inflow experienced at the beginning of a storm. These values typically have the most effect on the modeled response. R2, T2, and K2 represent the medium response associated with a combination of inflow and some infiltration experienced toward the end of a storm. These values typically reflect the way that the system reacts as a storm begins to come to an end and the inflow begins to slow while groundwater begins to seep through cracks in the pipe. R3, T3, and K3 represent the slow response associated with infiltration experienced after a storm event has passed. These values reflect the way that the system reacts after a storm has come to an end and water infiltrates into the system through cracks in the gravity sewer mains rather than direct or indirect inflow. A high R1 value indicates the RDII is primarily inflow driven, while higher R2 and R3 values indicate the RDII is primarily driven by infiltration.

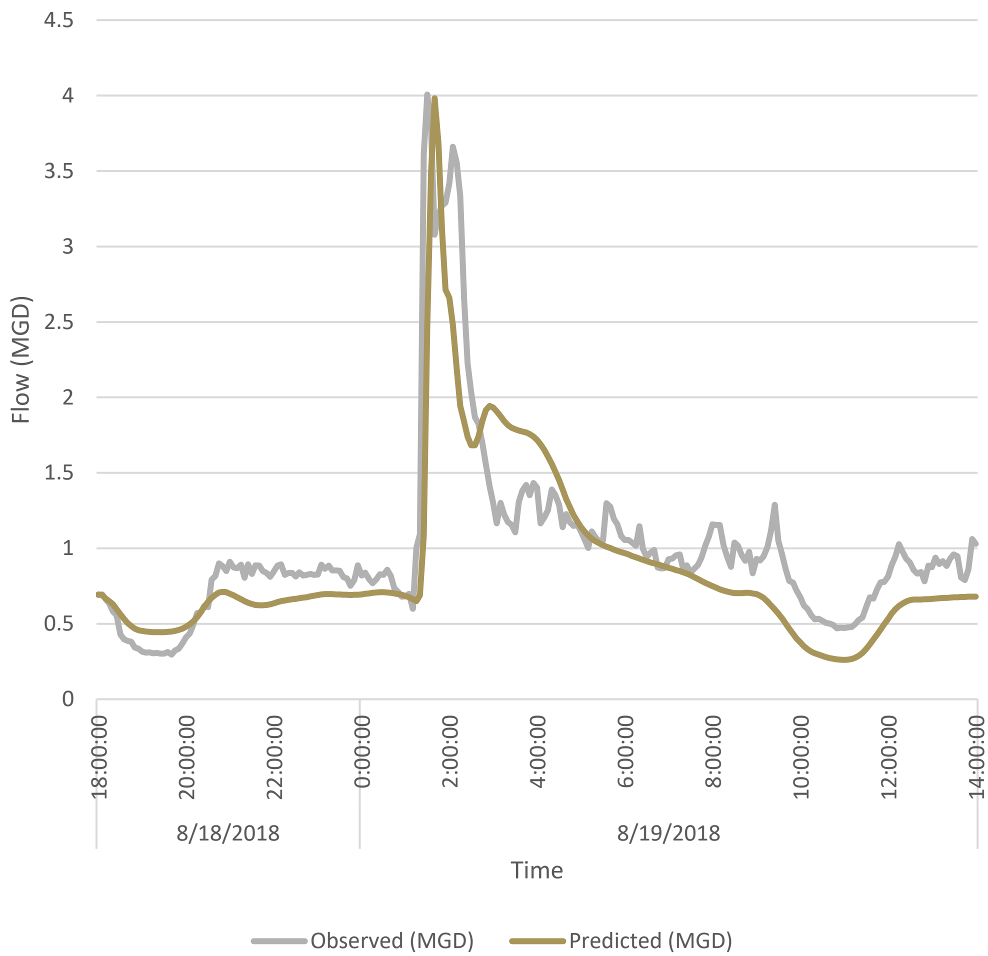
The RTK hydrograph developed for the Walnut Creek flow monitor basin was applied to all catchments, and the GARR data provided by Vieux and Associates for the calibration event was applied to the model. The model calculates the I/I that enters the wastewater system using the values in the RTK hydrographs and the contributing area of each catchment. These RTK values were adjusted until the modeled wet weather flows closely matched the observed wet weather flows. **Table 5-1** provides a summary of the wet weather calibration, and **Figure 5-4** shows the graphical result of wet weather calibration for the August 18, 2018 event. The model was calibrated to less than 1.0% of peak flow and 2.5% of total volume for the calibration event, well within the industry standard 10.0 percent.

Table 5-1: Wet Weather Calibration Summary

	Modeled	Recorded	Percent Difference
Peak Flow (MGD)	3.98	4.01	0.75%
Total Volume (MG)	1.117	1.144	2.42%

FNI calibrated the model to closely match the observed dry and wet weather flows based on the flow monitoring data recorded within the Basin. The dry and wet weather calibration results provide a high level of confidence that the model closely matches real world conditions and is suitable to use for hydraulic analyses and CIP development.

Figure 5-4: Wet Weather Calibration Results



6.0 WASTEWATER SYSTEM ANALYSES

Hydraulic analyses were conducted to identify deficiencies in the Town's existing wastewater collection system and establish a CIP to address existing system deficiencies and accommodate the projected wastewater flows through 2050. A 5-year, 24-hour center-weighted storm was utilized as an *assessment storm* for the existing and future system analyses. A 5-year, 12-hour Soil Conservation Service (SCS) storm was utilized as a *design storm* for capital improvement project sizing. Various combinations of improvements and modifications were investigated to determine the most efficient approach to convey projected flows. Considerations in developing the wastewater CIP included increasing system reliability, conveying peak wet weather flows, and reducing system surcharging and model-predicted sanitary sewer overflows (SSOs).

6.1 DESIGN STORM

Understanding and evaluating the collection system's response to wet weather events is a critical component of the wastewater master planning process. I/I can lead to hydraulic bottlenecks in the system and could potentially cause surcharging and sanitary sewer overflows. To evaluate the system as a whole, a common storm event must be selected to be the basis for evaluation moving forward; this is referred to as a design storm. Regulatory agencies, such as the EPA and North Carolina Department of Environmental Quality (NCDEQ), allow regulated entities to select the design storm. A regulated entity must demonstrate that they have selected a design storm that is representative of commonly observed rainfall events while being conservative enough to protect against potential wet weather overflows in the collection system. The selection of the design storm for the purpose of evaluating the hydraulic performance of the wastewater collection system is an important process as it guides the identification of potential CIP projects. To be up to date on trends in the industry with respect to design storms, FNI studied the design storm selections for medium to large sized municipalities in the region. **Table 6-1** shows typical modeled storms for several utilities across North Carolina. Some utilities are using a single storm for assessment and design, others have two different storms, and some are using SCS synthetic storms (as noted in the table), while others are using storm data from the NOAA Atlas 14 source (those not designated as SCS in the table).

Table 6-1: Regional Municipalities Design Storm Comparison

Municipality (last year updated)	Assessment Storm	Design Storm for Sizing	Existing System Selection Criteria	Future System Design Criteria
Town of Cary (2021)	**5-year, 24-hour**	**5-year, 12-hour SCS**	**< 3 feet of manhole**	**2/3 pipe flow**
City of Durham (2020)	5-year, 24-hour SCS	-	< 3 feet of manhole rim	Full-pipe flow
Raleigh Water (2014)	10-year, 24-hour SCS	10-year, 24-hour SCS	d/D >= 1	No surcharge
Greenville Utilities (2009)	1-year storm	2-year, 24-hour SCS	< 1 foot of manhole rim	Diameter based d/D criteria
Charlotte Water (2019)	2-year, 24-hour	10-year, 24-hour	80% d/D at peak flow < 1.5 feet of manhole rim	-
City of Greensboro (2017)	10-year, 24-hour SCS	Multiple	< 2 feet of manhole rim	-

To assist the Town in making an informed decision with respect to design storm selection, FNI contracted with Vieux and Associates to perform a historical analysis of 1,688 events to better understand patterns and distributions of storm events in the Town. Vieux and Associates found that the most common rainfall distribution for the Town is a First Quartile storm, accounting for 41% of all storms in the past 72 years. A First Quartile storm is one in which the maximum accumulation of rainfall occurs within the first quartile of the event. Vieux and Associates summarized the historical data in **Table 6-2**, displaying the rainfall depths associated with various storm event return frequencies for the Town. Vieux and Associates also provided full hyetographs for each storm event listed below, which can be found in **Appendix D**.

Table 6-2: Precipitation frequency depths (inches) for targeted storm durations

Duration	Return Frequency	
	5-year Depth (in)	10-year Depth (in)
6-hour	2.89	3.40
12-hour	3.44	4.07
24-hour	4.17	4.89

6.1.1 Design Storm Sensitivity Analysis

FNI utilized the data provided by Vieux and Associates to develop design storm scenarios in the model to further understand the impacts each storm would have on the Walnut Creek Pump Station Basin. The hyetographs provided by Vieux and Associates show the rainfall distribution for National Oceanic and Atmospheric Administration (NOAA) storm profiles, which are derived from empirical data. FNI utilized these events in the hydraulic model, along with SCS Type II storms, which are synthetic design storms that follow a rainfall distribution based on regional generalizations. SCS design storms are often more conservative than their NOAA counterparts due to their pronounced peaks in rainfall intensity. FNI modeled each of the design storms identified in **Table 6-3**.

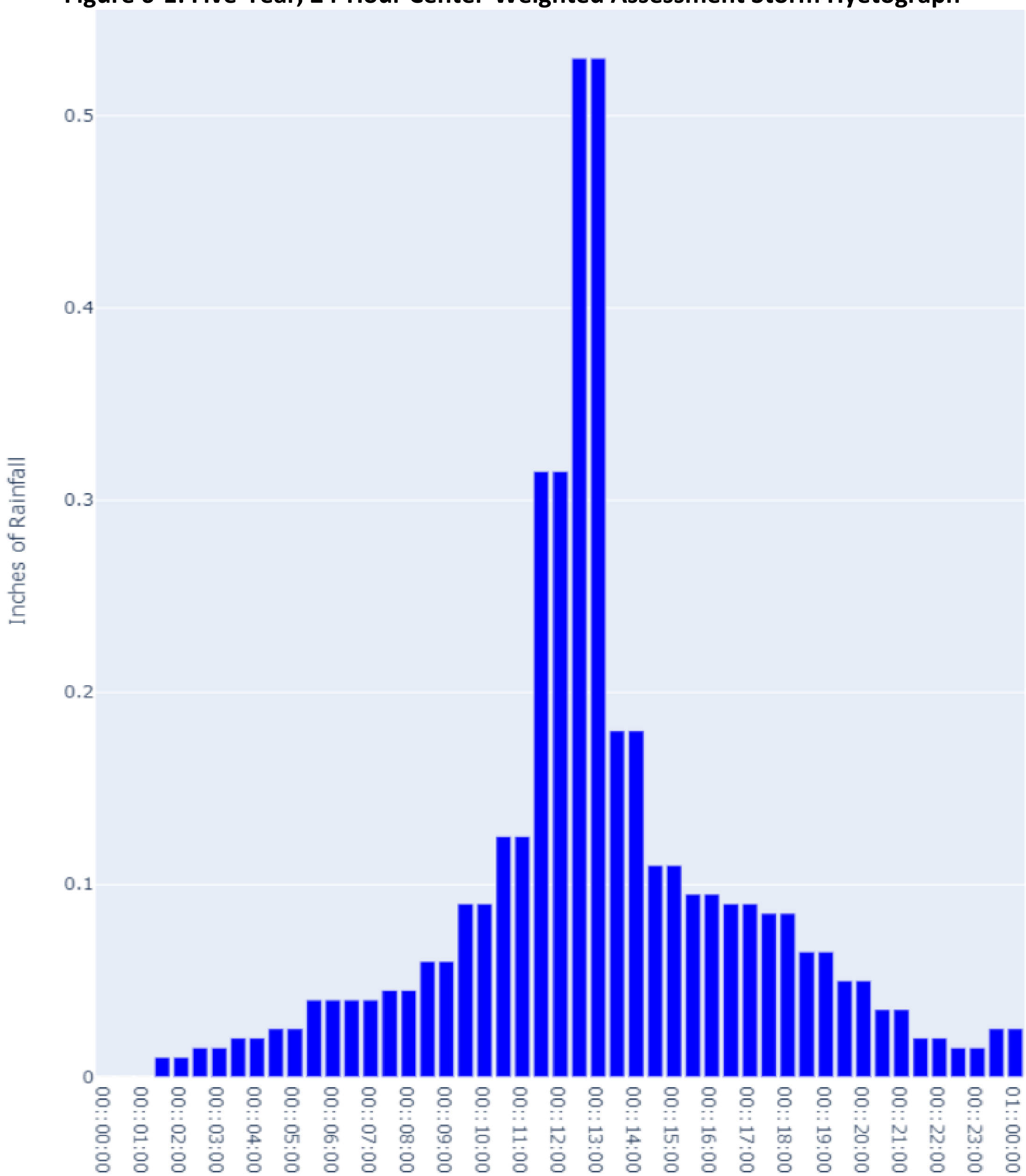
Table 6-3: Design Storms Modeled by FNI

5-year, 12-hour 1st Quartile NOAA
5-year, 12-hour Center-Weighted
5-year, 24-hour Center-Weighted NOAA
10-year, 12-hour 1st Quartile NOAA
10-year, 24-hour 1st Quartile NOAA
5-year, 12-hour SCS
5-year, 24-hour SCS
10-year, 12-hour SCS
10-year, 24-hour SCS

As a result of this analysis, the Town selected two different storms to serve different purposes: the *assessment storm* would be used to identify deficiencies through existing and future system analyses, and the *design storm* would be used to size capital improvement projects. A 5-year, 24-hour center-weighted storm was utilized as the *assessment storm*. When the level reaches three feet from any manhole rim during the *assessment storm*, that manhole and its surrounding infrastructure are flagged for consideration for a CIP project. A 5-year, 12-hour Soil Conservation Service (SCS) storm was utilized as the *design storm*. If the *assessment storm* indicated an area should be considered for a CIP project, the *design storm* was used to size new infrastructure based on the future system flows and gravity sewer mains flowing at two-thirds full under peak flow condition.

Based on a collaborative effort between FNI and the Town, an *assessment storm* with a total depth based on NOAA Atlas 14 Point Precipitation Frequency estimates was selected. The NOAA Atlas 14 Point Precipitation Frequency provides location specific intensity-duration-frequency (IDF) rainfall data for general hydrologic engineering use. Based on the precipitation frequency estimates contained in Volume 2 of the NOAA Atlas 14, the 5-year 24-hour storm for the Town is a 4.17-inch rainfall event. The 5-year, 24-hour center-weighted storm hyetograph shown in **Figure 6-1** was applied to the wastewater model as the *assessment storm*.

Figure 6-1: Five-Year, 24-Hour Center-Weighted Assessment Storm Hyetograph



6.2 EXISTING SYSTEM ANALYSIS

The existing collection system was evaluated to assess the ability of the system to adequately convey wastewater without excessive surcharge or model-predicted overflows. This analysis was performed to identify existing system deficiencies and to provide a baseline for the current level of service.

The critical flow condition for analyzing a wastewater collection system is peak wet weather. Flow, depth, and velocity are important factors when analyzing the peak wet weather simulations. When the *assessment storm* is applied to the calibrated model, the effects of rainfall derived I/I entering the system can be seen. As the storm intensifies (shown through time on **Figure 6-1**), additional flow enters the system as I/I. The model determines the point in time at which the amount of wastewater flow during a wet weather event reaches the peak within the system. This peak represents the most taxing load the system experiences during the event. The peak model-predicted condition during the *assessment storm* event is utilized to identify existing capacity constraints within the collection system. For the purposes of this analysis, the Walnut Creek Pump Station was modeled as a free outfall in order to more accurately assess the capacity of the upstream gravity collection system.

Wastewater Model Results

Figure 6-2 displays a color-coded map that illustrates the model-predicted gravity sewer main capacities and hydraulic grade lines (HGL) of modeled mains and manholes under the peak conditions of a 5-year, 24-hour, center-weighted *assessment storm* (4.17 inches of rainfall) for Cary. Locations where the model-predicted maximum HGL (water level) rises to within 3 feet of the manhole rim are shown as **yellow** circles on the map. The locations of model-predicted sanitary sewer overflows resulting from the modeled 5-year, 24-hour *assessment storm* are shown as **red** circles on the map. **Orange** and **red** lines represent mains that are surcharging and experiencing flow in excess of their capacity, respectively. **Green** lines represent mains that are between 75% and 100% capacity. Some of these locations are due to flat or nearly-flat slopes, as indicated by the field survey conducted by the Town. There is model-predicted surcharge within three feet of the manhole rim or model-predicted overflows in the gravity mains along Chapel Hill Road north of East Durham Road. These predicted results are influenced by the shallow depths of the manholes in the area, as well as backwater conditions created by downstream restrictions.

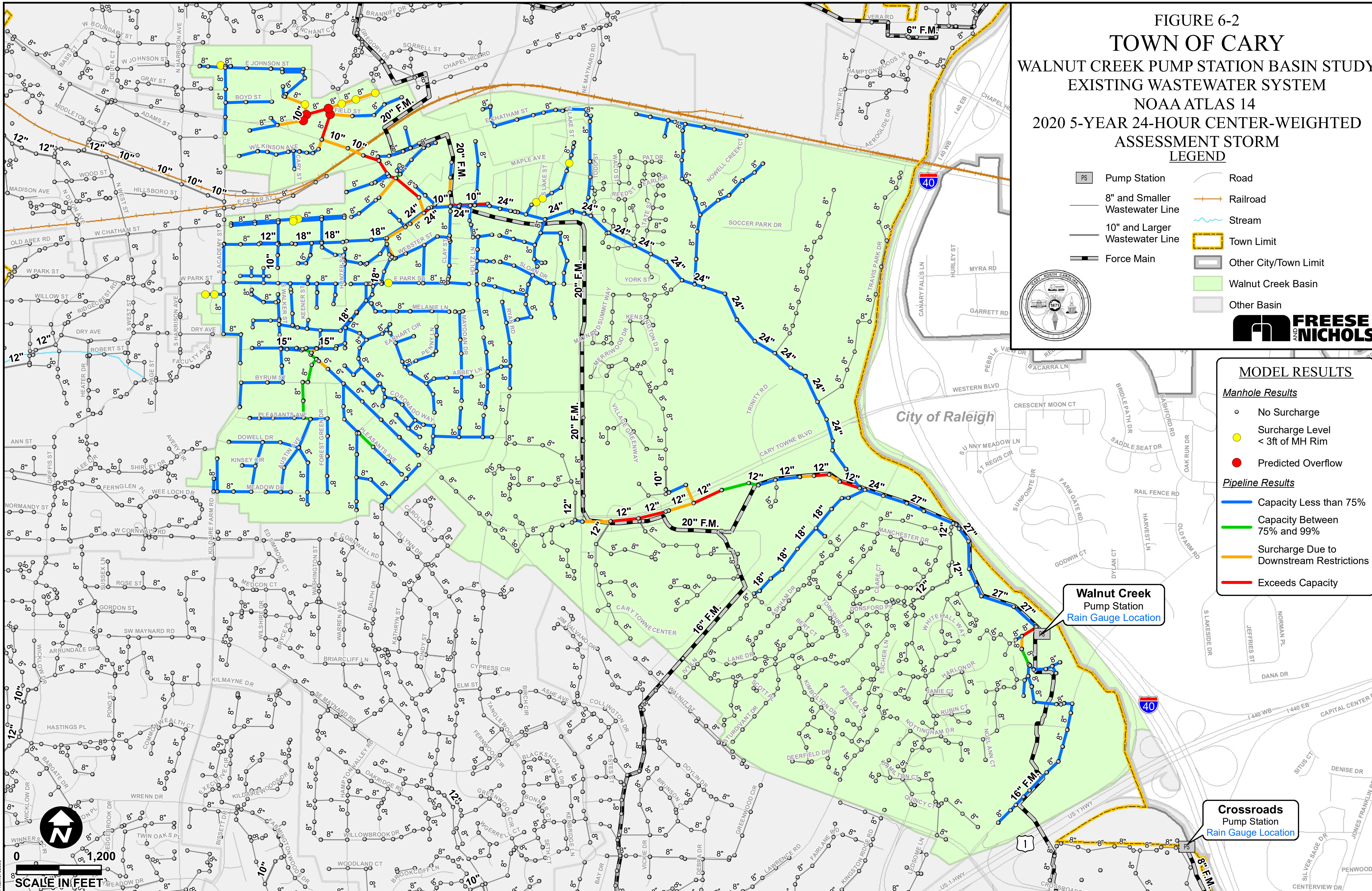


FIGURE 6-2
TOWN OF CARY
WALNUT CREEK PUMP STATION BASIN STUDY
EXISTING WASTEWATER SYSTEM
NOAA ATLAS 14
2020 5-YEAR 24-HOUR CENTER-WEIGHTED
ASSESSMENT STORM
LEGEND
Pump Station
8" and Smaller Wastewater Line
10" and Larger Wastewater Line
Force Main
Road
Railroad
Stream
Town Limit
Other City/Town Limit
Walnut Creek Basin
Other Basin
FREESE AND NICHOLS
MODEL RESULTS
Manhole Results
No Surcharge
Surcharge Level < 3ft of MH Rim
Predicted Overflow
Pipeline Results
Capacity Less than 75%
Capacity Between 75% and 99%
Surcharge Due to Downstream Restrictions
Exceeds Capacity
Walnut Creek
Pump Station
Rain Gauge Location
Crossroads
Pump Station
Rain Gauge Location
City of Raleigh
0
1,200
SCALE IN FEET

6.3 FUTURE SYSTEM ANALYSIS

Once the existing system hydraulic analysis was complete, FNI conducted hydraulic analyses to evaluate the existing collection system's performance while conveying the Town's projected wastewater flows through 2050. FNI distributed the projected wastewater flows into the hydraulic model for the 2025, 2030, 2040, and 2050 planning periods as separate model scenarios. As the Walnut Creek Pump Station Basin is primarily experiencing growth via redevelopment, future wastewater catchments were generated from existing parcels and were only changed where known development plans exist. These new catchments were assigned loads based on the flows proposed in each developments' respective plans. The existing wastewater infrastructure with existing and future catchments was assessed under the peak conditions of a 5-year, 24-hour, center-weighted *assessment storm*.

Future Wastewater System Analyses

Figure 6-3 displays a color-coded map that illustrates the model-predicted gravity sewer main capacities and HGL of modeled mains and manholes under 2050 loading conditions and the peak conditions of a 5-year, 24-hour, center-weighted *assessment storm* (4.17 inches of rainfall) for the Town. In addition to the location listed in **Section 6.2**, there is also model-predicted surcharge within three feet of the manhole rim or model-predicted overflows in the gravity mains in the following areas:

- Gravity sewer mains along Cary Towne Boulevard
- Gravity sewer mains along West Circle Drive near Urban Park
- Gravity sewer mains along Waldo Street between Hunter Street and Urban Drive

Where model-predicted surcharges are caused by capacity issues, the gravity mains are targeted for CIP consideration. CIP improvements will be proposed and sized based on the model results of the 2050 future system analysis. Where model-predicted surcharges are caused by factors such as shallow manholes, as opposed to capacity issues, the gravity mains are not targeted for CIP consideration.

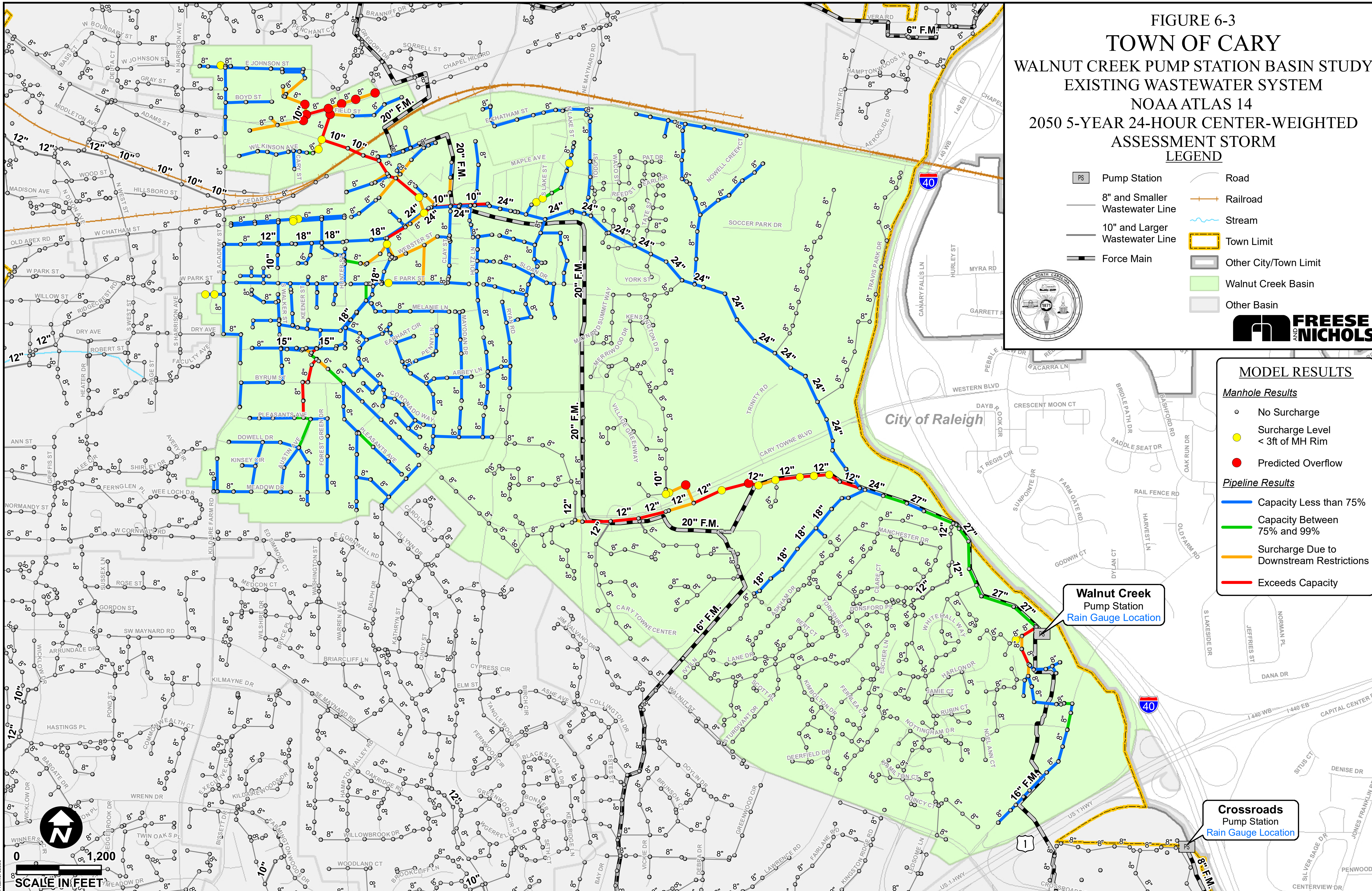


FIGURE 6-3
TOWN OF CARY
WALNUT CREEK PUMP STATION BASIN STUDY
EXISTING WASTEWATER SYSTEM
NOAA ATLAS 14
2050 5-YEAR 24-HOUR CENTER-WEIGHTED
ASSESSMENT STORM
LEGEND
Pump Station
8" and Smaller Wastewater Line
10" and Larger Wastewater Line
Force Main
Road
Railroad
Stream
Town Limit
Other City/Town Limit
Walnut Creek Basin
Other Basin
FREESE AND NICHOLS
MODEL RESULTS
Manhole Results
No Surcharge
Surcharge Level < 3ft of MH Rim
Predicted Overflow
Pipeline Results
Capacity Less than 75%
Capacity Between 75% and 99%
Surcharge Due to Downstream Restrictions
Exceeds Capacity
Walnut Creek
Pump Station
Rain Gauge Location
Crossroads
Pump Station
Rain Gauge Location
City of Raleigh
20" F.M.
16" F.M.
0
1,200
SCALE IN FEET

7.0 CAPITAL IMPROVEMENTS PLAN

A wastewater system capital improvements plan was developed for the Walnut Creek Pump Station Basin service area and is shown on **Figure 7-1**. The recommended projects improve the system's ability to convey wastewater flows and provide the required conveyance capacity to serve the projected residential and commercial growth through 2050. All projects address existing capacity deficiencies and are sized to convey the projected 2050 peak wastewater flows (including I/I). Locations shown for new mains and other recommended improvements were generalized for hydraulic analyses. Specific alignments and site selection should be determined as part of the design process.

A recommended in-service planning year is not provided for the projects; instead, a project trigger is provided. When a specific criterion is met at a given location, the design of the CIP project is triggered. Consistent with the recommendations of other studies (*Crabtree Creek Interceptor Hydraulic Model Analysis* by CDMSmith) within the wastewater collection system, the Town of Cary chose to set their CIP trigger criteria to activate when flows in the system reach three feet from the rim of a manhole at a given location.

Capital costs were calculated for all recommended improvements and do not include individual service connections or subdivision lines. The costs are provided as estimates based on previous similar engineering experience in 2021 dollars and include allowances for engineering, surveying, mobilization, and contingencies. Costs do not include easements or land acquisition. A summary of the wastewater CIP costs is provided in **Table 7-1**. Detailed cost estimates and project drivers are included in **Appendix A**. While not included as an explicit item in the CIP, it should be noted that under the *assessment storm* and buildout conditions, the total predicted peak flow to the Walnut Creek Pump Station is approximately 8.5 MGD, which exceeds the current design capacity.

Table 7-1: Wastewater Capacity CIP Summary

Project ID	Project Name	Cost
A	15-inch Durham Road Gravity Mains	$ 1,545,600
B	15-inch Urban Park Gravity Mains	$ 856,500
C	18/21/27-inch Cary Towne Boulevard Gravity Mains	$ 3,945,200
	CIP Total	**$ 6,347,300**

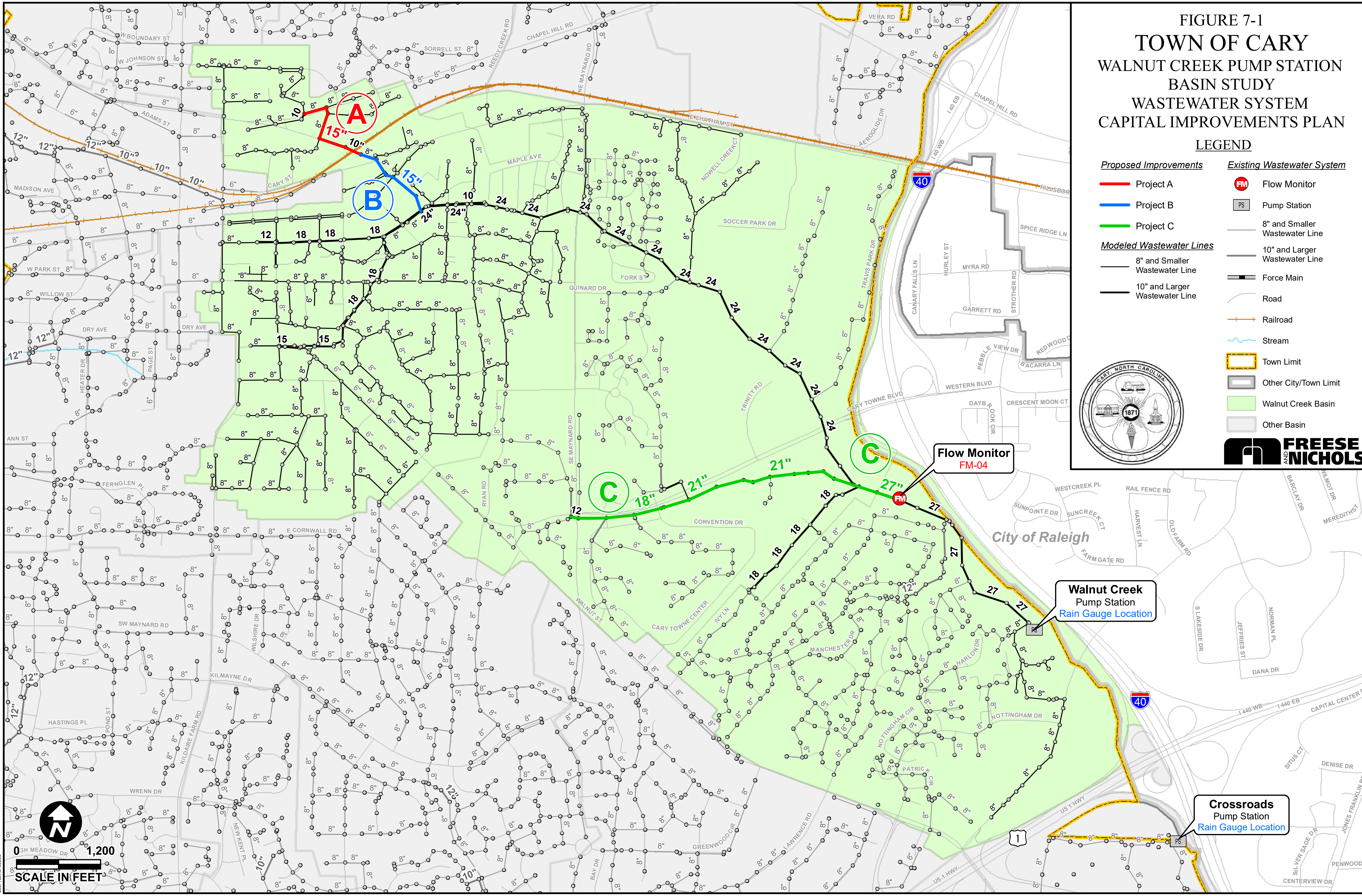


FIGURE 7-1
TOWN OF CARY
WALNUT CREEK PUMP STATION
BASIN STUDY
WASTEWATER SYSTEM
CAPITAL IMPROVEMENTS PLAN
LEGEND
Proposed Improvements
Project A
Project B
Project C
Modeled Wastewater Lines
8" and Smaller Wastewater Line
10" and Larger Wastewater Line
Existing Wastewater System
Flow Monitor
Pump Station
8" and Smaller Wastewater Line
10" and Larger Wastewater Line
Force Main
Road
Railroad
Stream
Town Limit
Other City/Town Limit
Walnut Creek Basin
Other Basin
FREESE AND NICHOLS
Flow Monitor
FM-04
Walnut Creek
Pump Station
Rain Gauge Location
Crossroads
Pump Station
Rain Gauge Location
City of Raleigh
0
1,200
SCALE IN FEET

7.1 DESIGN CRITERIA

The Town provided the following design criteria to identify gravity mains in need of improvement and sizing of proposed projects. Gravity sewer mains were determined to require improvement if the hydraulic grade line of the main exceeded a depth of three feet from the manhole rim under the predicted peak wet weather flow based on the *assessment storm*. Proposed projects to address areas in need of improvement were designed such that new gravity mains were no more than two-thirds full during 2050 peak wet weather conditions based on the *design storm*. Proposed gravity main projects were also designed to correct adverse slopes, if present in the existing gravity main being replaced. For proposed gravity main projects, the slopes utilized to size the mains are included in the hydraulic model.

7.2 CIP PROJECTS

Although the CIP for the Walnut Creek Pump Station Basin is trigger-based, planning year scenarios were modeled to predict the planning year in which portions of the system began to reach unacceptable performance levels. The CIP projects identified for the Basin are shown below with the planning year in which they were identified and a brief description of factors influencing their performance issues. The projects also include a trigger description to assist the Town to make a well-informed decision on timing for design of each CIP project. The triggers provided include manhole flow depth triggers at critical nodes in the system and an associated flow trigger. The Town may opt to utilize manhole level sensors or flow monitoring data to inform the CIP design triggers.

CIP trigger locations should be monitored and the depth and flow information under various wet weather events should be considered based on the event's total depth, duration and frequency compared with the Town's assessment and design storms. When the triggers are reached multiple times under comparable events to the assessment and design storms, then the Town should consider implementation of the CIP project for that area.

Project A: 15-inch Durham Road Gravity Mains

This project includes the construction of new 15-inch gravity mains to replace existing 8 and 10-inch gravity mains along Bowden Street, Chapel Hill Road, and East Durham Road from Bowden Street to the southeastern edge of the railroad rights-of-way (ROW). This project will require coordination with the railroad and an encroachment agreement for the portion of the alignment which passes underneath the railroad bridge. This project was identified in the existing (2020) planning scenario, as there is currently model-predicted surcharge within three feet of the manhole rim or model-predicted overflows in the gravity mains under the *assessment storm*. A significant portion of the existing capacity constraints identified are caused by downstream restrictions in the vicinity of Project B. Project B should be completed first; however, future growth in the vicinity of Project A will ultimately trigger this CIP project.

Project Trigger: *Flow depth of 14.4 inches at MH SP76415090*

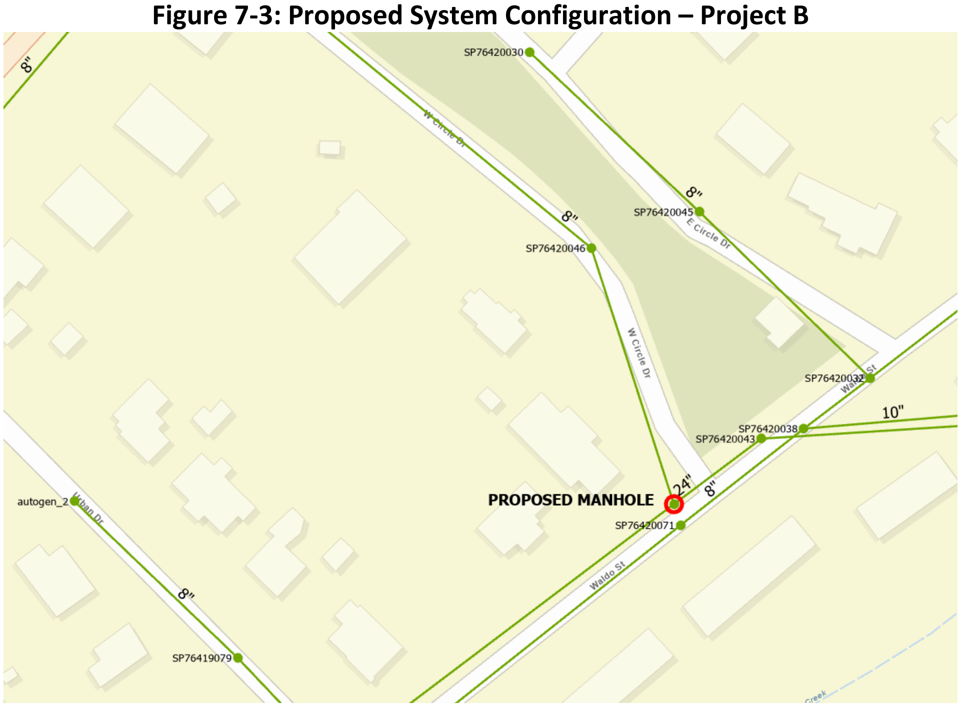
Project B: 15-inch Urban Park Gravity Mains

This project includes the construction of new 15-inch gravity mains to replace existing 8 and 10-inch gravity mains along West Circle Drive, Ward Street, and East Durham Road from Waldo Street to the southeastern edge of the railroad rights-of-way (ROW). This project was identified in the 2050 planning scenario. However, model-predicted capacity constraints in this area contribute to the model-predicted surcharge conditions in the vicinity of Project A. Therefore, this project should be prioritized before Project A. By upsizing these mains and correcting slope inefficiencies, the surcharge conditions near Project A will be reduced. As a part of this project, gravity sewer main **SL76420064** should be disconnected from the 8-inch main (**SL76420019**) and re-directed to the parallel 24-inch main (**SL76420112**) via a new doghouse manhole. This redirection creates capacity in the 8-inch main on Waldo Street and eliminates the model-predicted surcharge at manhole **SP76419008** (located 324 Waldo Street) which was identified in planning year 2040. The reconnection to the 24-inch main can be seen **Figure 7-2** and **Figure 7-3**. **Figure 7-2** shows the existing system configuration, and **Figure 7-3** shows the proposed connection.

Project Trigger: *Flow depth of 14.4 inches at MH SP76415090*

Figure 7-2: Existing System Configuration – Project B

Figure 7-3: Proposed System Configuration – Project B



Project C: Cary Towne Boulevard Gravity Mains

This project includes the construction of new 18 and 21-inch gravity mains to replace existing 12-inch gravity mains along Cary Towne Boulevard from Southeast Maynard Road to Walnut Creek and replacement of a section of the 24-inch Walnut Creek interceptor with 27-inch. This project was identified in the 2030 scenario, when model-predicted surcharge within 3 feet of the rim occurs at several manholes under the *assessment storm*.

The proposed improvements are based on maintaining current pipe slopes and inverts. Details of the other utilities in the area are unknown currently. These may impact changes in pipe slope and should be investigated during preliminary design. The Town may be able to further refine the sizing of the main along Cary Towne Boulevard and potentially eliminate the upsizing of the 24-inch to 27-inch, depending on the realignment that is possible in that corridor.

Project Trigger: *Flow depth of 51.0 inches consistently at MH SP77306011, or peak flow in gravity sewer main SL77306015 consistently greater 1.5 MGD*

Walnut Creek Pump Station Improvements Trigger:

To ensure that the Walnut Creek PS can continue to reliably serve the anticipated growth in this basin, it is recommended that the Town consider planning improvements to the PS when the peak hourly wet-weather flow at the existing Walnut Creek Basin flow monitor (FM-04) consistently reaches 75% of the current PS operational capacity. Based on the hydraulic model, the total flow contribution from the area upstream of the flow monitor is approximately 75% of the total flow in the basin, so based on a design capacity of 5.80 MGD, when the flow at FM-04 reaches 4.35 MGD, the total flow at the PS will be nearing capacity and the Town should consider action.