Sewer System Master Plan

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April 2018

Sewer System Master Plan

Concord
NORTH CAROLINA
High Performance Living

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April 23, 2018 1992.001 (1)

Ms. Christie L. Putnam, P.E.
Water Resources Director
City of Concord
Post Office Box 308
Concord, North Carolina 28026

Subject: Sewer System Master Plan

Dear Ms. Putnam:

Attached for your use is the Report documenting the City of Concord Sewer System Master Plan. This Report includes information regarding the overall Master Plan effort as well as details of the projection of future flows, wastewater modeling, and the Capital Improvement Plan.

We appreciate all of the hard work contributed by the City of Concord staff in making this Master Plan possible and hope you will find it to be a useful tool in your planning efforts. If you have any questions or we can provide any additional assistance, please let us know.

Yours very truly,

WILLIS ENGINEERS

Charles A. Willis Jr.

Charles A. Willis, Jr., P.E., BCEE

Attachment

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City of Concord, North Carolina
Sewer System Master Plan

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City of Concord, North Carolina
Sewer System Master Plan

1 Executive Summary

The City of Concord, North Carolina has undertaken a comprehensive Sewer System Master Plan in order to describe the capabilities of its existing wastewater collection system and plan for future expansion. A large portion of the Concord collection system is in fully developed areas and appears to provide adequate service to those customers. These areas were not evaluated as part of the Master Plan. The evaluation focused on assets where additional customers are anticipated. In these areas the Master Plan included development of a complex computer hydraulic model utilizing the InfoWorks ICM software package to model the capabilities of the existing sewer facilities. The result of this modeling effort revealed several areas within the City where some improvements may be necessary in order to provide adequate service to future customers. In general, however the size and capacity of the existing collection system is adequate to meet the needs of future customers.

The City also evaluated the potential for expansion of the wastewater collection system into areas outside the City's corporate limits as well as providing support to the Town of Midland. A number of potential service areas were identified, and the appropriate future facilities were determined and tabulated in a Capital Improvement Plan.

Development of the Model was supported by a short-term flow monitoring effort utilizing thirteen temporary flow meters installed and managed by the City of Concord. City staff also undertook a significant effort to confirm the location, size and elevation of portions of the wastewater collection system. This data was provided in the form of a Geographical Information System (GIS).

The City's wastewater collection system facilities operate in conjunction with the Water and Sewer Authority of Cabarrus County who provides the major wastewater transmission and treatment facilities necessary to serve the City's customers. The WSACC facilities were generally found to be adequate to meet the City's needs and the WSACC Master Plan includes the appropriate facilities to provide service for future customers.

A principal component of the Sewer System Master Plan is the development of a Capital Improvement Plan (CIP). The CIP is intended to guide the City in planning and implementation of future improvements. The CIP includes approximately 37 projects totaling approximately $68 million that may be implemented over the next few decades.

In general, it was found that the City of Concord collection system is well maintained and capable of meeting the needs of its current customers. The City is encouraged to continue with periodic updates and maintenance of the Capital Improvement Plan as well as continuing routine flow monitoring efforts and continuous improvement to its GIS system to allow for an accurate depiction of the existing facilities.

2 Introduction

The City of Concord has undertaken a Sewer System Master Plan to guide future investment in its sewer infrastructure. The team of consultants, led by Willis Engineers and supported by LandDesign and Gavel & Dorn Engineering, worked together with City staff to assess the condition and capabilities of the existing sewer system, define any necessary improvements to serve existing customers and define those facilities that may be necessary for continued expansion of the system.

The Master Plan effort, documented herein, is somewhat unique in that the City of Concord provides wastewater collection services for its customers but does not own and operate the major transmission and treatment facilities. The City of Concord and other municipalities within Cabarrus County joined together in the early 1990s to form the Water and Sewer Authority of Cabarrus County (WSACC) who provides those services in support of the member jurisdictions. This Master Plan is therefore limited to the City of Concord collection systems including the service areas it supports for the Town of Midland but does not include detailed evaluation of the WSACC system. The Sewer System Master Plan does however build upon previous efforts undertaken by the project team in support of WSACC through its Master Plan completed in 2013.

In addition to the previous WSACC Master Plan, the City of Concord has undertaken several master planning efforts over the years. Those projects have typically utilized generalized population growth models to predict the necessary facilities to serve citywide growth. Unfortunately, some of the predictions have proven to be overly conservative, resulting in recommendations for facilities which are too large for the service area. The City of Concord therefore wished to undertake a more realistic prediction of future wastewater needs utilizing a far more detailed approach to future customer growth.

The result of that flow projection effort is a detailed prediction of future development within the Concord service area to allow for definition of appropriately sized facilities to serve existing and future customers.

2.1 Master Plan Objectives

A typical sewer system master plan will have multiple objectives. The City of Concord staff worked with the Project Team to identify these objectives and provided significant assistance in gathering the data necessary for the analyses. In particular, the Master Plan objectives included:

1. Identifying any existing collection system deficiencies within the City of Concord service area.
2. Evaluating the potential for future growth within the existing service areas and in new areas outside of the existing service boundaries.

3. Defining the facilities necessary to provide reliable service to both the existing and future customers.
4. Generally confirming adequacy of the WSACC facilities and consistency with the WSACC Master Plan to ensure WSACC will have sufficient capacity to serve City of Concord customers.
5. Creating tools on which the City can continue to build an accurate Asset Registry, Wastewater Conveyance Model and Capital Improvement Plan for future facilities.

The Sewer System Master Plan documented herein accomplished all of these objectives in a format that allows City staff to make continual updates and modify the Master Plan on a routine basis.

2.2 Approach

The approach taken by the Project Team is somewhat unique compared to traditional municipal sewer system master plans. Much of the service area within Concord is heavily developed and the City staff generally confirms that the facilities are adequate for those existing customers. Other areas of the City are partially developed and will likely develop with higher density in the years to come. These areas are already equipped with existing collection system facilities which may or may not have adequate capacity to handle new customers. Still other areas within the study boundary do not currently have municipal sewer facilities but may be candidates for future development.

The Project Team recognized that the City of Concord could better utilize its resources by studying those areas most likely to develop. For example, some areas downtown are candidates for redevelopment with higher residential density and should be carefully evaluated. Conversely, there is little benefit to be gained from analyzing an existing collection system in a fully developed residential area, which is unlikely to receive any additional customers. The Team therefore separated the planning area into small drainage basins (sub-basins) representing the individual service boundaries. These basins are categorized as follows:

Areas Fully Developed – Areas that are equipped with a City of Concord collection system and are not likely to experience any significant increase in flow. These areas have not been modeled as part of the Master Plan.

Modeled Service Areas – Those areas which are partially developed and have City of Concord sewer collection assets. These areas were analyzed using a detailed hydraulic conveyance model to evaluate their capability.

Future Service Areas – Areas outside the existing City of Concord service area which are suitable for development but would require entirely new collection systems.

Based on this separation of service areas, the general approach for conducting the Master Plan was to undertake the following activities:

- Data Collection and Analysis
- Flow Monitoring
- Future Flows Prediction
- Model Development
- Future Facilities Definition

2.2.1 Data Collection and Analysis

During the initial phases of the planning effort, the Project Team and City of Concord collected a tremendous amount of data regarding customer water use and existing facilities. One of the primary components utilized for the hydraulic model is a description of the wastewater collection assets found in the City's Graphical Information System (GIS). During this data collection process, the City found that much of the GIS data was incomplete, primarily with respect to pipeline size and elevation. The City subsequently undertook a significant effort in field surveying and data collection, which resulted in adequate information for development of a model and a significant improvement in the quality of the City's GIS system.

Also utilized extensively during the analysis was data related to customer billing history. The City of Concord provides service to over 40,000 customer connections utilizing an average of over 8 million gallons per day (MGD). Accurate characterization of this water use by customer type and location was critical to conducting the evaluation.

Once the data related to wastewater use was collected, it was corroborated against the flow monitoring data utilized by WSACC in preparing bills for the member jurisdictions. In addition to confirming the accuracy of the data, the WSACC flow monitoring station provides a valuable tool for calibration of the wastewater conveyance model.

2.2.2 Flow Monitoring

Another useful tool in calibrating hydraulic models is the use of temporary flow monitors. The City of Concord owns and operates a number of metering devices that can be placed within the sewer collection system to continuously monitor the flow of wastewater at specific locations. The City worked closely with Gavel & Dorn in identifying appropriate locations for a short-term flow study that would be utilized by Gavel & Dorn in calibrating the wastewater collection model. Unfortunately, during the study period the Concord area experience abnormally dry conditions resulting in a fairly limited analysis of wet weather peak flows. Nonetheless, the data set was valuable in providing sufficient information for model calibration.

2.2.3 Future Flows

Some of the most significant work of the Sewer System Master Plan was the analysis of customer use patterns and predictions of new customer growth. Much of this work was undertaken by LandDesign who had performed a similar evaluation for WSACC as part of its Master Plan several years prior. Critical to the future flow analysis was the implementation of a planning model called Community VIZ. Community VIZ is an advanced planning tool that allows the analyst to predict the likelihood of future development based on a variety of socio-economic and environmental factors. Community VIZ accurately describes the likelihood of new connections based on these parameters and results in a prediction of future flows within each of the service areas. This prediction of future wastewater connections, along with accurate representation of each customer type, results in an accurate flow projection for each of the areas being served by the City of Concord or being considered for future service.

2.2.4 Model Development

The City of Concord specifically requested that the hydraulic analysis of the existing system be undertaken utilizing one of the advanced computerized simulation systems currently on the market. The Project Team selected InfoWorks CIM which is a state of the art analytics package utilized for evaluating capacity and operating conditions within gravity sewer systems. The InfoWorks model was implemented in those areas likely to experience future growth and resulted in an accurate analysis of the existing system's capacity. The Model was developed, and simulations were run for a variety of flow scenarios.

2.2.5 Future Facilities

InfoWorks CIM is also useful when predicting future flows within the services area and evaluating if the existing facilities are capable of providing adequate service. In those areas where existing facilities are not adequate, the Project Team selected appropriate new facilities to supplement or replace the existing system.

Likewise, in future service areas where no current infrastructure exists, the Team identified the future facilities that would be necessary to provide wastewater collection and conveyance to the WSACC interceptor system. These definitions are fairly general in nature and may be modified significantly as future development plans become more detailed.

The combination of these activities led to the development of a Capital Improvement Plan (CIP). The Capital Improvement Plan provides a succinct tabulation and description of future facilities necessary for orderly sewer system improvement and expansion. Implementation of the CIP can be adjusted over time and is generally organized into several categories of projects, including those necessary to correct existing deficiencies and those necessary to provide service for future customers.

2.3 Acknowledgements

The Project Team wishes to acknowledge the efforts by the City of Concord staff in assisting with the Master Plan. In particular, the Water Resources Department and Planning Department provided a tremendous amount of data necessary for the analysis. Thomas A. Bach, P.E. of the Water Resources Department served as coordinator for the City and led the effort of field data collection necessary for the mapping and modeling efforts.

The Project Team would also like to acknowledge the staff of the Water and Sewer Authority of Cabarrus County for their assistance in providing data related to the interceptor sewer system and allowing the City of Concord continued use of the WSACC Master Plan as the City of Concord prepares its own plans.

3 Flow Monitoring Program

As part of the evaluation and modeling effort, the Project Team in coordination with the City of Concord undertook a fairly comprehensive flow monitoring program. The City of Concord installed and maintained thirteen temporary flow meters within their sanitary sewer collection system. The data collected was used as the basis for sanitary sewer collection system model calibration. The flow metering also identified the collector lines and associated sub-basins contributing the highest levels of infiltration and inflow (I/I). Gavel & Dorn Engineering completed the analysis of the collected flow metering data, which is summarized herein.

3.1 Flow Metering

The City of Concord installed thirteen flow meters in strategic locations throughout the sanitary sewer collection system as shown in Figure 1. The flow meter ID corresponds to the GIS manhole ID where the flow meter was installed. The meters were installed just upstream of the connection points to the Water and Sewer Authority of Cabarrus County (WSACC) trunk sewers. Concord also placed four rain gages within the project area.

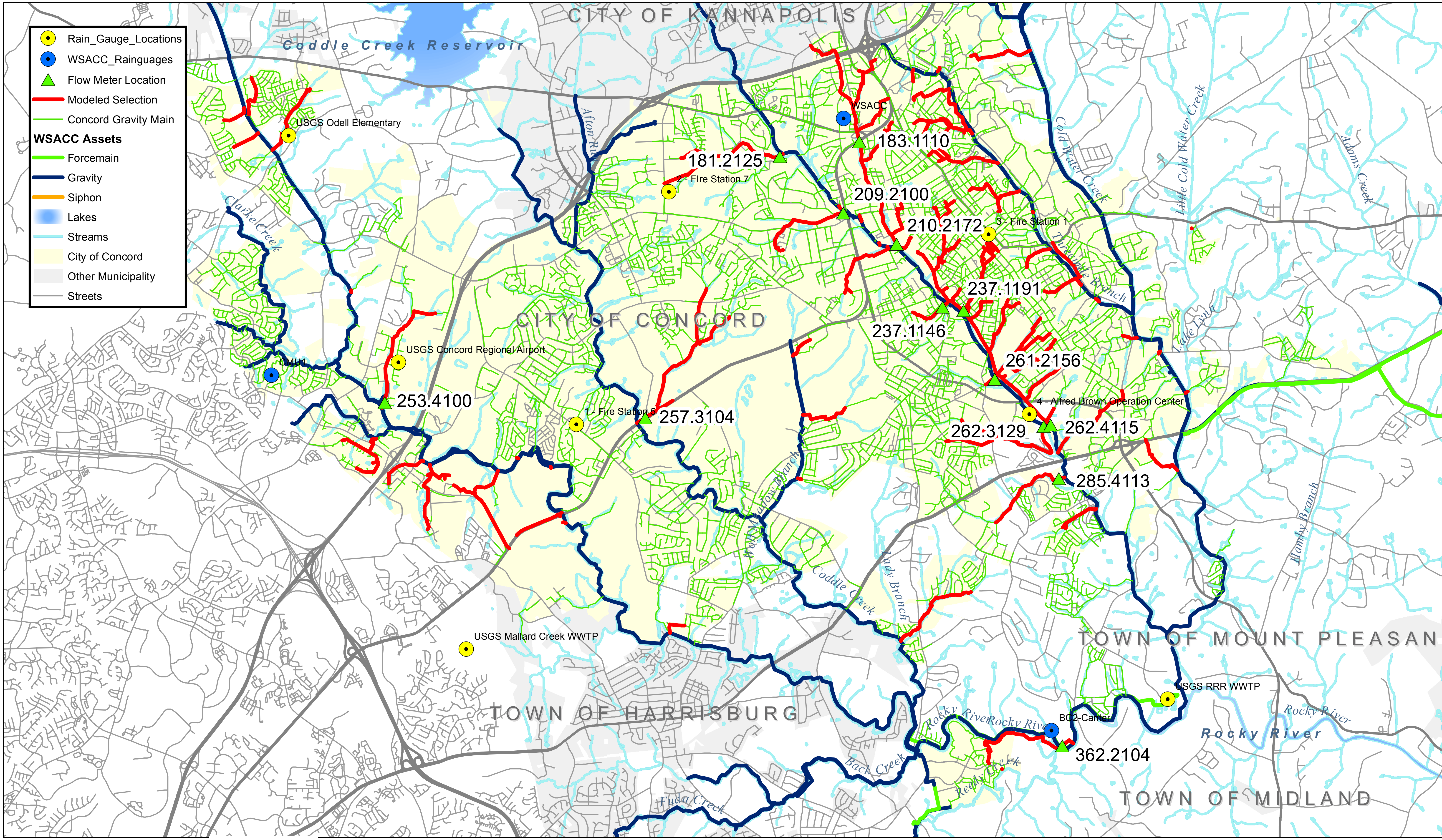
Concord provided Gavel & Dorn with flow metering data throughout the study. Gavel & Dorn reviewed the data and returned comments and suggestions for meter maintenance. Maintenance activities included checking and adjusting recorded flow levels, checking and replacing batteries, and cleaning velocity sensors as necessary. The meters were installed from November 2016 to April 2017. The flow monitoring period was extended to try to capture additional rainfall events.

3.2 Flow Meter and Rainfall Data Analysis

Gavel & Dorn compiled and analyzed the gathered temporary flow monitoring data, to determine the following parameters: (1) average daily dry weather flow, (2) peak I/I flow, (3) calculation of I/I volume, (4) percent of rain becoming I/I (R-value), (5) peaking factors for peak wet weather flow, and (6) event rain totals. The flow monitoring data was analyzed and is the basis of quantifying I/I presented below.

3.2.1 Quality Analysis

Gavel & Dorn first performed a quality analysis on the gathered data (i.e., scattergraph analysis) from all temporary flow metering locations. The scattergraph is a plot of recorded level (depth) versus associated velocity at the same time. In a typical open channel sanitary sewer flow installation, this graph exhibits a characteristic shape as defined by Manning's equation of open channel flow as seen in Figure 2 for the data gathered at meter location 237.1191. By examining the shape of the graph and any outliers, an experienced analyst can make various inferences about both the quality of the data and the behavior of the sewer system in the vicinity of the flow meter.



Concord NORTH CAROLINA

Date: 2/1/2018

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FIGURE 1
FLOW METER LOCATIONS
CONCORD, NORTH CAROLINA

Analysis of the scattergraph of depth and velocity can be used to diagnose many common metering or collection system problems such as (i) silt build-up, drifting level or velocity sensor, (ii) backwater and surcharge, and (iii) the occurrence of sewer overflows.

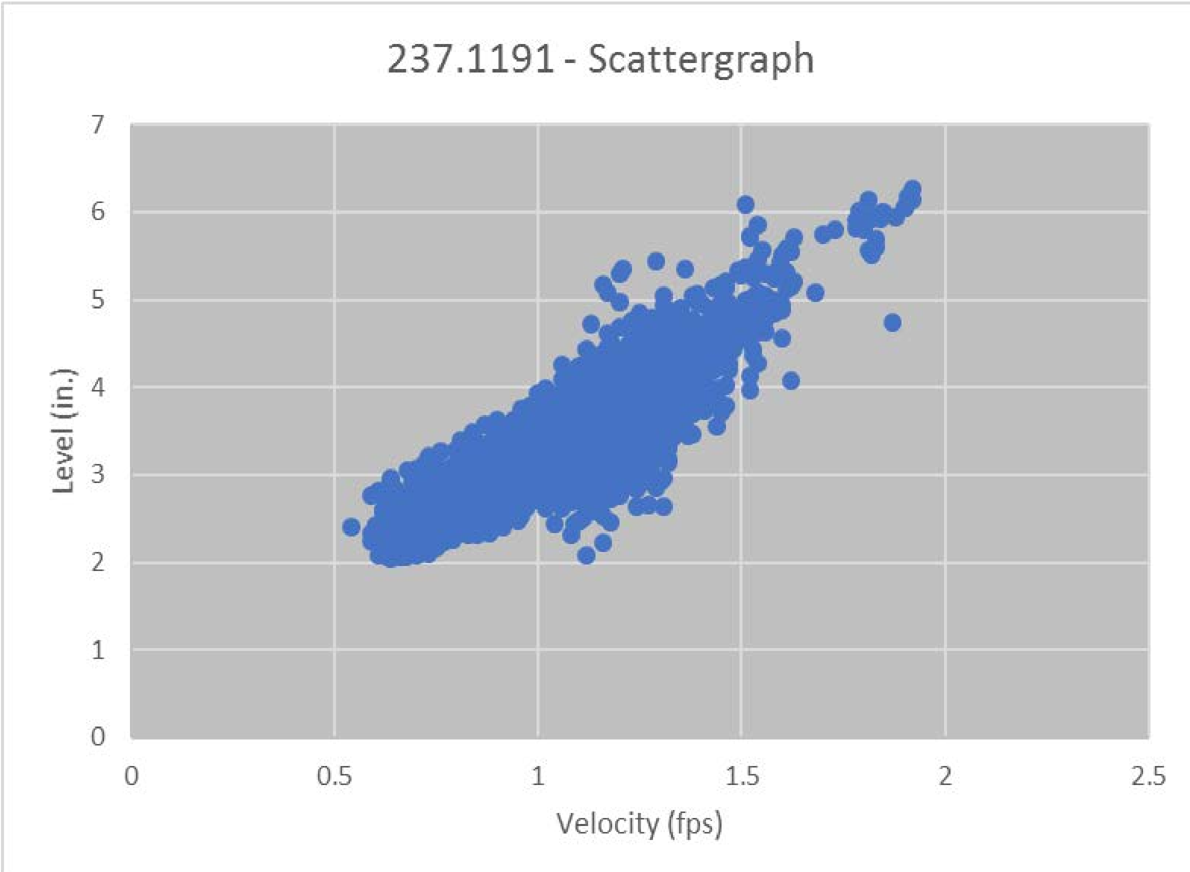


Figure 2. Meter location 237.1191 Scattergraph used for data QA/QC (42-inch Diameter Pipe).

During the study, meter location 209.2100 exhibited data typical of low flows. The level frequently drops below 1-inch in depth. An A/V sensor requires the sensor to be submerged to collect accurate velocity data. When the sensor is not submerged, the velocity readings often return zero values as seen in Figure 3.

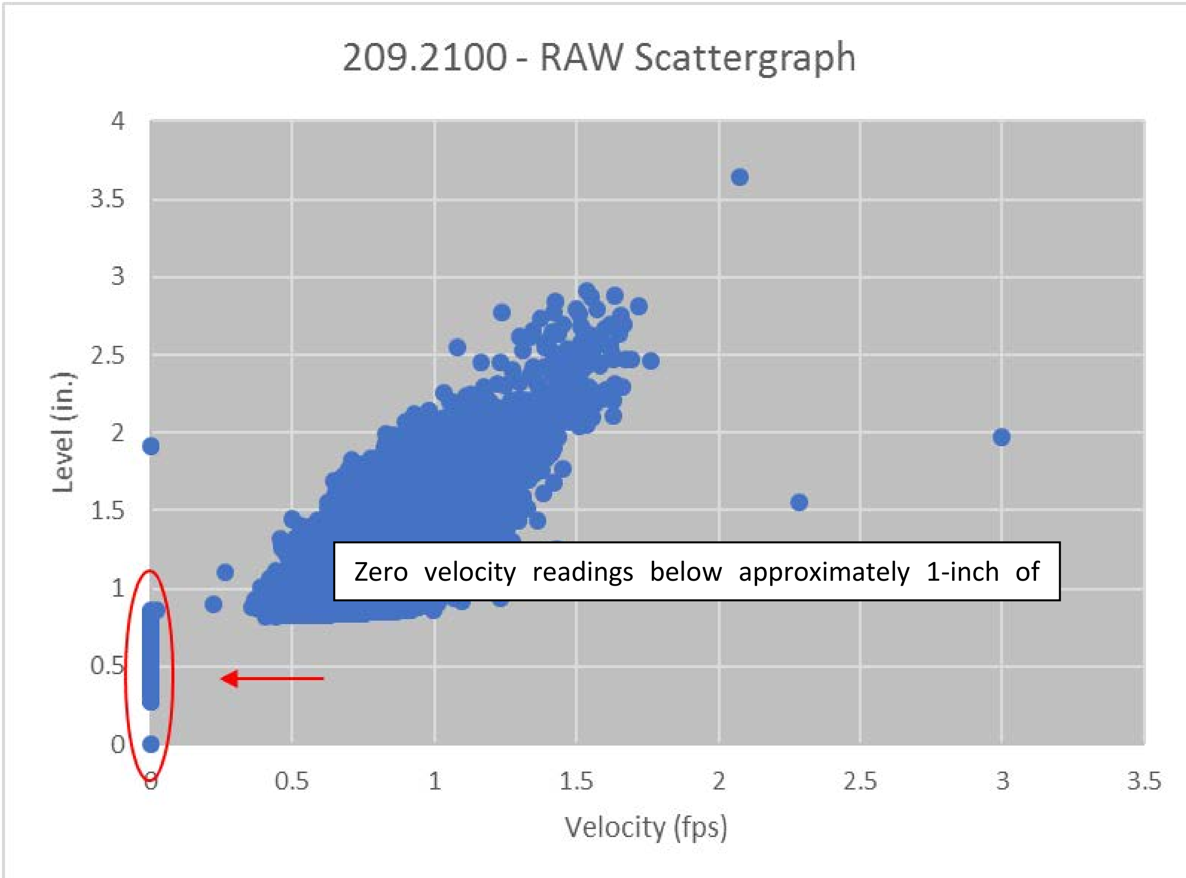


Figure 3. Meter Location 209.2100 RAW Data Scattergraph.

Intermittent zero velocity readings are adjusted based on experience and curve fitting or interpolation (i.e., “scrubbing”). For curve fitting, a best-fit curve is developed from good quality data to estimate missing or erroneous velocity/level data. This equation is then used to replace the erroneous data and the associated flow rate is then re-calculated based on pipe diameter and the continuity equation (Q=VA). Curve fitting is generally used when level or velocity data drop out for extended periods of time. The metering data included no long-term data dropouts; therefore, Gavel & Dorn used interpolation to address the intermittent drop outs of level and/or velocity. This method uses the neighboring good data points to calculate the values of the erroneous data. The results of this type of scrubbing can be seen in the “scrubbed” scattergraph for meter location 209.2100, Figure 4. While these are generally accepted data adjustment practices, doing so during wet weather events may result in an under-estimation of peak flows.

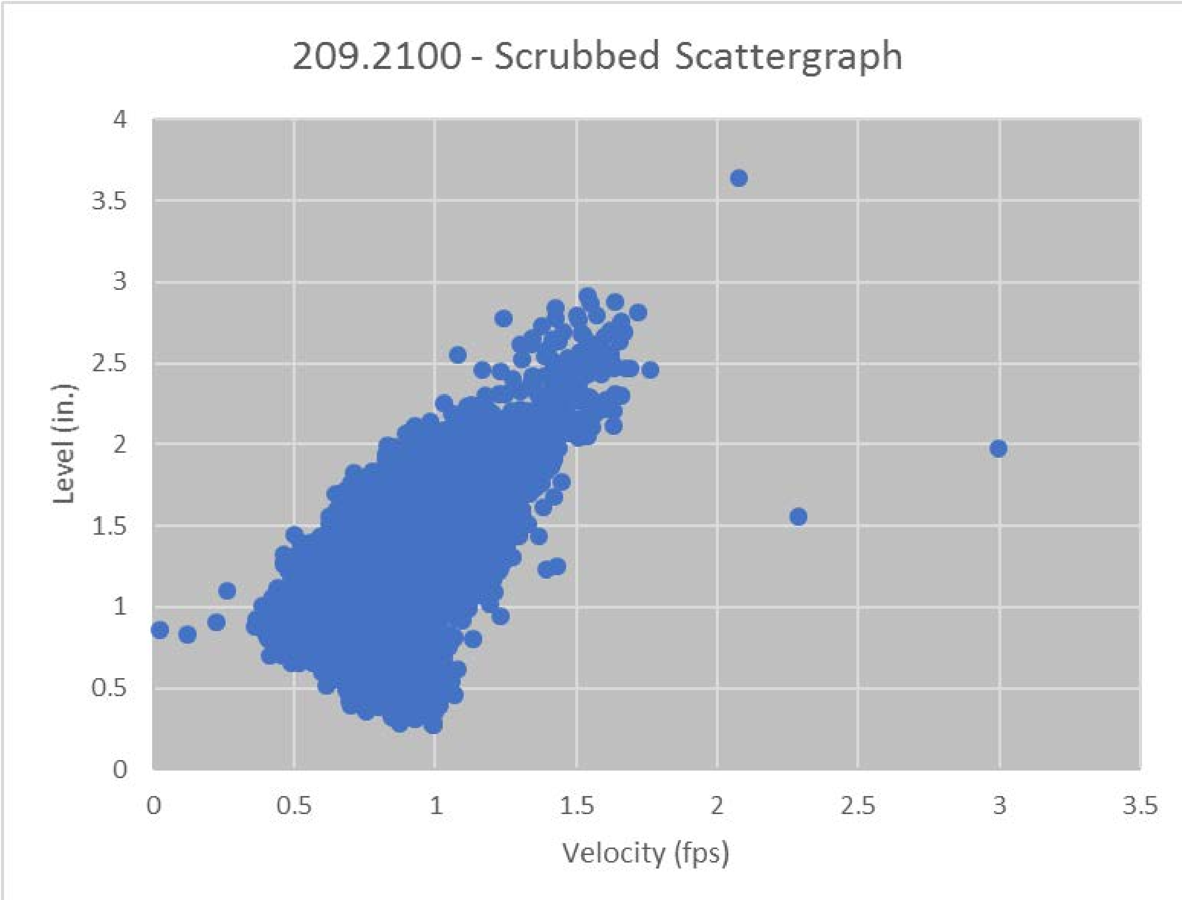


Figure 4. Meter location 209.2100, interpolation used to approximate missing velocity information.

3.2.2 Flow Balance

The final QA/QC step is to perform a flow balance to check that the sum of all flows measured upstream of a given metering site, on a volumetric basis, are less than or equal to the volume of flow measured at the downstream site. This is an important QA/QC step that is especially important for a temporary flow metering study in support of calibration of a hydraulic sewer model.

For this study, there were two locations that allowed for a flow balance to be constructed. Gavel & Dorn constructed one flow balance for meter location 237.1191 versus 262.4115 and one for meter location 183.1110 versus 210.2172. The results of the flow balance are presented in Table 1 below. In all cases, the flow volumes were found to satisfactorily balance.

Table 1. Concord Sanitary Sewer Master Plan Temporary Flow Metering Flow Balances		
Item	**Temporary Flow Metering Site**	**11/03/2016 13:30 to 03/06/17 07:15 Total Volume (Gals)**
1	237.1191 (Upstream Meter)	33,263,966
2	262.4115 (Downstream Meter)	69,421,216
		11/02/2016 15:00 to 04/24/17 03:00 Total Volume (Gals)
4	183.1110 (Upstream Meter)	91,640,006
5	210.2172 (Downstream Meter)	118,331,217

3.3 Flow Meter and Rainfall Data Results

Gavel & Dorn compiled and analyzed the gathered temporary flow monitoring data. This section summarizes the results of this analysis. The following parameters were determined for each monitor during the monitoring period:

- ✓ Average daily weekday dry weather flow
- ✓ Average daily weekend dry weather flow
- ✓ Weekday dry weather diurnal curve
- ✓ Weekend dry weather diurnal curve
- ✓ Peak wet weather flow for each monitored storm event
- ✓ Peaking factors (PF) for wet weather flow
- ✓ Volume of I/I for each monitored storm event
- ✓ Metric of I/I volume relative to drainage area (R-value).

Analysis of wastewater flow data typically involves differentiating three major flow components: base wastewater flow (BWWF), groundwater infiltration (GWI), and rainfall induced infiltration and inflow (I/I). BWWF is domestic wastewater from residential, commercial, or institutional sources. It is affected by population and land use in a drainage area and varies throughout the day in response to personal habits and business operations. Peaks usually occur between 6:00 a.m. and 9:00 a.m. and again between 6:00 p.m. and 9:00 p.m. Minimum flows occur during the late night/early morning hours. Weekdays and weekends typically exhibit different flow patterns. These diurnal variations are often accounted for by applying a peaking factor to the average BWWF rate.

Groundwater infiltration (GWI) is defined as groundwater entering the collection system through defective pipes, pipe joints, and manhole walls. The magnitude of GWI is dependent on the depth of the groundwater table above the pipelines, the percentage of the system that is submerged and the physical condition of the system. GWI fluctuates throughout the year due to the seasonal nature of groundwater levels with maximum flows typically occurring in the late spring and minimum flows typically occurring in the fall (October). While GWI is also affected by rainfall, it responds gradually and is not directly related to any individual rainfall event. Therefore, dry weather flow (DWF) is comprised of both BWWF and GWI.

Rainfall induced infiltration and inflow (I/I) is stormwater that enters the collection and trunk sewer system in direct response to the intensity and duration of individual rainfall events. I/I sources may include roof downspouts illegally connected to the sanitary sewers, yard and area drains, holes in manhole covers, cross-connections with storm drains, and storm water that enters defective pipes, pipe joints, and manhole walls after percolating through the soil.

Flow monitoring data analysis involves separating, or decomposing, total measured wastewater flows into dry weather (BWWF+GWI) and wet weather (I/I) components. Gavel & Dorn utilizes the U.S. EPA's Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox to perform this analysis. SSOAP is a suite of software computer tools used to quantify I/I in sewer systems. The analysis first develops an average diurnal base flow hydrograph for a typical weekday and a typical weekend day from the recorded data for dry-weather conditions. These typical base flow hydrographs are then subtracted from a wet-weather total hydrograph to determine the I/I component as illustrated in Figure 5 for meter location 285.4113. This method of hydrograph decomposition is an important step in analyzing and simulating wet weather flows in a sewer system.

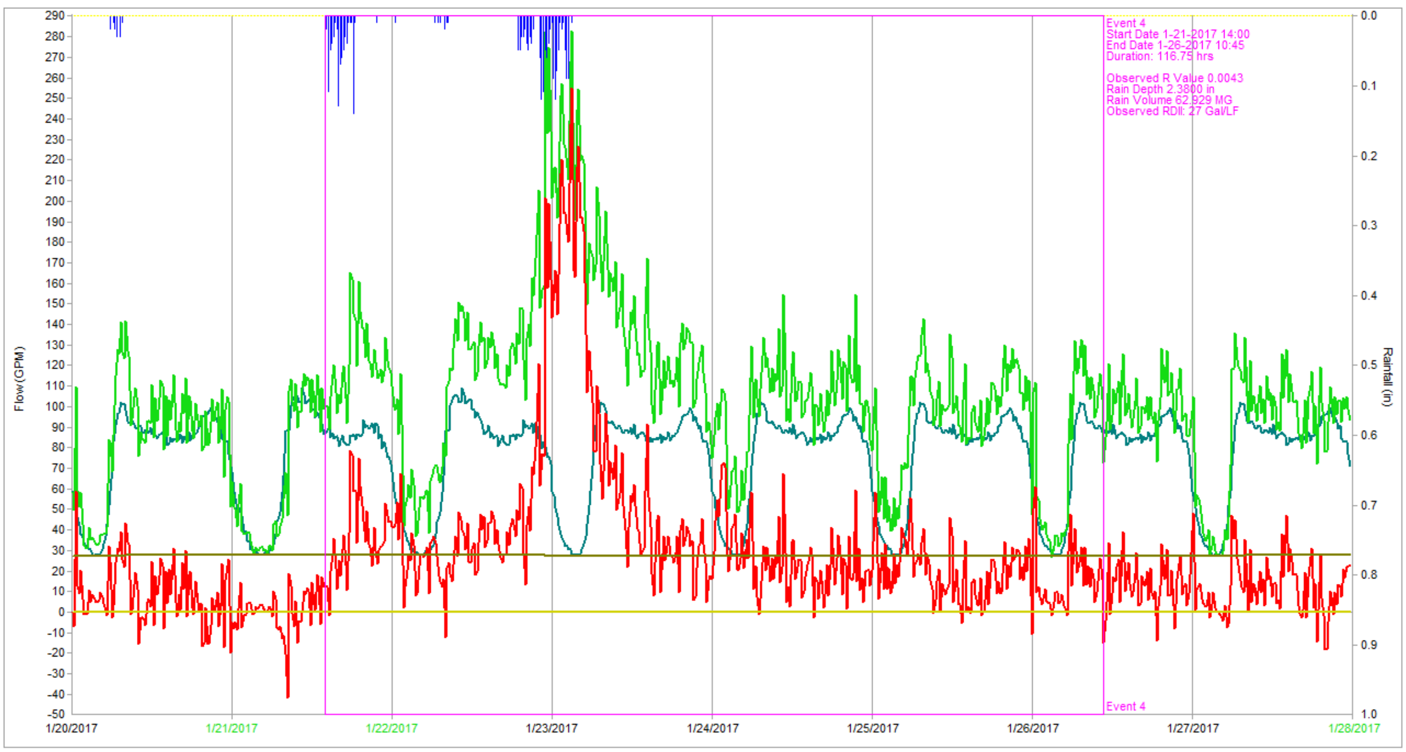


Figure 5. Graphics illustrates the hydrograph decomposition process to calculate the total I/I flow hydrograph for meter location 285.4113. The total flow hydrograph is shown as the green line, and the ADF is the blue line. The difference in these two curves represent the I/I hydrograph as shown in red. Rainfall is shown at the top.

3.3.1 Dry Weather Analysis

Gavel & Dorn analyzed the compiled flow monitoring data to quantify the average dry weather flow. Table 2 presents the calculated dry-weather average BWWF+GWI for each temporary flow meter location, for the period the meters were installed, and for both weekdays and weekends. Figure 6 is a sample graph of the dry weather diurnal hydrographs generated by SSOAP for meter location 253.4100 for both weekdays and weekends.

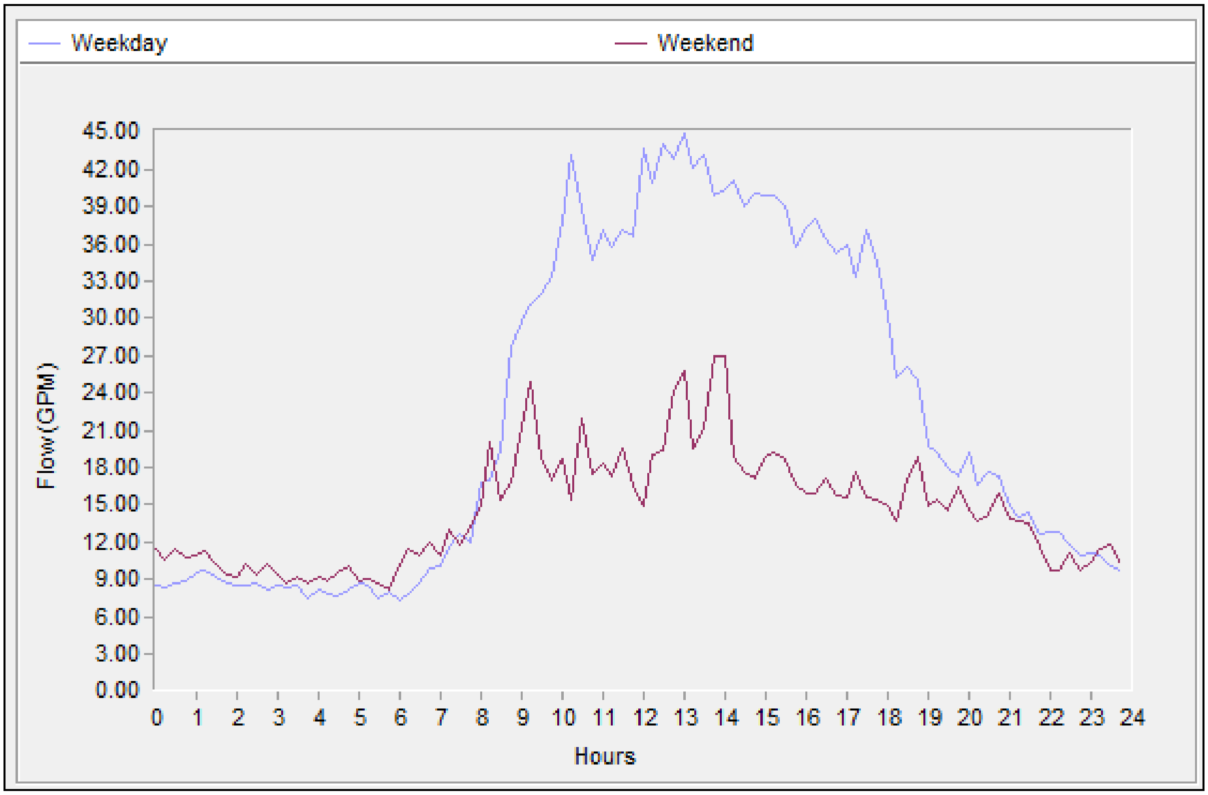


Figure 6. Average dry weather hydrographs for meter location 253.4100

The calculated dry weather average flow includes GWI. Depending on the time of year, 50-80% of the observed minimum nighttime flows can be attributed to GWI. This metering study was conducted during the high ground water period. Therefore, 75% of minimum nighttime flows were assumed to be GWI. An industry rule-of-thumb is that a GWI rate greater than 1500 gallons per day (GPD) per inch-diameter-mile (IDM) is considered excessive as highlighted below. Table 2 presents the calculated GWI rate for each metering location. Meter location 210.2172 demonstrated GWI rates more than 1500 GPD/IDM.

Table 2. Average Daily Base Wastewater Flow Statistics							
Meter ID		Average Dry Weather Flow (gpm)	Daily Weighted Average (gpm)	Daily Weighted Minimum (gpm)	GWI Rate (GPD) (75% of Daily Weighted Minimum)	IDM	GWI/ IDM
181.2125	Weekday	87.11	85.38	10.71	11,567	134.22	86
	Weekend	81.04					
183.1110	Weekday	338.90	334.10	75.35	81,378	93.54	870
	Weekend	322.09					
209.2100	Weekday	17.32	19.18	5.77	6,232	78.09	80
	Weekend	23.83					
210.2172	Weekday	460.20	460.36	211.46	228,377	149.87	1,524
	Weekend	460.77					
237.1146	Weekday	20.45	20.26	9.02	9,742	31.38	310
	Weekend	19.80					
237.1191	Weekday	166.07	162.88	70.05	75,654	176.64	428
	Weekend	154.92					
253.4100	Weekday	22.24	20.05	7.56	8,165	49.07	166
	Weekend	14.57					
257.3104	Weekday	102.57	103.94	42.23	45,608	156.73	291
	Weekend	108.12					
261.2156	Weekday	16.91	17.36	5.82	6,286	45.11	139
	Weekend	18.49					
262.3129	Weekday	131.13	130.48	65.36	70,589	157.57	448
	Weekend	128.84					
262.4115	Weekday	329.13	326.80	148.67	160,564	305.77	525
	Weekend	320.99					
285.4113	Weekday	75.95	75.24	27.57	29,776	87.54	340
	Weekend	73.45					
362.2104	Weekday	25.46	25.76	5.86	6,329	47.45	133
	Weekend	26.51					

3.3.2 Wet Weather Analysis

Once the dry-weather analysis was complete, and the hydrograph was decomposed as illustrated in Figure 5, Gavel & Dorn compared the volume of I/I to the volume of rainfall that fell on the drainage area contributing flow to that monitor location for each monitored storm event using SSOAP. The ratio of I/I volume to rainfall volume is defined as the 'R-value':

$$R = \frac{V}{P * A}$$

Where the parameters are (in consistent units):

V = Volume of I/I (i.e., total measured flow minus average BWWF+GWI)
P = Rainfall total
A = Drainage (or sewered) Area, which was estimated based on existing model data.

The R-value is the fraction of rainfall from a storm event that enters the sewer system as I/I. An additional parameter of interest is the peaking factor, or ratio of peak wet weather flow to that of average dry daily flow. In general, the higher the peaking factor the higher the inflow and the greater the possibility of sewer capacity limitation during wet weather.

3.3.3 Summary of Monitored Storm Events

The flow metering time period included one rain event greater than 1-inch in 24-hours. Recall that the main purpose of this metering study was to support a hydraulic model calibration. Therefore, our interest is generally only in storm events of more than 1-inch in 24-hours, as these events reasonably simulate I/I response of the larger design storm events used to size sewers. Some rain events observed were greater than 1-inch at certain rain gauges and less than 1-inch at others. These storm events were analyzed at all meters regardless of rainfall totals.

Separate R-values were computed for each installed flow monitor for each event. Table 3 provides a summary of monitored storm events at each meter including total measured rainfall, calculated R-value and peaking factor. Some of the meters exhibited negative R-values and I/I volumes. In general, a negative R-value occurs when a rain event is not large enough to generate a response in the sewer flows. Dry antecedent moisture conditions could also cause the sewer flows during the rain event to be below the average dry weather flow; therefore, returning a negative R-value.

In order to summarize the data across multiple storm events for each meter, rainfall weighted averages were calculated. All analyzed storm events that generated a positive R-value were used when calculating the rainfall weighted R-Value and peaking factors. This Information is summarized in Table 3, which indicates that meter location 183.1110 had the highest overall rainfall weighted R-value (3.5%). Meter location 253.4100 had the highest rainfall weighted peaking factor (15.64). A majority of the meters exhibited relatively low R-values at less than one percent.

The sewered areas used to calculate R-Values for the areas upstream of the meters were provided by LandDesign based on analysis of existing land use and are listed in Section 4. Meters with high R-values have higher overall I/I volumes entering the collection system on a unit rainfall basis. Meters with higher peaking factors are typically subject to more inflow (versus infiltration, which takes longer to respond) and could be indicative of sewer capacity problems. This Information is summarized in Table 3. For comparison, Table 3 also includes the calculated "allowable" peaking factor per the following Babbitt Peaking Factor trunk sewer design equation:

$$PF = \frac{5}{\left(\frac{\mathrm{P}}{1000}\right)^{0.167}}$$

Where, P=Population (in thousands). In this equation, population is approximated by assuming a per capita average dry daily flow rate of 100 gpcd.

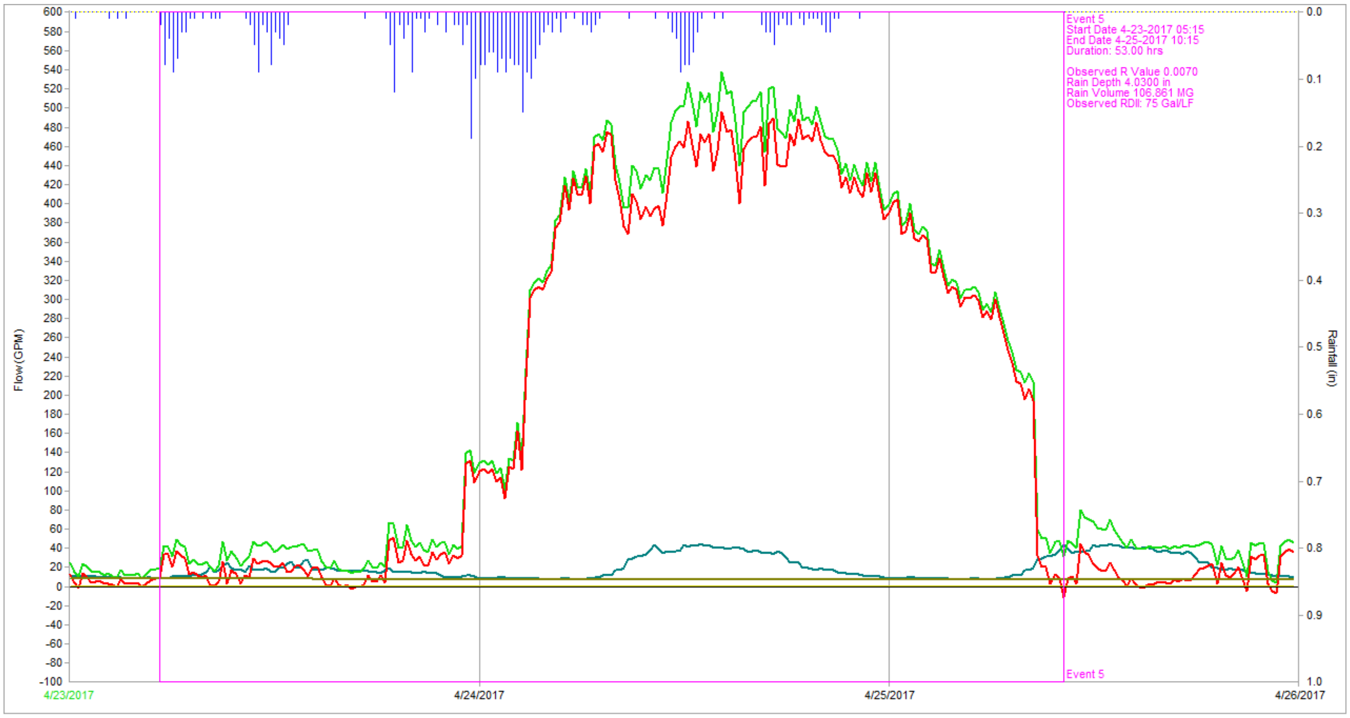
Table 3. Storm Event R-value and Peaking Factor Summary			
Meter	**Rainfall Weighted R-Value**	**Rainfall Weighted Peaking Factor**	**Allowable Babbitt Peaking Factor**
181.2125	0.006	5.48	4.83
183.1110	0.035	3.99	3.85
209.2100	0.002	5.27	6.20
210.2172	0.009	2.59	3.65
237.1146	0.005	7.51	6.14
237.1191	0.016	3.63	4.34
253.4100	0.003	15.64	6.15
257.3104	0.004	2.97	4.67
261.2156	0.006	15.38	6.30
262.3129	0.007	3.87	4.50
262.4115	0.019	5.88	3.86
285.4113	0.003	3.43	4.93
362.2104	0.000	2.78	5.90

Table 3 indicates that meter locations 181.2125, 183.1110, 253.4100, 261.2156 and 262.4115 exceeded the "allowable" Babbitt Peaking Factor based on basin population. This suggests that these meters are subject to elevated levels of inflow. One of the meters, 183.1110 also exhibited an R-value of greater than 3 percent. As a rule of thumb, an R-value of 3.0 percent or more is indicative of a significant I/I issue.

3.4 Conclusions

Sufficient data has been gathered to facilitate calibration of a sanitary sewer collection system model. Meter location 183.1110 exhibited R-values greater than 3 percent and peaking factor greater than Babbitt. Gavel & Dorn recommends performing Sanitary Sewer Evaluation Survey (SSES) practices within the collection system upstream of this metering location to determine the source of I/I.

Meter location 253.4100 exhibited the highest rainfall weighted peaking factor. During the January 22, 2017 and the April 23, 2017 rain events, a large inflow source was observed in the flow metering data as shown in Figures 7 and 8. It appears that a sanitary sewer structure is being flooded, allowing the inflow to occur. Gavel & Dorn recommends performing Sanitary Sewer Evaluation Survey (SSES) practices within the collection system upstream of this metering location to determine source of inflow.



Figures 7 and 8. Wet weather hydrographs during the January 22, 2017 and April 23, 2017 rain events at meter 253.4100

Table 4. Wet Weather Event Summary

Meter	Sewered Area (acres)	EVENT	START DATE	END DATE	DURATION (hrs.)	RAIN Volume (in.)	TOTAL R-Value	PEAK I/I Total Flow (gpm)	PEAK TOTAL Flow (gpm)	PEAKING Factor	I/I Volume Gals
181.2125	1137.03	1	12/4/2016 4:00	12/5/2016 4:15	24.25	0.82	0.0032	203.9	297.0	3.7	81,017
		2	1/1/2017 5:00	1/3/2017 0:00	43	1.46	0.0030	217.8	360.9	4.1	135,234
		3	1/3/2017 0:15	1/5/2017 7:30	55.25	0.63	0.0148	373.7	388.1	4.5	287,881
		4	1/21/2017 14:00	1/22/2017 1:00	11	0.86	0.0021	226.2	296.2	3.7	55,761
		5	1/22/2017 18:45	1/24/2017 0:45	30	1.45	0.0077	523.5	538.1	6.2	344,722
		6*	4/23/2017 5:15	4/26/2017 2:30	69.25	3.66	0.0048	531.7	546.3	6.7	542,416
183.1110	512.98	1	12/4/2016 6:45	12/5/2016 8:00	25.25	0.79	0.008	578.2	767.6	2.3	88,035.11
		2	1/1/2017 5:00	1/7/2017 7:00	146	2.14	0.0567	1031.2	1371.5	4.0	1,690,190.59
		3	1/21/2017 14:00	1/23/2017 8:45	42.75	2.38	0.0238	1475.5	1628.2	4.8	789,028.63
		4*	4/23/2017 5:15	4/26/2017 4:00	70.75	3.66	0.0187	1206.0	1287.5	3.8	953,370.12
209.2100	621.84	1	12/4/2016 6:00	12/5/2016 6:45	24.75	0.81	-0.0005	3.0	32.1	1.3	(6,838.68)
		2	1/1/2017 4:30	1/2/2017 9:15	28.75	1.46	-0.0001	18.9	46.6	2.7	(2,465.30)
		3	1/3/2017 0:15	1/4/2017 10:00	33.75	0.63	0.0018	28.0	49.0	2.8	19,148.30
		4	1/21/2017 14:00	1/22/2017 8:15	18.25	0.93	0.0003	15.9	46.0	1.9	4,711.09
		5	1/22/2017 18:45	1/25/2017 11:45	65	1.45	0.0034	181.5	187.2	10.8	83,246.12
		6*	4/23/2017 5:15	4/26/2017 3:15	70	3.66	0.0023	102.4	108.2	6.2	142,143.17
210.2172	1137.78	1	12/4/2016 6:00	12/5/2016 4:45	22.75	0.81	0.0009	236.1	748.1	1.6	22,522.90
		2	1/1/2017 5:00	1/2/2017 14:00	33	1.46	-0.0002	612.3	1074.8	2.3	(9,021.52)
		3	1/3/2017 0:15	1/3/2017 8:15	8	0.63	0.0036	420.5	634.3	1.4	70,071.23
		4	1/21/2017 12:30	1/21/2017 18:45	6.25	0.84	0.0021	313.4	911.3	2.0	54,499.85
		5	1/22/2017 18:45	1/25/2017 17:15	70.5	1.45	0.0187	733.6	1023.7	2.2	837,734.34
		6*	4/23/2017 5:15	4/24/2017 22:15	41	3.66	-0.0027	1337.4	1561.0	3.4	(305,310.37)
237.1146	193.03	1	12/4/2016 6:15	12/5/2016 4:45	22.5	0.8	-0.0012	14.2	38.1	1.9	(5,031.93)
		2	1/1/2017 5:00	1/3/2017 8:15	51.25	2.09	0.0012	22.0	43.2	2.1	13,145.91
		3	1/21/2017 14:00	1/21/2017 19:45	5.75	0.84	0.0008	22.0	45.5	2.3	3,522.35
		4	1/22/2017 18:45	1/23/2017 23:30	28.75	1.45	0.0121	199.8	213.6	10.4	91,963.73
		5*	4/23/2017 5:15	4/24/2017 10:45	29.5	3	0.0015	248.2	261.5	12.8	23,587.16
237.1191	677.27	1	12/4/2016 7:45	12/5/2016 12:30	28.75	0.77	0.0078	184.4	382.8	2.5	110,455.05
		2	1/1/2017 5:00	1/2/2017 23:00	42	1.46	0.0062	372.6	501.8	3.0	166,473.38
		3	1/3/2017 0:15	1/5/2017 8:30	56.25	0.63	0.0203	357.2	427.9	2.6	235,199.74
		4	1/21/2017 14:00	1/30/2017 7:30	209.5	2.38	0.0225	677.6	774.5	4.7	984,826.50
253.4100	976.51	1	1/1/2017 4:30	1/2/2017 12:15	31.75	1.53	0.0004	68.9	81.0	3.6	16,228.06
		2	1/3/2017 0:15	1/3/2017 9:00	8.75	0.92	0.0007	163.2	171.4	7.7	17,076.58
		3	1/21/2017 14:00	1/21/2017 20:15	6.25	0.86	0.0004	37.0	51.6	3.5	9,121.65
		4	1/22/2017 18:45	1/24/2017 12:00	41.25	1.79	0.0063	327.7	368.9	16.6	299,025.82
		5	4/23/2017 5:15	4/25/2017 10:15	53	4.03	0.0070	496.2	537.3	24.2	748,028.59
257.3104	1447.25	1	12/4/2016 6:00	12/5/2016 11:00	29	1.05	0.0002	26.9	153.7	1.4	8,252.80
		2	1/1/2017 4:30	1/6/2017 19:00	134.5	2.45	0.0025	147.1	205.9	2.0	240,706.64
		3	1/21/2017 14:00	1/31/2017 0:15	226.25	2.76	0.0065	339.1	384.1	3.8	705,024.83
		4*	4/23/2017 5:15	4/26/2017 3:00	69.75	4.03	0.0028	304.2	349.4	3.4	443,450.40
261.2156	299.47	1	12/4/2016 4:00	12/5/2016 6:30	26.5	0.82	0.0011	63.4	88.2	4.8	7,334.97
		2	1/1/2017 5:00	1/2/2017 20:45	39.75	1.46	0.0032	141.7	159.7	9.4	37,992.21
		3	1/3/2017 0:15	1/4/2017 7:00	30.75	0.63	0.0088	128.1	134.5	8.0	45,083.22
		4	1/21/2017 14:00	1/22/2017 8:00	18	0.92	0.0031	116.6	139.3	7.5	23,192.16
		5	1/22/2017 18:45	1/24/2017 22:00	51.25	1.45	0.0115	246.3	256.3	15.2	135,599.34
		6*	4/23/2017 5:15	4/26/2017 3:00	69.75	3.66	0.0133	389.0	396.7	23.5	395,844.36
262.3129	987.41	1	12/4/2016 6:00	12/5/2016 9:45	27.75	0.81	0.0025	159.7	313.9	2.4	54,295.14
		2	1/1/2017 5:00	1/2/2017 19:15	38.25	1.46	0.0023	284.6	454.9	3.5	90,036.09
		3	1/3/2017 0:15	1/6/2017 7:30	79.25	0.63	0.0151	352.5	454.6	3.5	255,066.51
		4	1/21/2017 14:00	1/21/2017 20:45	6.75	0.84	0.0004	129.8	288.0	2.2	9,008.97
		5	1/22/2017 18:30	1/27/2017 5:45	107.25	1.45	0.0132	441.6	532.8	4.1	513,189.63
		6*	4/23/2017 5:15	4/26/2017 3:00	69.75	3.66	0.0054	549.0	617.0	4.7	529,920.57
262.4115	1874.51	1	12/4/2016 6:00	12/8/2016 14:15	104.25	1.55	0.0094	500.4	871.9	2.6	741,627.33
		2	1/1/2017 5:00	1/8/2017 9:15	172.25	2.17	0.0180	1184.4	1359.0	4.1	1,988,192.42
		3	1/21/2017 14:00	1/27/2017 17:45	147.75	2.38	0.0254	2180.6	2367.6	7.2	3,077,066.26
		4*	4/22/2017 23:15	4/26/2017 4:00	76.75	3.7	0.0169	2252.6	2441.1	7.4	3,182,838.51

Meter	Sewered Area (acres)	EVENT	START DATE	END DATE	DURATION (hrs.)	RAIN Volume (in.)	TOTAL R-Value	PEAK I/I Total Flow (gpm)	PEAK TOTAL Flow (gpm)	PEAKING Factor	I/I Volume Gals
285.4113	973.73	1	12/4/2016 6:00	12/5/2016 10:45	28.75	0.81	0.0006	48.8	125.9	1.7	12,850.30
		2	1/1/2017 5:00	1/2/2017 15:45	34.75	1.46	0.0010	94.1	190.8	2.5	38,603.78
		3	1/3/2017 0:15	1/4/2017 7:45	31.5	0.63	0.0041	167.8	200.7	2.6	68,296.96
		4	1/21/2017 14:00	1/26/2017 10:45	116.75	2.38	0.0043	254.8	283.0	3.7	270,596.63
		5	4/23/2017 5:15	4/25/2017 16:45	59.5	3.66	0.0021	241.9	302.4	4.1	203,225.10
362.2104	584.41	1	1/1/2017 16:00	1/2/2017 18:30	26.5	1.01	0.0003	37.1	66.6	2.6	4,808.38
		2	1/3/2017 0:00	1/3/2017 5:00	5	0.6	0.0002	41.5	56.3	2.2	1,904.31
		3	1/21/2017 14:00	1/21/2017 22:15	8.25	0.64	0.0002	30.0	66.5	2.5	2,031.26
		4	1/22/2017 18:30	1/23/2017 17:00	22.5	1.38	0.0008	72.2	86.5	3.3	17,519.64

*R-value and I/I volumes are under reported as the flow meters were removed prior to returing to normal flows. In general, peak flows were observed, and peaking factors are accurately reported. R-values not used in rainfall weighted average

4 Future Flows

LandDesign led the development of sewer flow forecasts to be utilized as a key input into the hydraulic model. This document is meant to provide an overview of the parcel-based forecasting model created to develop the sewer flow forecasts.

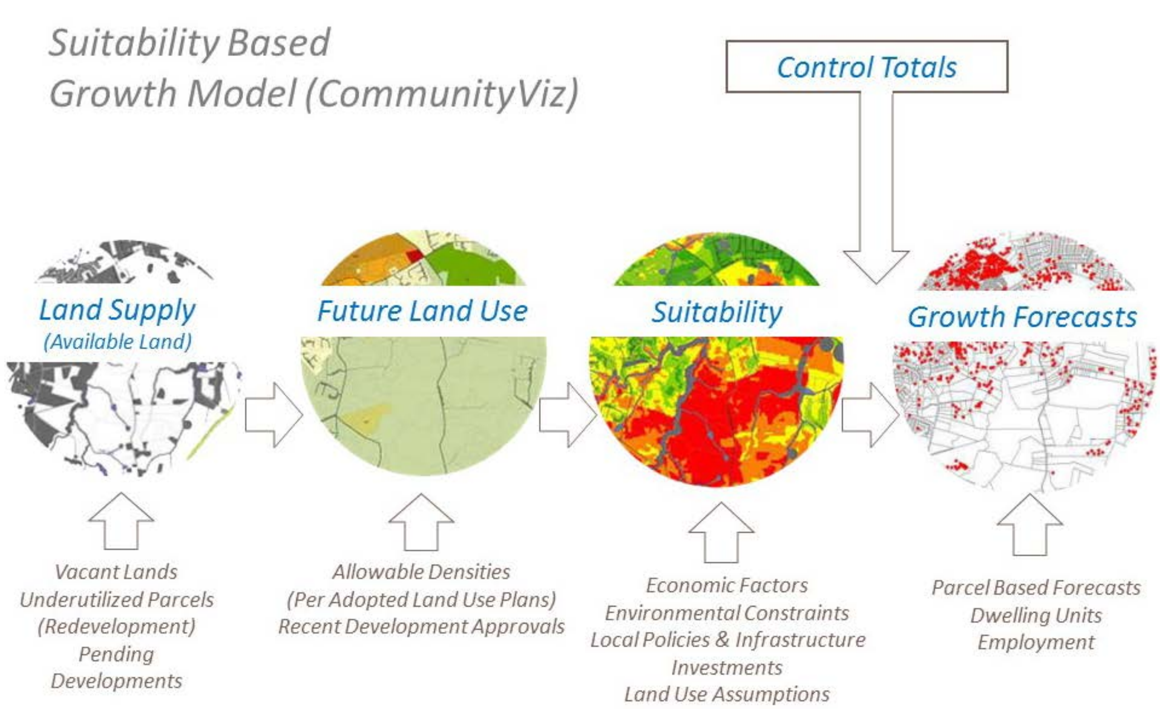
4.1 Overview of the Growth Model

A custom, GIS-based Model was created by modifying the Water and Sewer Authority of Cabarrus County (WSACC) Growth Model developed during the WSACC FY 2012-2013 Master Plan effort. The Growth Model is a parcel-based forecasting model developed with Geographic Information System (GIS) datasets and software. Software used includes ArcGIS 10.3 and Community Viz 5.1.1.

The Model creates disaggregate dwelling unit and employment forecasts by determining the probable distribution of future housing units and employment locations based on currently adopted land use policy regulations and suitability of available land.

The Model is made up of five main components: (1) baseyear water and sewer usage data, (2) a land supply and pending development inventory, (3) generalized future land use, (4) the land use suitability analysis and (5) municipal utility service area projections. Each component is made up of a set of assumptions that influence the distribution of future growth and sewer flow estimates. The following sections describe the model components and findings.

Figure 1: Growth Model Diagram



4.2 Baseyear Water and Sewer Usage

A principle input into future flows is existing flows. Baseyear water usage data was received from Hazen and Sawyer. This data included summarized data from 2014 billing records and estimated new usage between 2014 and 2016. Total estimated water usage for the baseyear (2016) is 9,595,576 gallons per day (9.6 MGD). Data included all water usage in the Concord and Midland Utility Service Areas (USAs) regardless of connection to sewer system. The dataset contained 23,253 records (points). In GIS, records were selected within 1200ft of a gravity main and within the Concord Utility Service Area (USA). This included 20,388 records which included 7.9 MGD (82% of total usage). Existing water usage was summarized by sewer subbasins provided by the City. Existing usage data was cross checked with an existing land use inventory derived from tax parcel records. Minor manual updates were made in order to account for flows in newly built areas. This added 155 gpd to the total.

Note: For the purposes of this study it was assumed that 100% of water usage within 1200ft of a sewer gravity main contributed to sewer flows. This assumption can be modified by adding a multiplier to the model.

Total baseyear water usage was 8.28 mgd / 248.4 million gallons per month. This is in-line with what was collected in 2012 in terms of usage for Concord (245 million gallon median monthly water usage). Below is a summary of statistics for baseyear water usage for the Concord USA.

Figure 2: Baseyear Water Usage Summary

Summary Statistic	Description	GPD	GIS Field Name*
Total Demand All Users	All water demand	8,286,236	N/A, summary of point based meter data
Total Demand All Users Served	All users within 1200ft of sewer	8,021,897	Demand2016
Industrial Users	Account with demand >50,000gpd	1,011,614	INDDem16
Total Subbasin Demand	(Total subbasin demand for all meters) – (Industrial users >50,000gpd)	7,274,622	TotDem16
Served Users	(Total subbasin demand for meters within 1200ft of sewer) – (Industrial Users > 50,000gpd)	7,010,283	TotDemSVD16

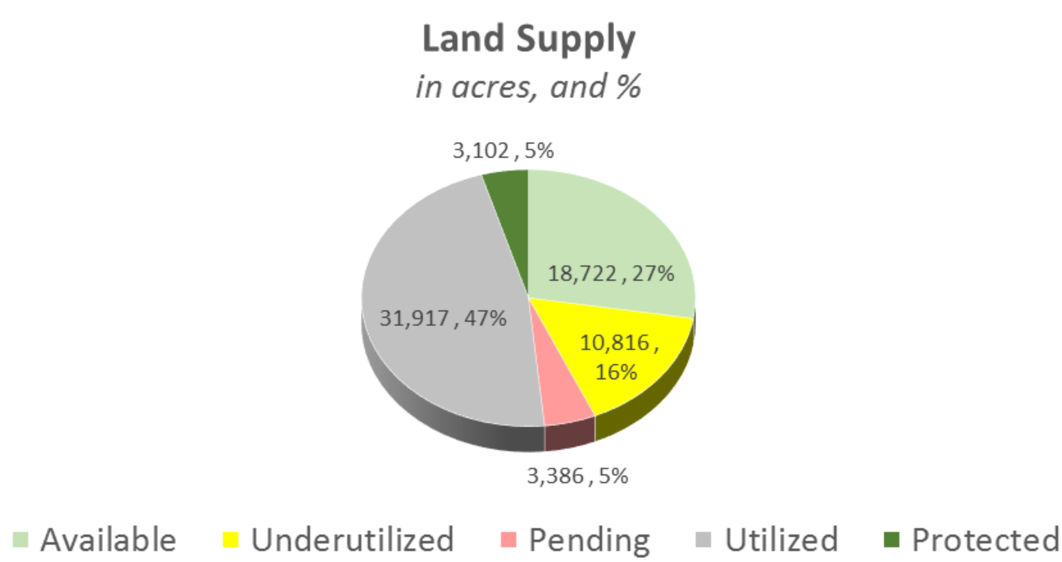
**GIS Field Name refers to the field in the subbasin dataset deliverable.*

4.2.1 Land Supply and Pending Development Inventory

The Land Supply inventory is used by the Model to determine lands that are built and areas where additional development can take place. Based on the existing land use inventory, tax parcel records, and staff review, an inventory of Available land (vacant or undeveloped) and Underutilized land (land likely to be redeveloped or support additional development) was created. The Available and Underutilized land in combination, minus environmental constraints (i.e. regulated floodplain, wetlands and buffers), is referred to as the "Land Supply". The Land Supply is a discretely measurable amount of acreage that could accommodate anticipated growth in new housing and non-residential uses based on projected demand for each. Concord staff provided comments on maps that was used to update the land supply. Manual edits to the land supply data included:

- Old Phillip Morris site coded as Underutilized
- Concord Mall area coded as Underutilized
- Redevelopment areas in Downtown Concord Master Plan changed to Underutilized
- Edits to cemeteries and NCRR property to change to Utilized

Figure 3: Land Supply Inventory for the Concord Utility Service Area



An inventory of Pending Development was created. This inventory was a parcel based inventory of approved development within the Concord Utility Service Area. The inventory included new single-family and multi-family subdivisions and non-residential developments and is used to estimate new sewer flow for approved developments. An Adequate Public Facilities (APF) spreadsheet inventory from Cabarrus County was used as a starting point for this inventory. Concord staff provided GIS data that was also used to create the Pending Development inventory.

Pending Developments included a total of:

- 3,386 acres
- 10,221 dwelling units
- 4,556,000 square feet of industrial
- 312,000 square feet of commercial
- 113,000 square feet of hotels
- 150,000 square feet of institutional

4.3 Future Land Use

Adopted land use plans were collected and used to create a set of Generalized Future Land Use categories. Each category has an associated set of allowable uses and densities (residential density and non-residential "floor area ratio"). These categories were used by the Model to determine the capacity of land to accommodate future development. Density assumptions reflect existing county and municipal agreements for utility provision.

For this effort, modifications were made to the model in order to better reflect the type of development intended for downtown Concord. The Downtown Concord Master Plan was consulted and changes included:

- Two parcels to the northeast of downtown were changed to High Density Res (15 DU/Acre) from Medium-High Density Residential (8 DU/Acre)
- A new generalized land use category was created (CCFLU-Center City Mixed Use) to factor in the density and use mix outlined in the Downtown Plan
    - Two floors of non-residential (50% commercial, 30% Office, 20% Lodging)—FAR of 2.0
    - Residential density of 20 units per acre

Other minor changes were made elsewhere in the Concord USA based on staff comments. These included:

- International Business Park changed to OI (Office and Industrial)
- Land opposite US 29 from former Phillip Morris changed from OI (Office and Industrial) to Residential MXU and Commercial MXU.

4.3.1 Land Use Suitability

Land suitability represents the likelihood that a parcel will experience growth by 2040, the horizon year. Parcels with high suitability values are more likely to receive future development in the Model. No two parcels are exactly the same, and the set of characteristics associated with each will determine its attractiveness, or suitability, for certain uses. A number of economic and environmental suitability factors were taken into account in the development of the Model. These factors vary based on land use type. Suitability analyses were conducted for two types of residential land uses (Single Family & Multi-Family) and five types of non-residential land uses (Commercial, Service, Industrial, Office/Institutional/Government, and Lodging).

For this effort, the Single Family Suitability analysis was updated to include a new input dataset that allowed the model to factor in the location of recent residential growth.

4.4 Municipal Service Area Projections

Control totals for dwelling units and employment by type were developed for the Concord Utility Service Area. These were updated from the market projections developed during the WSACC FY 2012-2013 Master Plan. Data was gathered on growth that has occurred between 2012 and 2016. Recent growth and pending development totals were netted out of the control totals prior to allocation. The control totals were used to understand the total amount of growth expected in the study area. Homes and jobs were allocated parcels (or portions of parcels) based on the suitability of that parcel and capacity derived from adopted land use plans.

Figure 4: Residential Projections

Residential						
	Baseyear (2012)	Projections (2012-2040)	% Δ 2012-2040	Growth 2012-2016	Pending Dev	For Allocation
Single Family	18,787	19,325	102.86%	1,285	6,732	11,308
Multi-family	1,096	5,290	482.85%	551	3,019	1,720
Townhomes	5,805	1,057	18.22%	-	470	587
Total Dwelling Units	25,688	19,325	75.23%	1,836	10,221	9,104

**Allocation for Townhomes included in MF allocation*

Figure 5: Employment Projections

Employment						
	Baseyear (2012)	Projections (2012-2040)	% Δ 2012 - 2040	Growth 2012-2016*	Pending Dev	For Allocation
Industrial	10,021	3,848	38%	275	2,278	1,295
Commercial	8,800	3,446	39%	246	520	2,680
OIGOV	20,212	12,605	62%	900	429	11,276
Lodge	838	555	66%	40	94	422
Service	5,051	3,426	68%	245	-	3,181
Total Jobs	44,923	23,880	53%	1,706		18,853

**Job growth between 2012 and 2016 assumed to be coincident with householder growth, which is 7% of total projected growth from 2012-2040.*

4.5 Sewer Flow Forecasts

4.5.1 Projection Allocation

The Land Supply, Future Land Use, and the Land Use Suitability Analysis, were used by the Model to distribute projected growth to parcels. The model uses a probability based allocation method that allocates homes and jobs to parcels based on suitability, with the highly suitable parcels receiving more growth. Total growth for each parcel is capped based on future land use.

4.5.2 Sewer Flow Projections

From the parcel based allocations of jobs and homes sewer flow projections were derived. For residential growth, sewer flow was estimated to be 200 gpd per housing unit. Projected employees were converted to non-residential square footage and to sewer flow based on the rates in the table below in Figure 6. Sewer flow rates were determined based on mean water usage per day records that were cross-checked with a detailed existing land use inventory and analyzed during the WSACC FY 2012-2013 Master Plan.

Figure 6: Future Sewer Flow and Employee Yield Assumptions for Non-residential Land Uses

GENLU	Description	Examples	Square Foot Per Employee	Mean Water Usage Per Day	Unit	Sewer Flow Assumption	Unit
COM	Commercial, Highway Commercial, Retail	FOOD LION, BEST BUY, CIRCLE K, SUNTRUST	600	90	gpd per 1k sqf t	125	gpd per 1k sqf t
IND	Industrial and Warehouse	FEDERAL EXPRESS, S&D COFFEE	1000-2000 (2000 for Warehouse)	112	gpd per 1k sqf t	150	gpd per 1k sqf t
OIGOV	Office, Institutional, Government and Schools	NORTHEAST MEDICAL CENTER, CABARRUS CO.SCH.ADMIN	350	99	gpd per 1k sqf t	150	gpd per 1k sqf t
LODGING	Hotel/Motel	HOLIDAY INN EXPRESS, COMFORT SUITES	1200	166	gpd per 1k sqf t	200	gpd per 1k sqf t
SERVICE	Service (incl. Restaurants, Car Washes, Salons)	T.G.I. FRIDAY'S, CAROLINA CAR WASH	250	521	gpd per 1k sqf t	650	gpd

4.5.3 Sewer Flow Projection Totals

Sewer flow from the Pending Development was added to the estimates from the allocation totals. The existing flows, as estimated based on existing water use data, were factored in to get a total sewer flow estimate for each basin. Total projected sewer flows in 2040 is shown in the following table Figure 7.

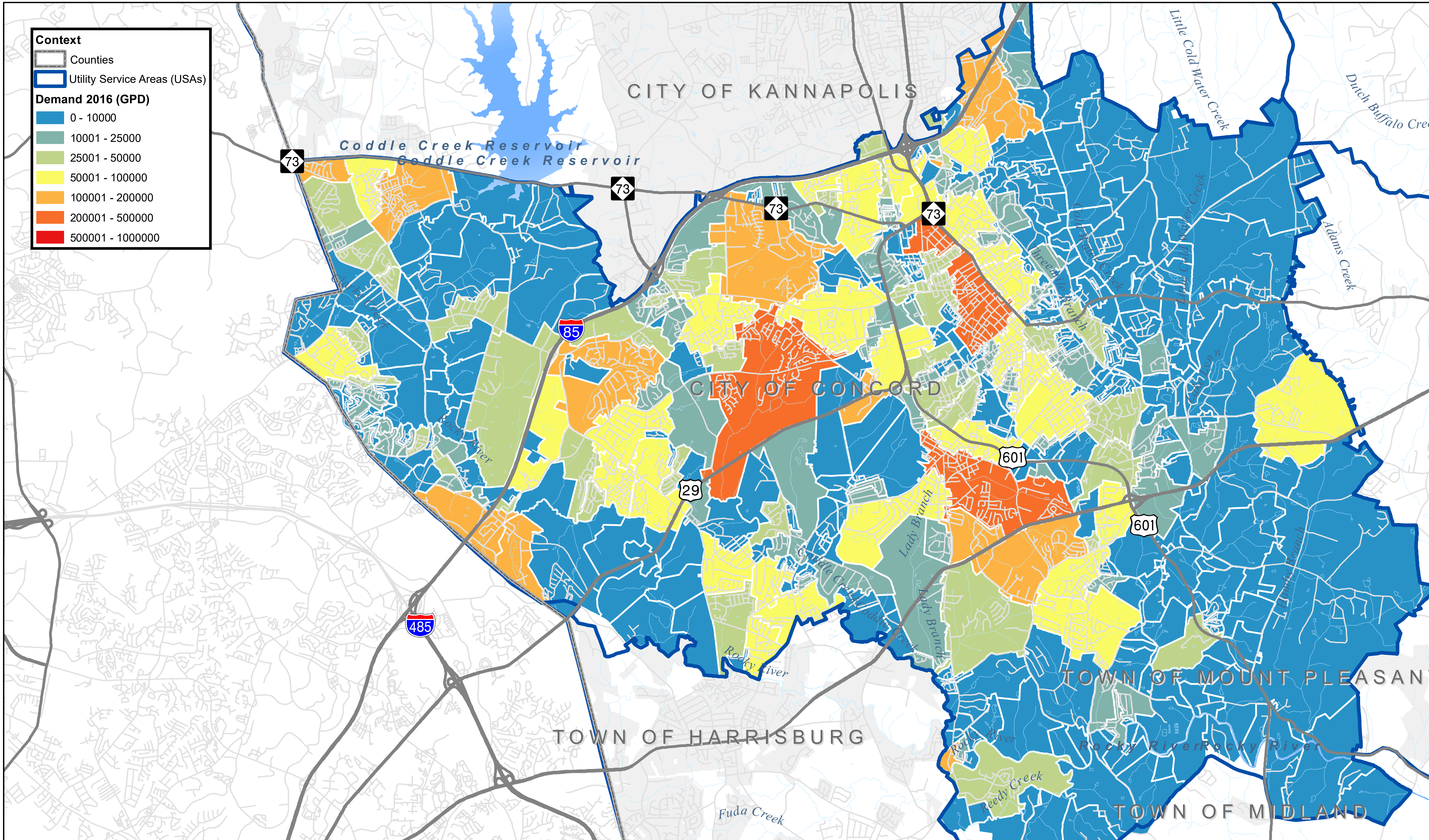
Figure 7: Sewer Flow Forecasts (units in gpd)

Statistic	Description	GPD	GIS Field Name*
Total New Demand All Users	New sewer flow from 2016-2040	8,034,599	TOTDEMAU40
Industrial Users	Base year and future year industrial users with demand >50,000gpd	1,899,338	INDUSE2040
Total Subbasin Demand	Base year and future year (Total subbasin demand for all meters) – (Industrial users >50,000gpd)	14,421,497	TOTDEM2040
Served Users	Base year (Total subbasin demand for meters within 1200ft of sewer), Future Year (subbasins that are served)) – Industrial Users (Base Year and Future Year Users > 50,000gpd)	13,539,775	TOTSVD2040

**GIS Field Name refers to the field in the subbasin dataset deliverable.*

4.5.4 Percent Served

Percent of each basin served was calculated by estimating acres of built parcels, pending developments and the amount of land projected to be developed between 2016 and 2040 based on model allocations. It was assumed that all new development in basins likely served by sewer would be connected to the City wastewater network. Assumptions for area built per home and employee were 2,000 sqft per employee and 0.6 acres for each dwelling unit. These rates were derived by comparing existing heated area for non-residential buildings to number of existing employees and by analyzing average size of lots for new residential parcels built since 2010. Built lands were then summarized by basin and provided in the GIS deliverable as the field “DEVPERREV”.



Date: 2/1/2018

FIGURE 8

BASEYEAR (2016) SEWER DEMAND

CONCORD, NORTH CAROLINA

N

0 0.5 1 2 Miles

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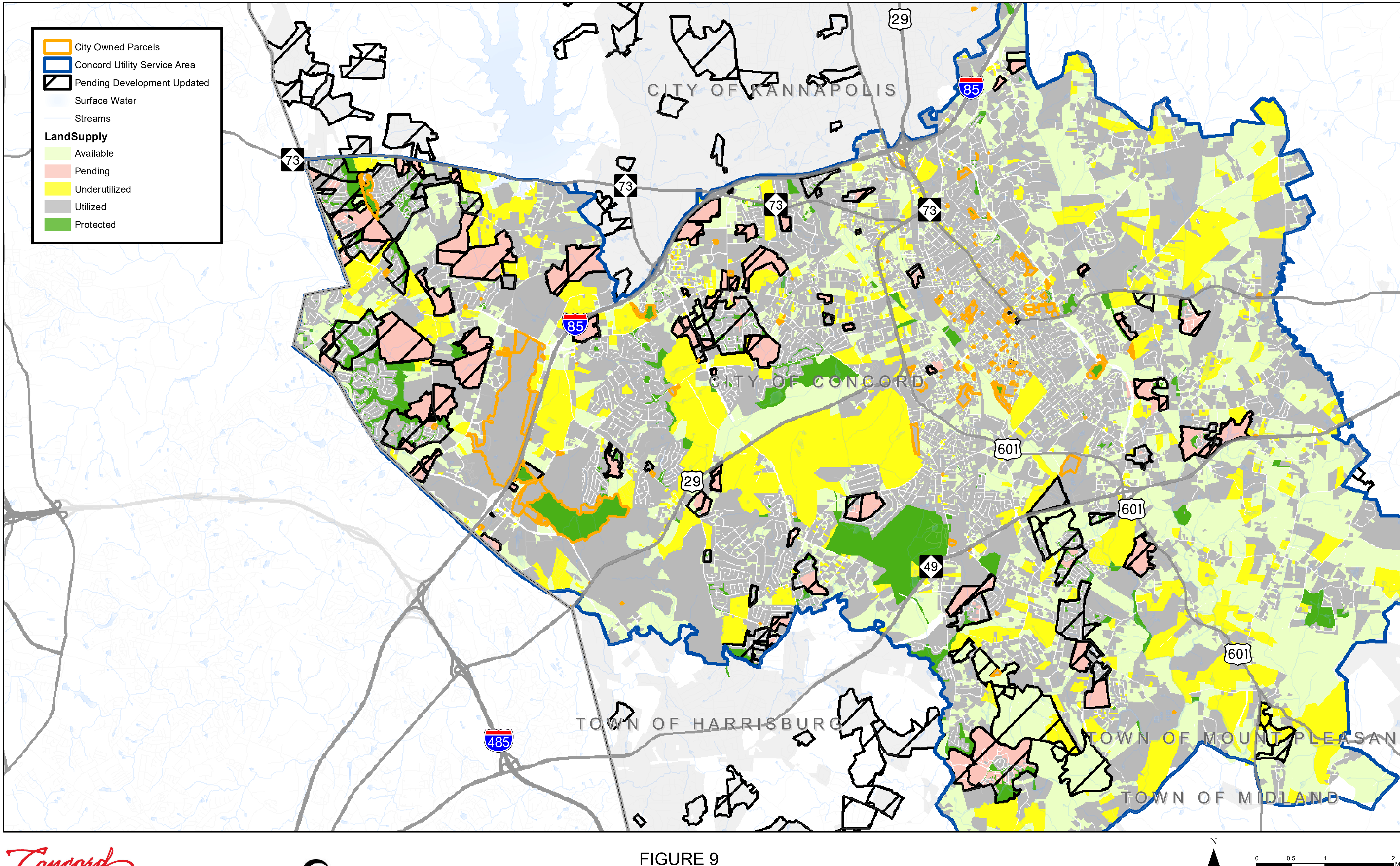

FIGURE 9

LAND SUPPLY AND PENDING DEVELOPMENT

CONCORD, NORTH CAROLINA

Date: 2/1/2018

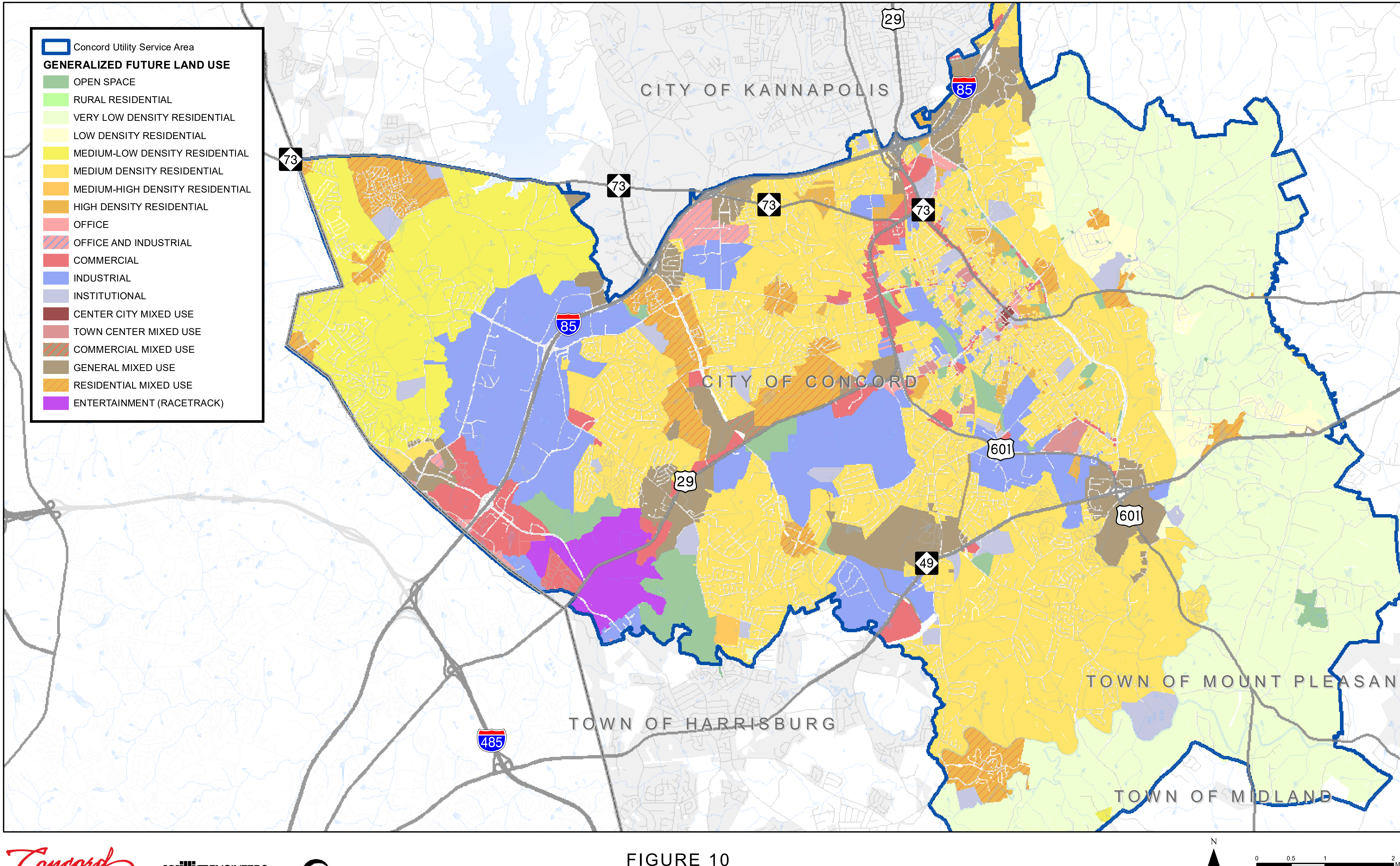

FIGURE 10
GENERALIZED LAND USE
CONCORD, NORTH CAROLINA

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Date: 2/1/2018

Table 1: Generalized Future Land Use Key

GENFLU	Description	SF	MF	Residential %	NonRes %	Commercial %*	Industrial %	SFDUDEN	MFDUDEN	FAR	General Commercial %	Office, Inst., Gov. %	Service / Lodging %	SF % of Res	MF % of Res	Primary Use	Secondary Use
OS	Open Space	No	No	0	0	0	0	0	0	0.00	0	0	0	0	0	Natural	None
RRES	Rural Residential	Yes	No	95	5	5	0	0.33	0	0.10	0.5	0	0.5	1	0	SF Residential	Commercial, Service
VLDRES	Very Low Density Residential	Yes	No	95	5	5	0	0.5	0	0.10	0.5	0	0.5	1	0	SF Residential	Commercial, Service
LDRES	Low Density Residential	Yes	No	95	5	5	0	1	0	0.10	0.5	0	0.5	1	0	SF Residential	Commercial, Service
MLDRES	Medium-Low Density Residential	Yes	No	95	5	5	0	2	0	0.10	0.5	0	0.5	1	0	SF Residential	Commercial, Service
MDRES	Medium Density Residential	Yes	Yes	95	5	5	0	3	4	0.10	0.5	0	0.5	0.75	0.25	SF Residential	MF Residential, Commercial, Service
MHDRES	Medium-High Density Residential	Yes	Yes	95	5	5	0	4	8	0.10	0.5	0	0.5	0.5	0.5	SF & MF Residential	Commercial, Service
HDRES	High Density Residential	Yes	Yes	95	5	5	0	8	15	0.10	0.5	0	0.5	0.25	0.75	MF Residential	SF Residential, Commercial, Service
OFF	Office	No	No	0	100	100	0	0	0	0.25	0.2	0.6	0.2	0	0	OIGOV	Commercial, Lodging/Service
OI	Office and Industrial	No	No	0	100	50	50	0	0	0.25	0.1	0.8	0.1	0	0	OIGOV and Industrial	Commercial, Lodging/Service
COM	Commercial	No	No	0	100	90	10	0	0	0.25	0.5	0.25	0.25	0	0	Commercial	OIGOV, Lodging/Service, IND
IND	Industrial	No	No	0	100	10	90	0	0	0.25	0.5	0.5	0	0	0	Industrial	Commercial, OIGOV
INST	Institutional	No	No	0	100	100	0	0	0	0.25	0.05	0.9	0.05	0	0	OIGOV	Commercial, Lodging/Service
TCMU	Town Center Mixed Use	Yes	Yes	30	70	70	0	8	15	0.50	0.4	0.3	0.3	0.25	0.75	Commercial	Residential, OIGOV, Lodging/Service
CCMU	Center City Mixed Use	No	Yes	70	30	100	0	0	20	2.00	0.5	0.3	0.2	0	1	Commercial, Residential	OIGOV, Lodging/Service
CMU	Commercial Mixed Use	No	Yes	25	75	50	25	4	8	0.25	0.6	0.2	0.2	0.25	0.75	Commercial	Residential, OIGOV, Lodging/Service
GMU	General Mixed Use	Yes	Yes	50	50	50	0	4	8	0.50	0.4	0.3	0.3	0.25	0.75	Commercial	Residential, OIGOV, Lodging/Service
RMU	Residential Mixed Use	Yes	Yes	70	30	30	0	4	8	0.50	0.4	0.3	0.3	0.25	0.75	Commercial	Residential, OIGOV, Lodging/Service
ENT	Entertainment (Racetrack)	No	No	0	100	70	30	0	0	0.25	0.4	0.3	0.3	0	0	Commercial, Industrial	Office, Lodging/Service

*COM Percent will also allow Service, Office, Institutional and Lodging

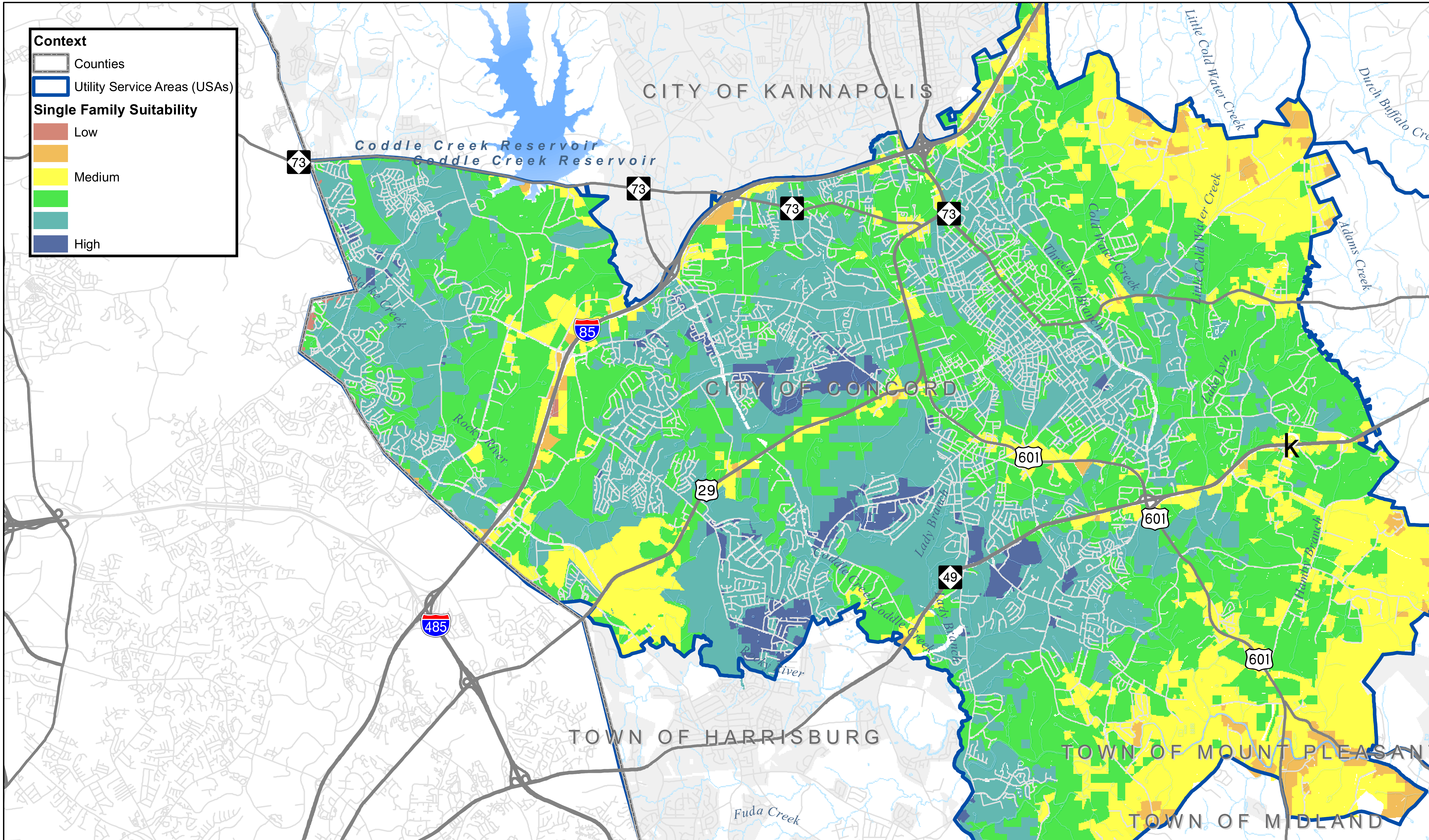

FIGURE 11

LAND USE SUITABILITY

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

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Gavel & Dorn Engineering

Date: 2/1/2018

N

0 0.5 1 2 Miles

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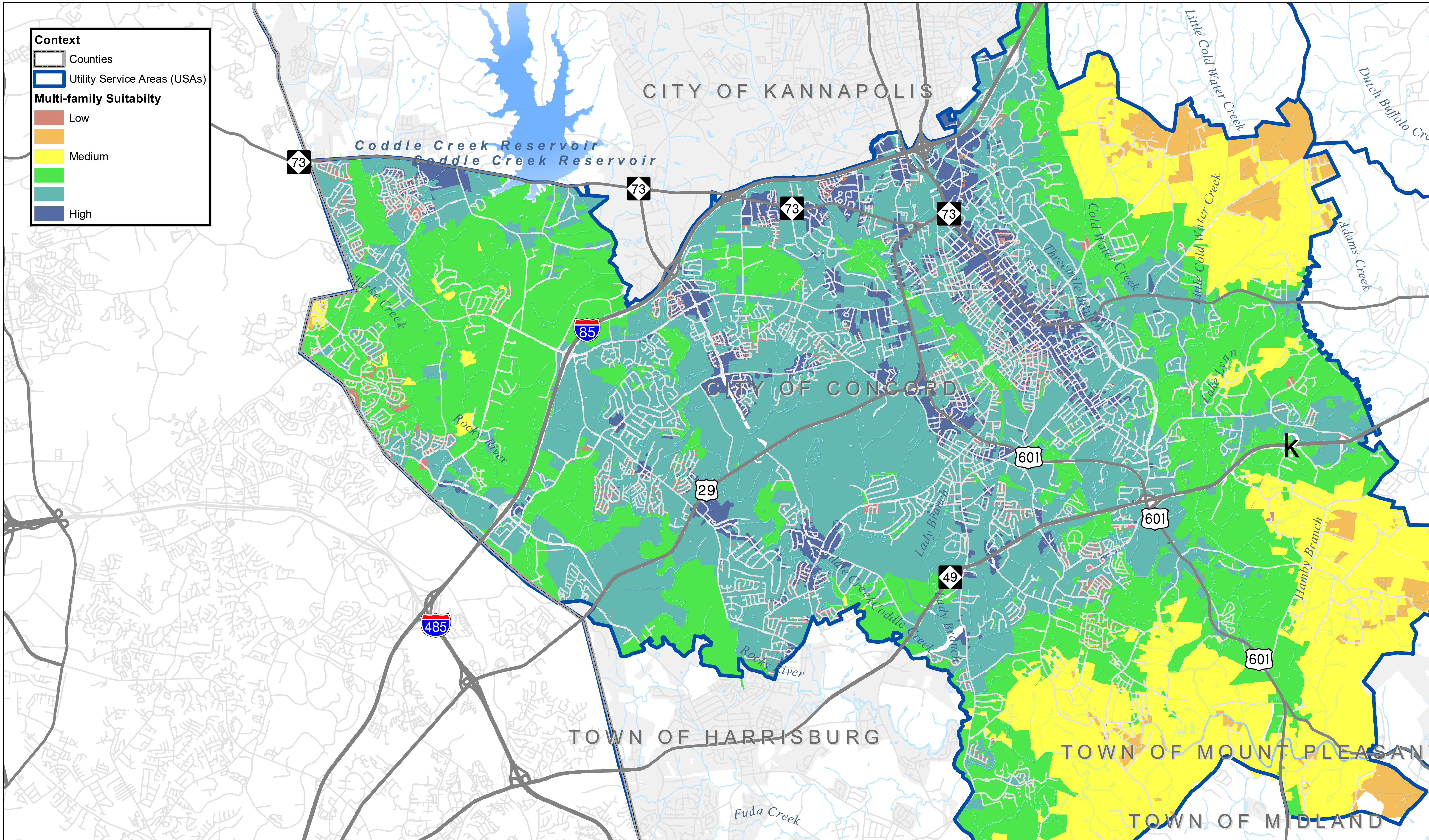

FIGURE 12
LAND USE SUITABILITY
CONCORD, NORTH CAROLINA

Date: 2/1/2018

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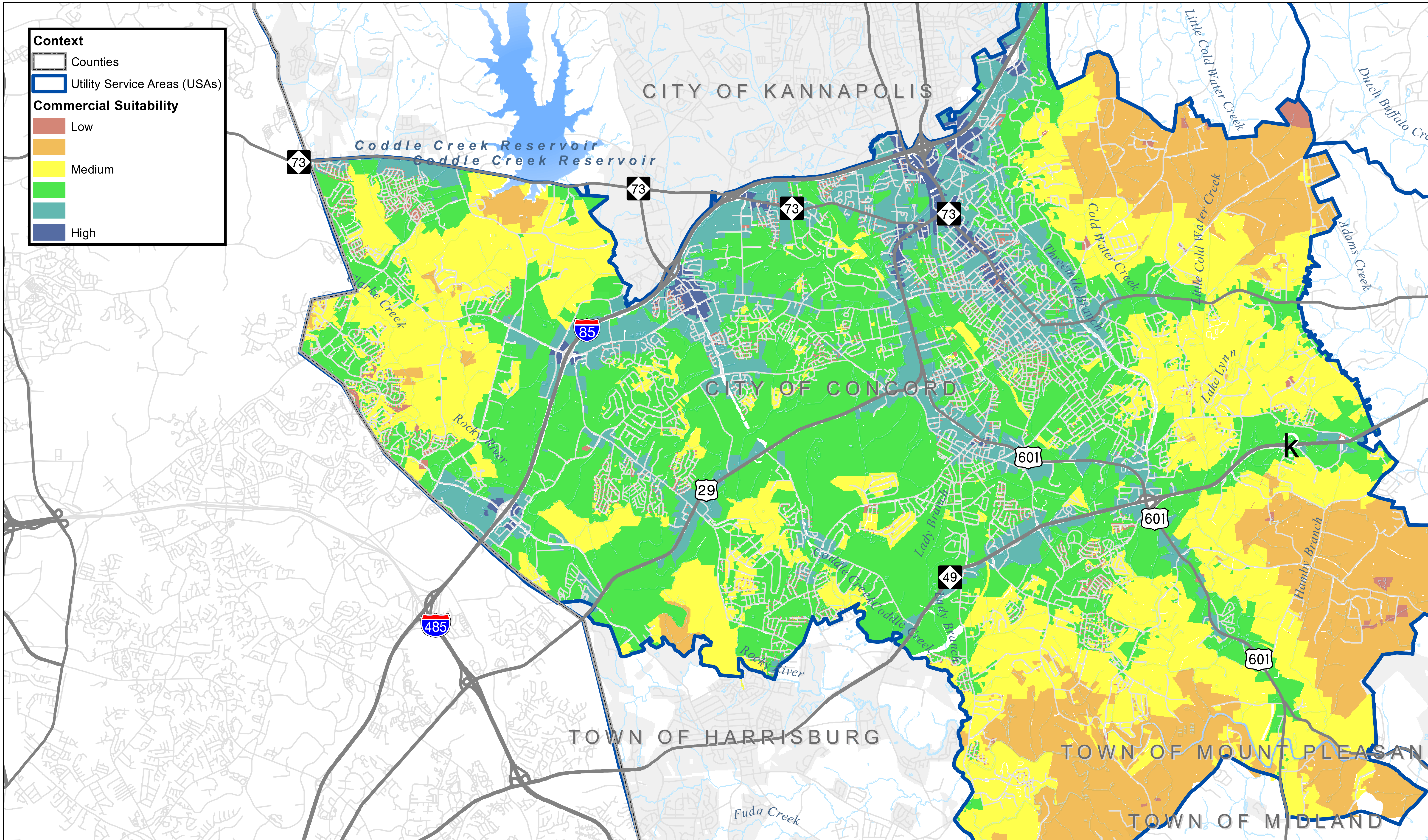

FIGURE 13

LAND USE SUITABILITY

CONCORD, NORTH CAROLINA

Date: 2/1/2018

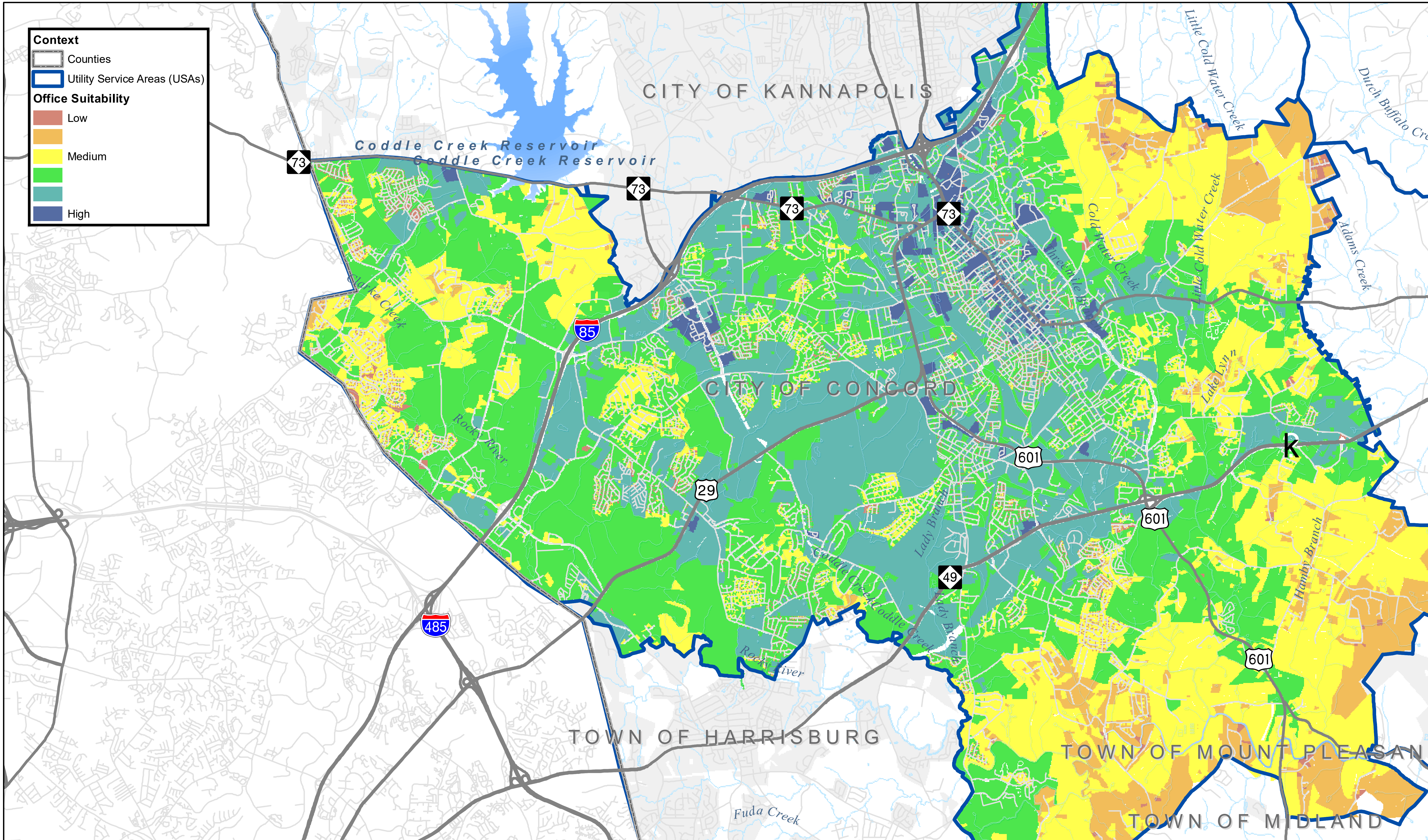

FIGURE 14

LAND USE SUITABILITY

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

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Date: 2/1/2018

0 0.5 1 2 Miles

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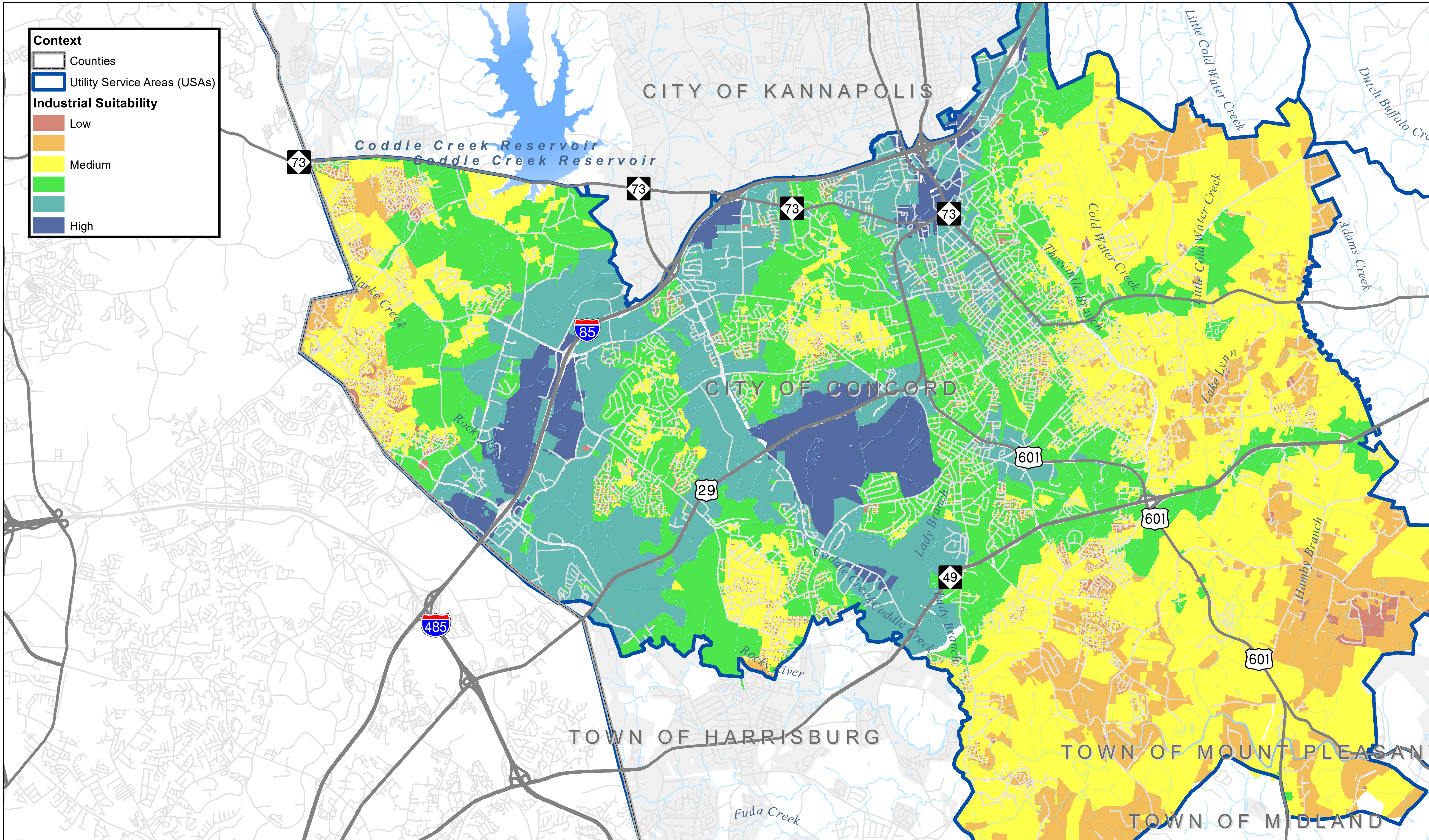

N
0 0.5 1 2 Miles

FIGURE 15

LAND USE SUITABILITY

CONCORD, NORTH CAROLINA

Date: 2/1/2018

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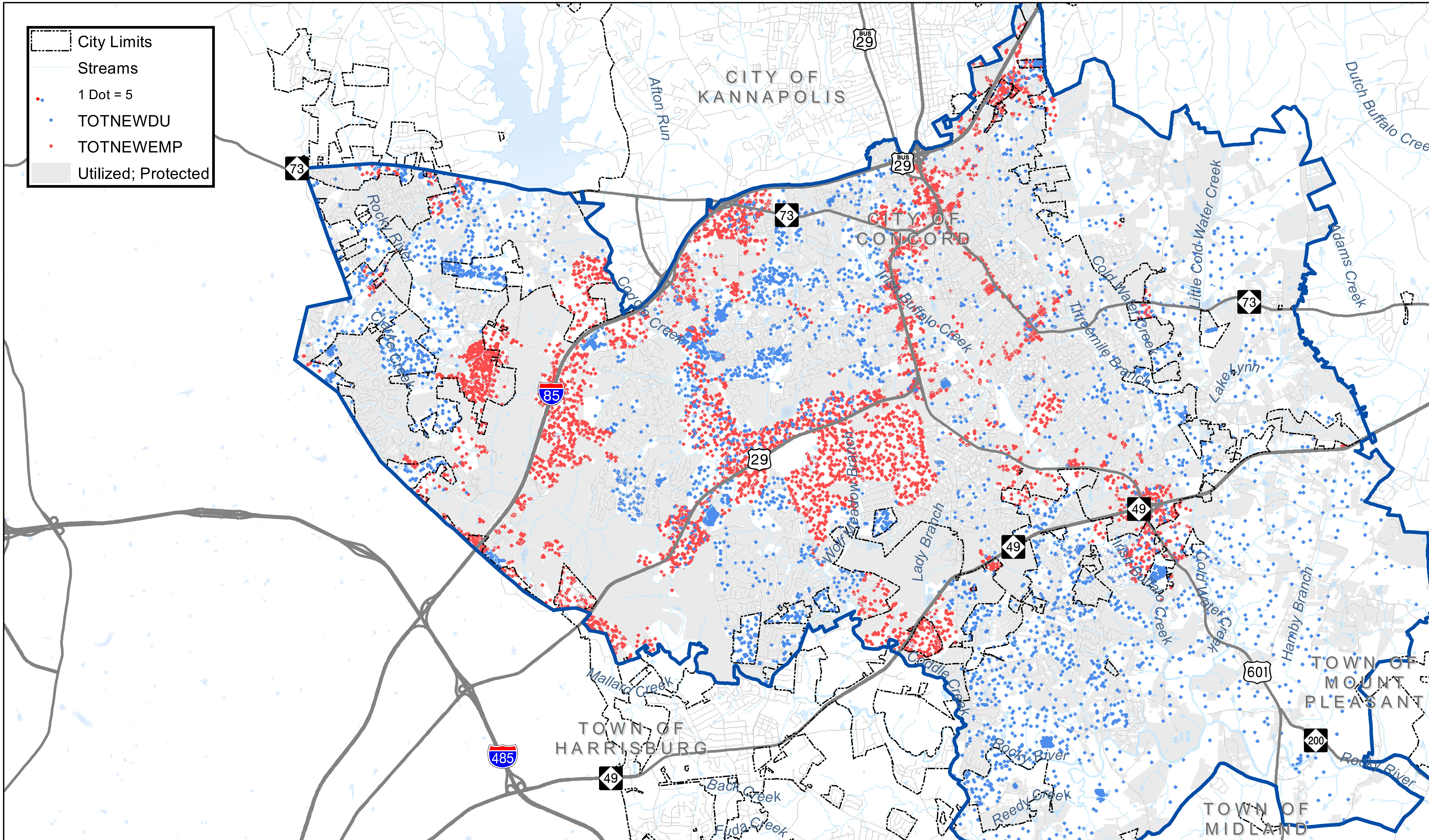

FIGURE 16

DRAFT FORECASTS

CONCORD, NORTH CAROLINA

Date: 2/1/2018

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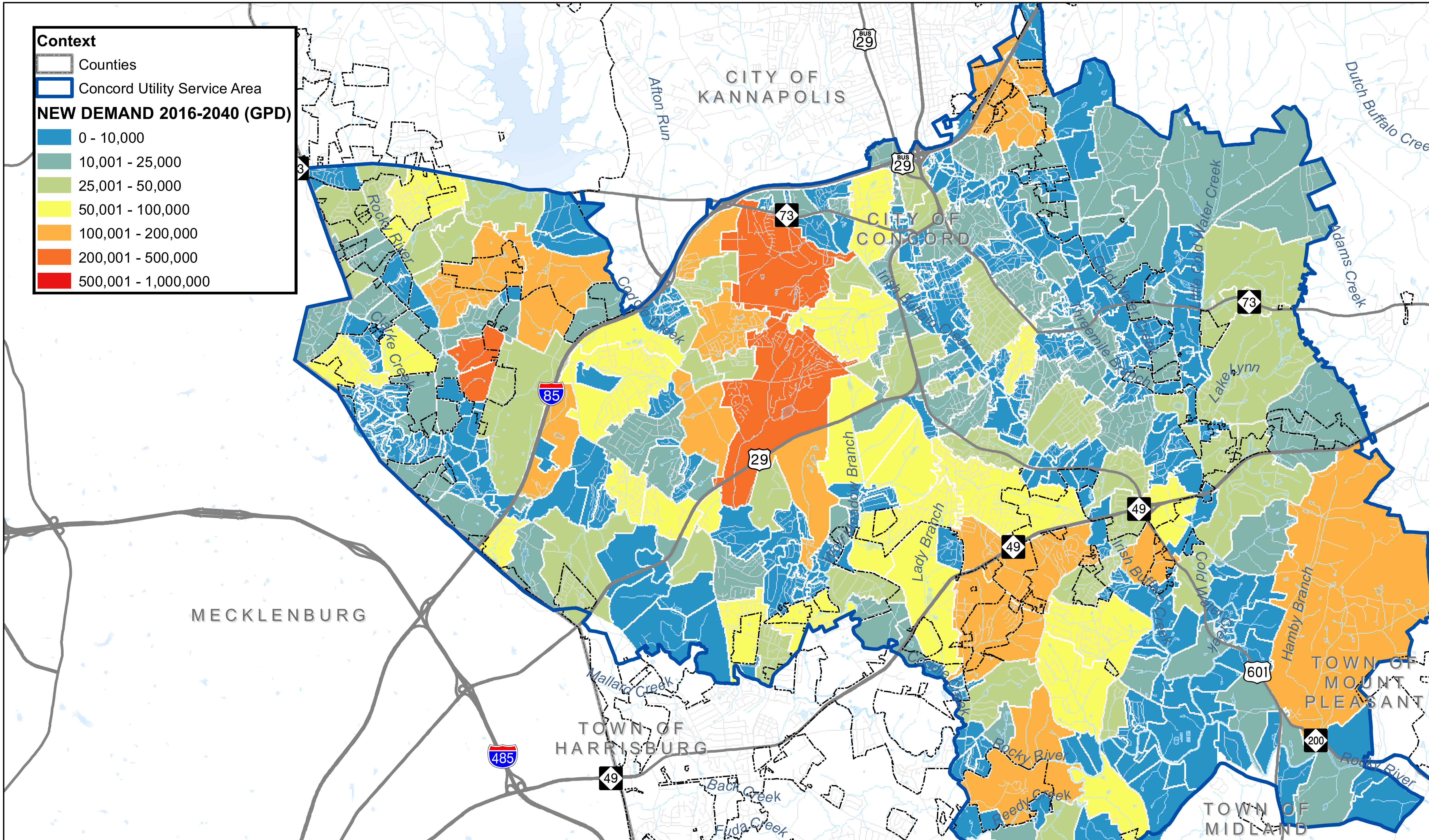

N

0 0.5 1 2 Miles

FIGURE 17
NEW SEWER DEMAND (2016-2040)
CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

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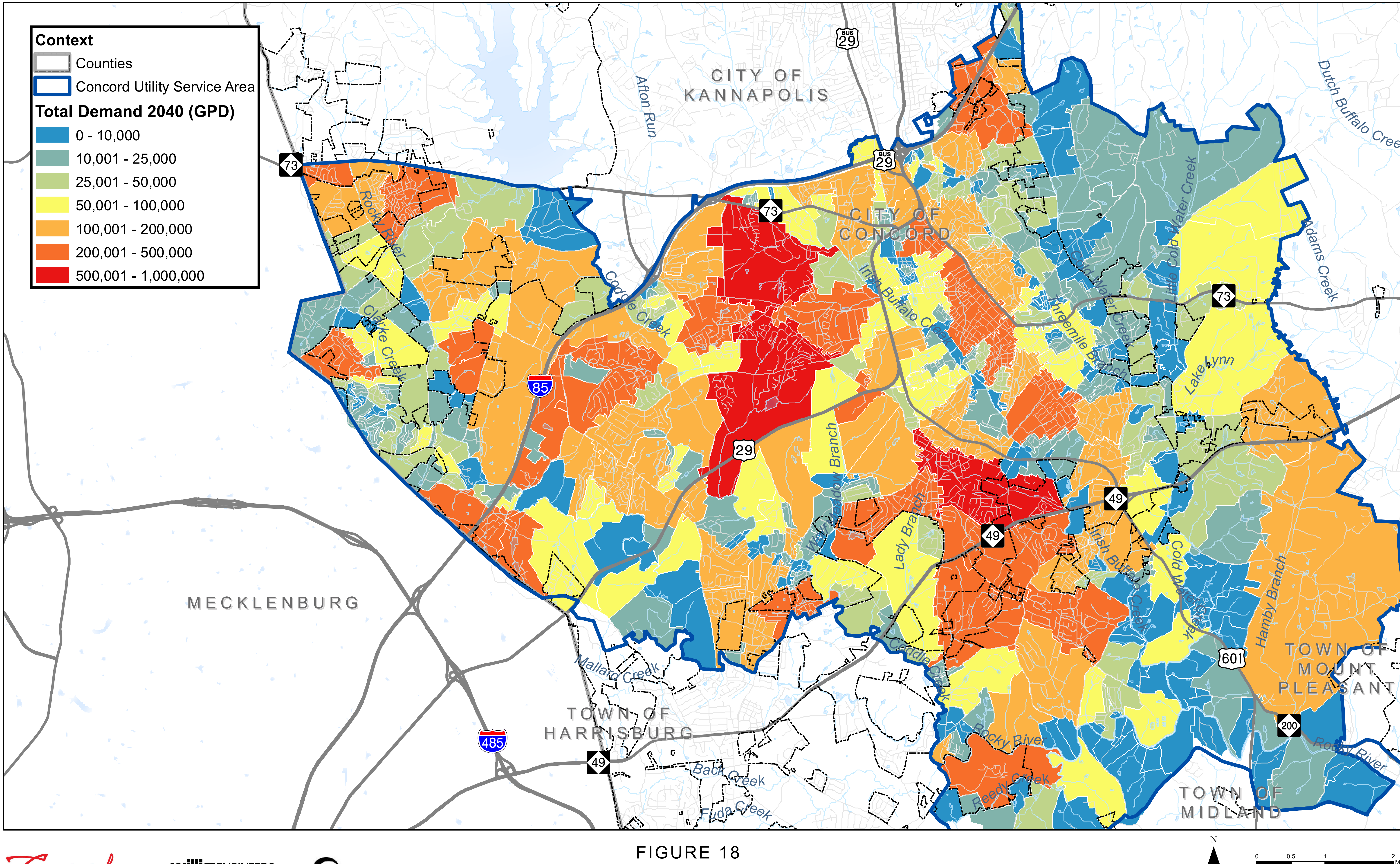

FIGURE 18

TOTAL SEWER DEMAND (2040)

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

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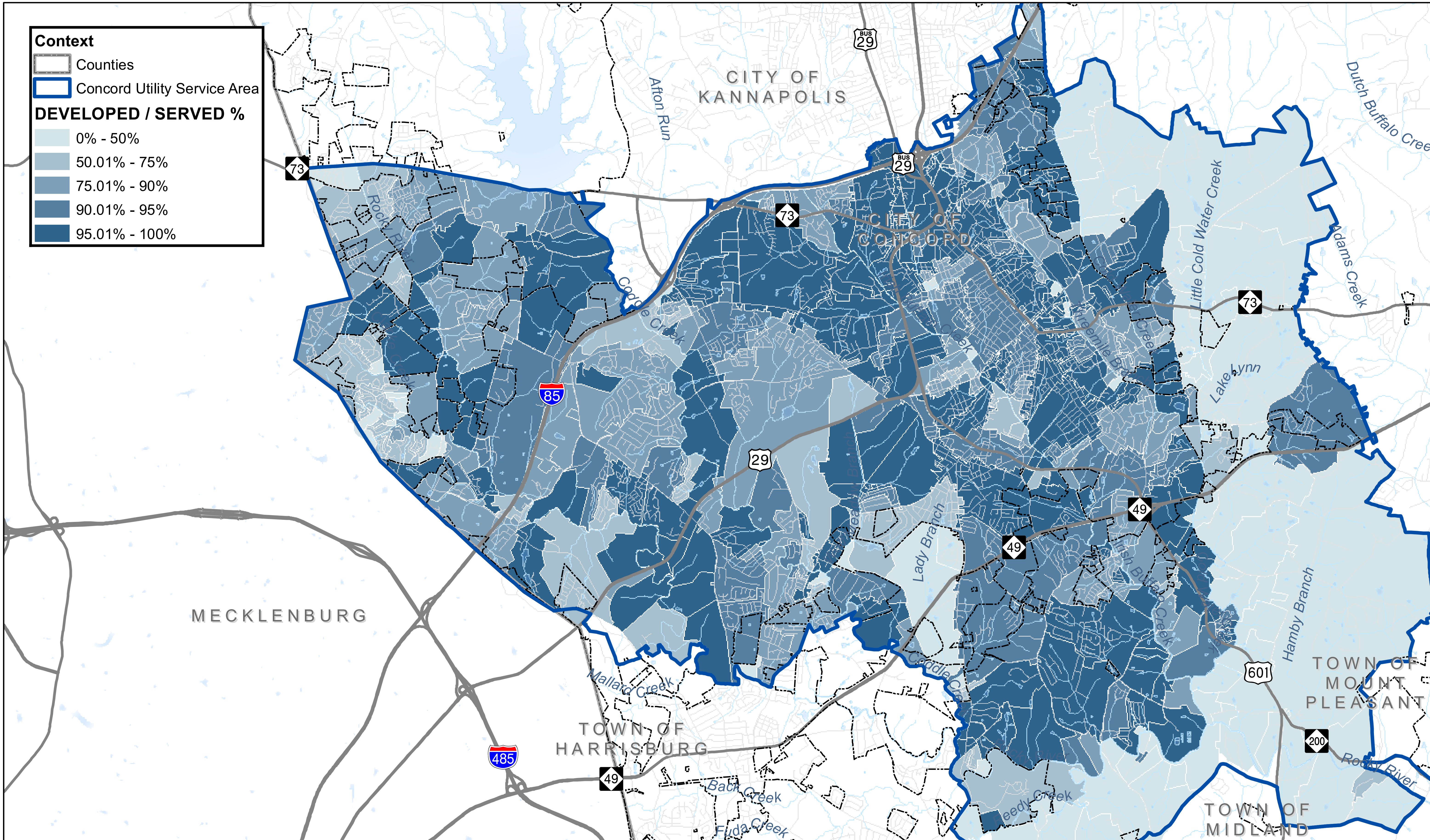

FIGURE 19

SERVED AREA (2040)

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

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5 Wastewater Conveyance Model

In order to accurately describe the performance of the existing wastewater facilities, Gavel & Dorn of the Project Team developed a computer hydraulic model of the portion of Concord's sanitary sewer collection system. The model was developed using InfoWorks ICM. InfoWorks is a fully dynamic model utilizing a graphical interface with the capabilities of modeling both separate and combined sewer systems.

5.1 Hydraulic Model Development

In general, only collector sewers containing pipes greater than 12-inches in diameter, based on available GIS, are included in the developed model. Furthermore, WSACC's trunk sewers are not included in the model. The portion of Concord's system modeled are highlighted in Figure 1. Figure 1 also shows the model subcatchments and locations of the various flow meters used to calibrate model. The results of the flow metering study are presented in Section 3.

The bulk of the data for the model is contained in 2 components: (1) the sewer network, and (2) the model subcatchments (sub basins). The sewer network represents the physical model components. In the case of the City of Concord model, the network includes conduits (pipes) and nodes (manholes). The conduits and nodes for the model were imported directly from the City of Concord GIS files.

5.1.1 GIS Data Import

The model is built by importing data from GIS. An initial review of Concord GIS data indicated over 80% of the manholes were missing elevation data (rim and/or depths) which are critical model parameters. In addition, a significant fraction of the pipe data was found to be missing invert, slope or size information. Finally, the data in the GIS was based on Record Drawings using different survey benchmarks, resulting in significant discontinuities in sewer profiles.

The City of Concord subsequently undertook a project collecting missing manhole rim and depth information and provided updated GIS data prior to model import. For those manholes that were still missing a rim elevation or a rim elevation that was on a different datum, Gavel & Dorn used available County LIDAR mapping data for estimating the rim elevations. Measured depth information, if available, was maintained. Finally, remaining discontinuities and reverse grade pipes were manually adjusted in the model. Gavel & Dorn recommends that the City continue to collect survey grade asset inventory information to refine the model and other uses.

A Mannings 'n' value of 0.013 was assumed throughout.

5.1.2 Model Development

Sewer basins are represented in the model by several smaller basins called "Subcatchments" which generate sewerage flow for the model. Model subcatchments correspond to the City of Concord sub-basin boundaries. Therefore, each model sub-basin, in general, corresponds to a connection to WSACC's trunk sewer. Flows from model sub-basins were, in general, loaded to the modeled collection system at a manhole closest to the centroid of the sub-basin polygon area.

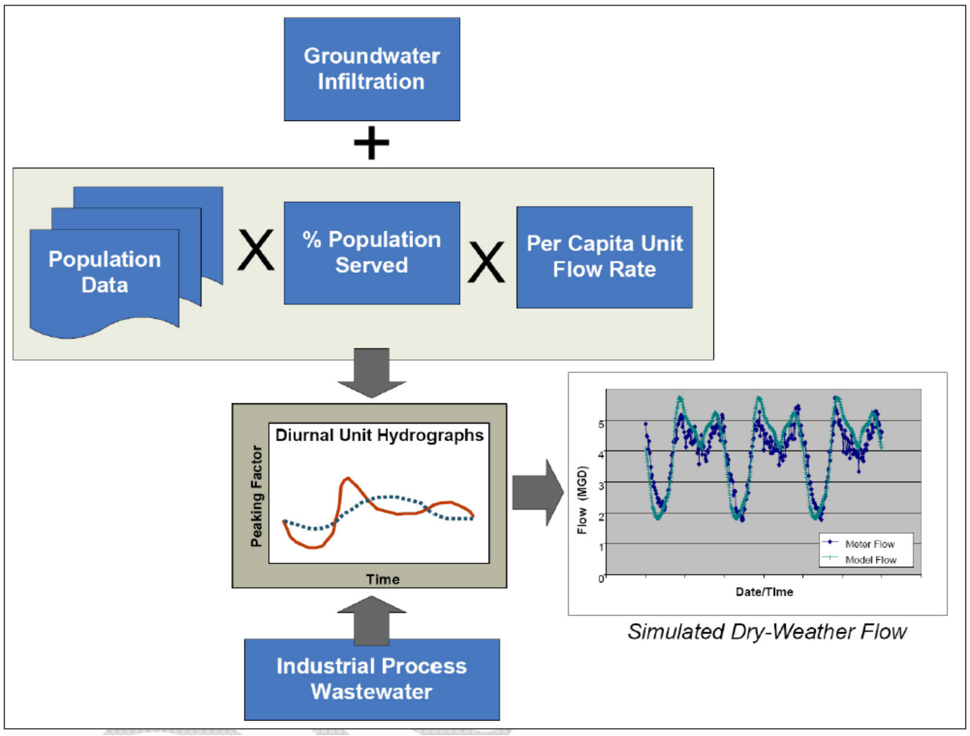

Figure 2. Graphic illustrates elements of the IWICM model to simulate dry weather

Critical subcatchment parameters related to sewer flow include: *population*, *per capita unit flow,* and *percent served* as illustrated in Figure 2.

1. *Population* fields represent residential and commercial populations by consolidating them into an equivalent residential population (ERP) using a typical unit flow rate.

2. The *per capita unit flow* assumed for this model was 60 gpcd. Significant industrial sewer flows (i.e., flows more than 50,000 gpd) are represented in the model as point loads to manholes and are not linked to population fields.

3. *Percent served* refers to the percent of the total subcatchment population served by the sewer system. This parameter was adjusted during the model calibration phase.

4. The timing of the sewerage flow into the model is controlled using diurnal unit hydrographs stored in the model as "Waste Profiles". Each subcatchment can be assigned a unique waste profile to represent the flow patterns in the smaller basins.

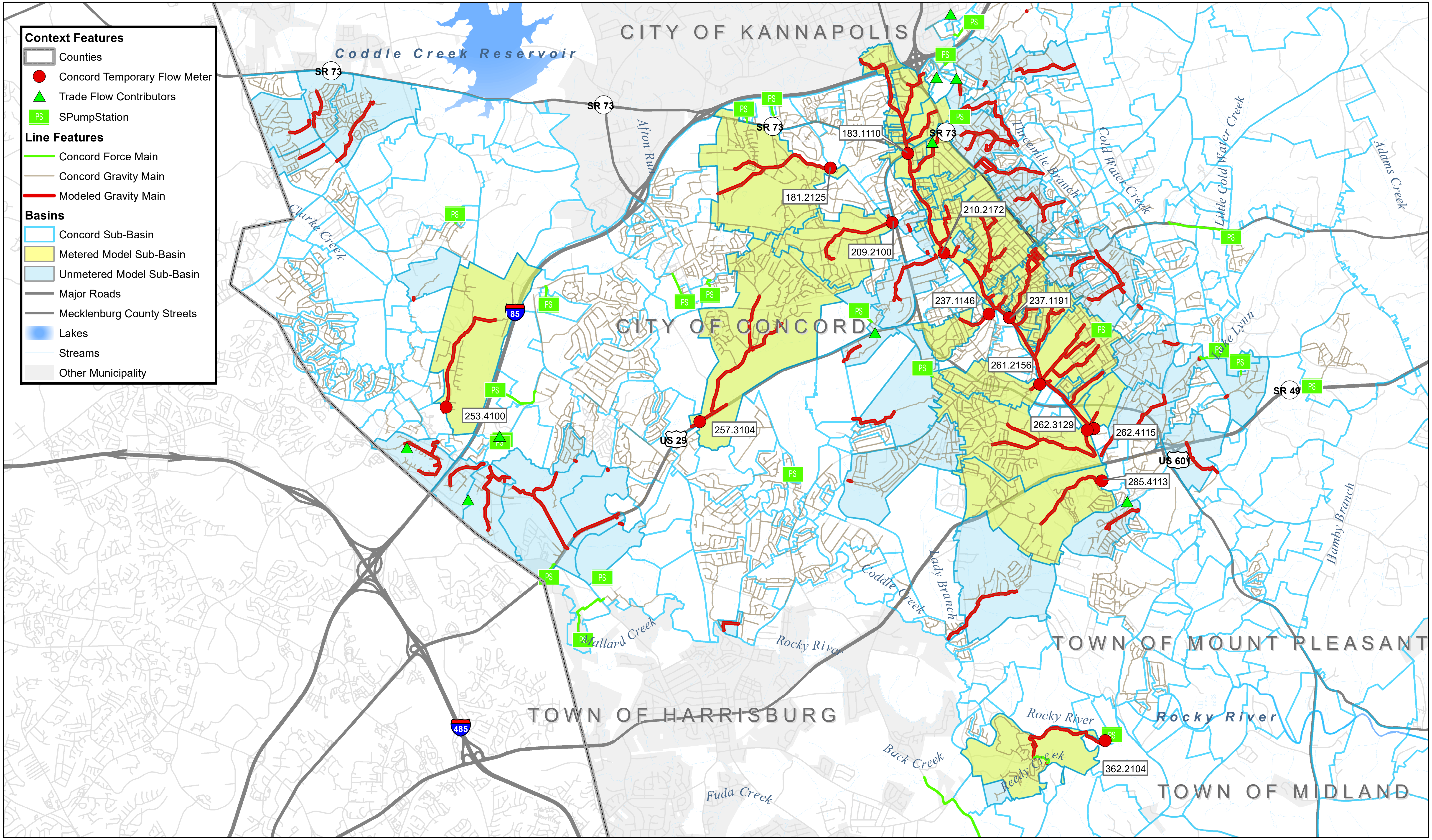

FIGURE 1: MODELED AREA MAP

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

Date: 2/1/2018

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5.1.3 Groundwater Infiltration

Groundwater infiltration (GWI) is defined as groundwater entering the collection system through defective pipes, pipe joints, and manhole walls. The magnitude of GWI is dependent on the depth of the groundwater table above the pipelines, the percentage of the system that is submerged and the physical condition of the system. GWI fluctuates throughout the year due to the seasonal nature of groundwater levels with maximum flows typically occurring in the late spring and minimum flows typically occurring in the fall (October). While GWI is also affected by rainfall, it responds gradually and is not directly related to any individual rainfall event. Therefore, dry weather flow (DWF) is comprised of both base wastewater flows and GWI.

For this study, GWI was approximated as a percentage (75%) of the minimum nighttime flows during the monitoring period. GWI was calculated in units of gpm per inch-diameter-mile of sewer for each of the flow meters. This amount was then distributed to the model subcatchments based on the amount of sewer contained therein. GWI was initially set based on flow metering data but could vary as part of model calibration. A GWI rate of 100 gpd/in-diameter-mile is used for unmetered subcatchments. Calibrated GWI values were carried forward to the future buildout modeling scenarios and not increased.

5.1.4 Industrial Process Wastewater

A direct input of flow to the model is provided for major industrial flow contributors. Major industrial contributors are defined as greater than 50,000 gpd and are modeled as separate inputs (point loads) to the model (i.e., population and unit flow factors are not used). Table 1 lists the major industrial users included in the model and their associated flow rates under existing and future conditions.

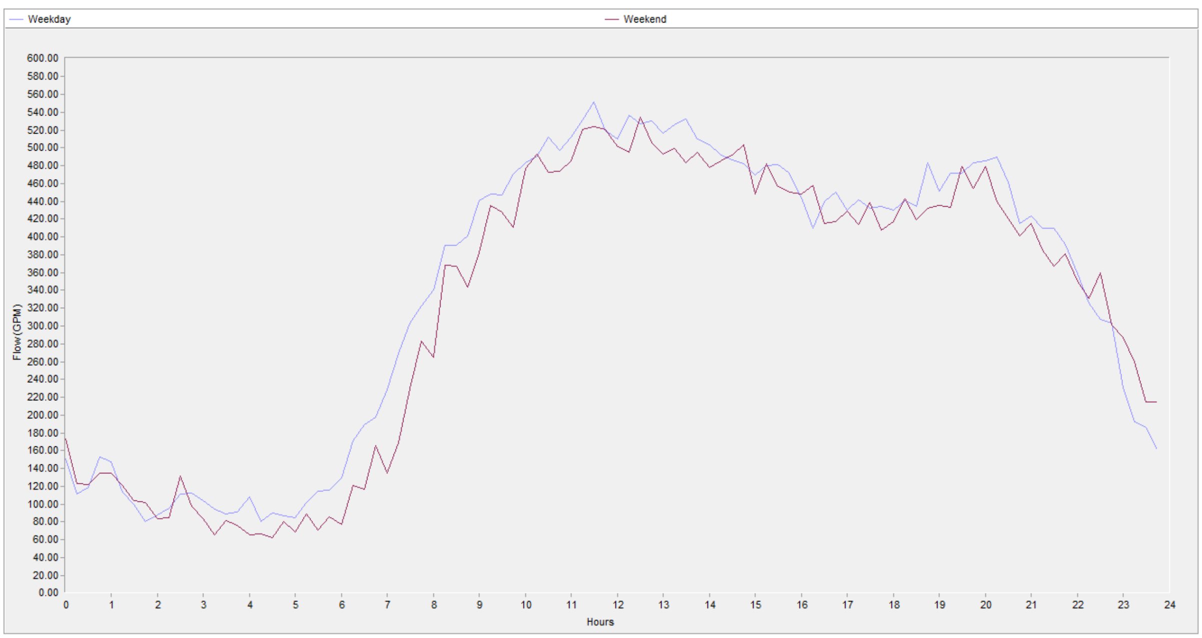
Table 1. Major Industrial Users in Model

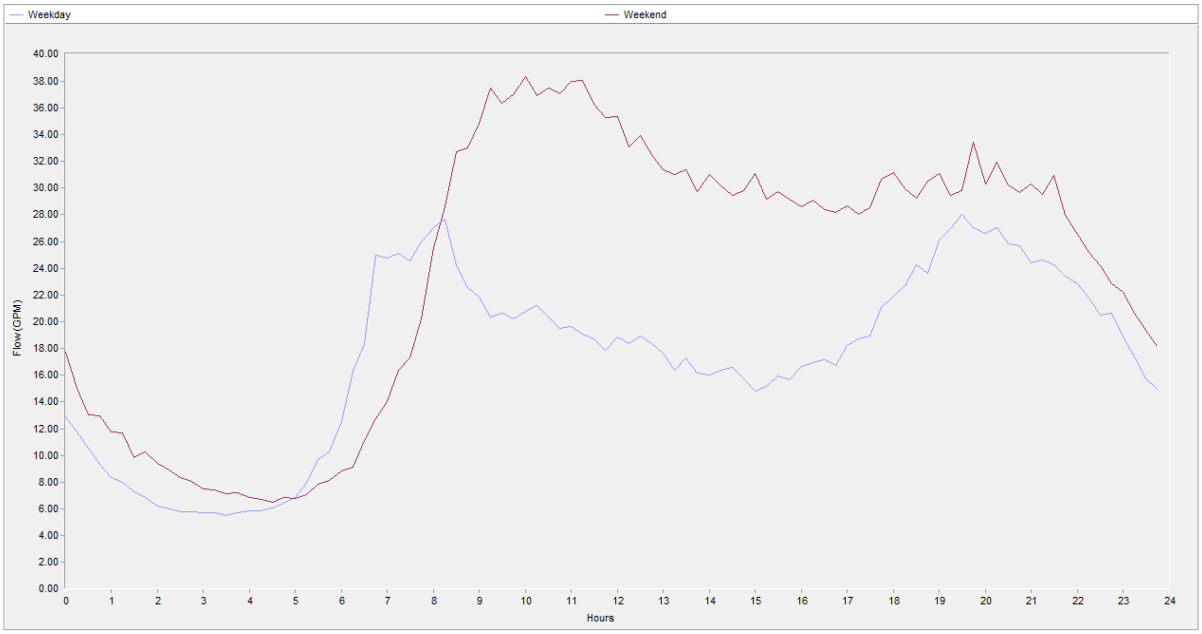
Industry	Flow (MGD)	Subcatchment
Purdue Farms, Inc.	0.312	STBC0800NE
Great Wolf Lodge	0.116	ROC5200SW
Concord Mills Mall	0.052	ROCT10100SW
Unknown Contributor	0.042	WMC1500NE

5.1.5 Diurnal Curves (Waste Profiles)

Dry weather diurnal curves were developed for each of the temporary flow meters and were assigned to the respective model subcatchments. Diurnal curves were developed for both weekend and weekday days. The diurnal curve of given subcatchment could vary from profile to profile as necessary to achieve model calibration to observed dry weather flow. For unmetered subcatchments, the diurnal curve was assigned based on the percentage of the subcatchment that was residential as illustrated in Figure 3.

Figure 3. Graphic illustrates diurnal curves used in unmetered subcatchments based on the percentage residential of the subcatchment. From left the curves correspond to (1) <33%, (2) 33-66%, and (3) >66%.





5.1.6 Population

Existing and future population data for the model were derived from wastewater flow projections as discussed elsewhere. Sewer flow projections are based on water demand data for City water accounts within 1,200 ft of existing sewers. This analysis assumes all residences within 1,200 ft would be connected to the sewer. Water demands from water accounts that are in the subcatchment but more than 1,200 ft from existing sewer are not considered to be contributing to sewer flow. For those sewer accounts within 1,200 ft of an existing sewer, there are no consumptive losses (e.g., irrigation) incorporated into the given sewer flows. Therefore, the initial model assumed 100% of the projected flow entered the system. Percent connected was adjusted during model calibration, as discussed above.

Population categories are consolidated into a single equivalent residential population (ERP) to simplify data management and ease of use. The ERP is determined by converting the non-residential population to residential population based on a typical unit flow rate. This allows the user to assign a per capita unit flow rate of 60 gpd to each subcatchment. Therefore, a per capita flow rate of 60 gpcd was assumed throughout the existing and future conditions analysis and was not used as a model calibration parameter.

5.1.7 Percent Served (Connectivity)

Connectivity in the model subcatchments refers to the percent of the total population served by the sewer system. Connectivity was used as a model calibration parameter. For future conditions, all increases in flow in each subcatchment were assumed to be connected to the sewer system.

5.1.8 Contributing Area

This parameter represents the area of the subcatchment that is contributing to sources of infiltration and inflow (I/I). It represents the portion of the drainage area that is sewered. For this analysis, it was assumed that all parcels within 1,200 ft of an existing sewer main were part of the contributing area. Under future conditions, 100 percent of the subcatchment area was assumed to be contributing to I/I (representative of future build out).

5.1.9 Model Outfalls

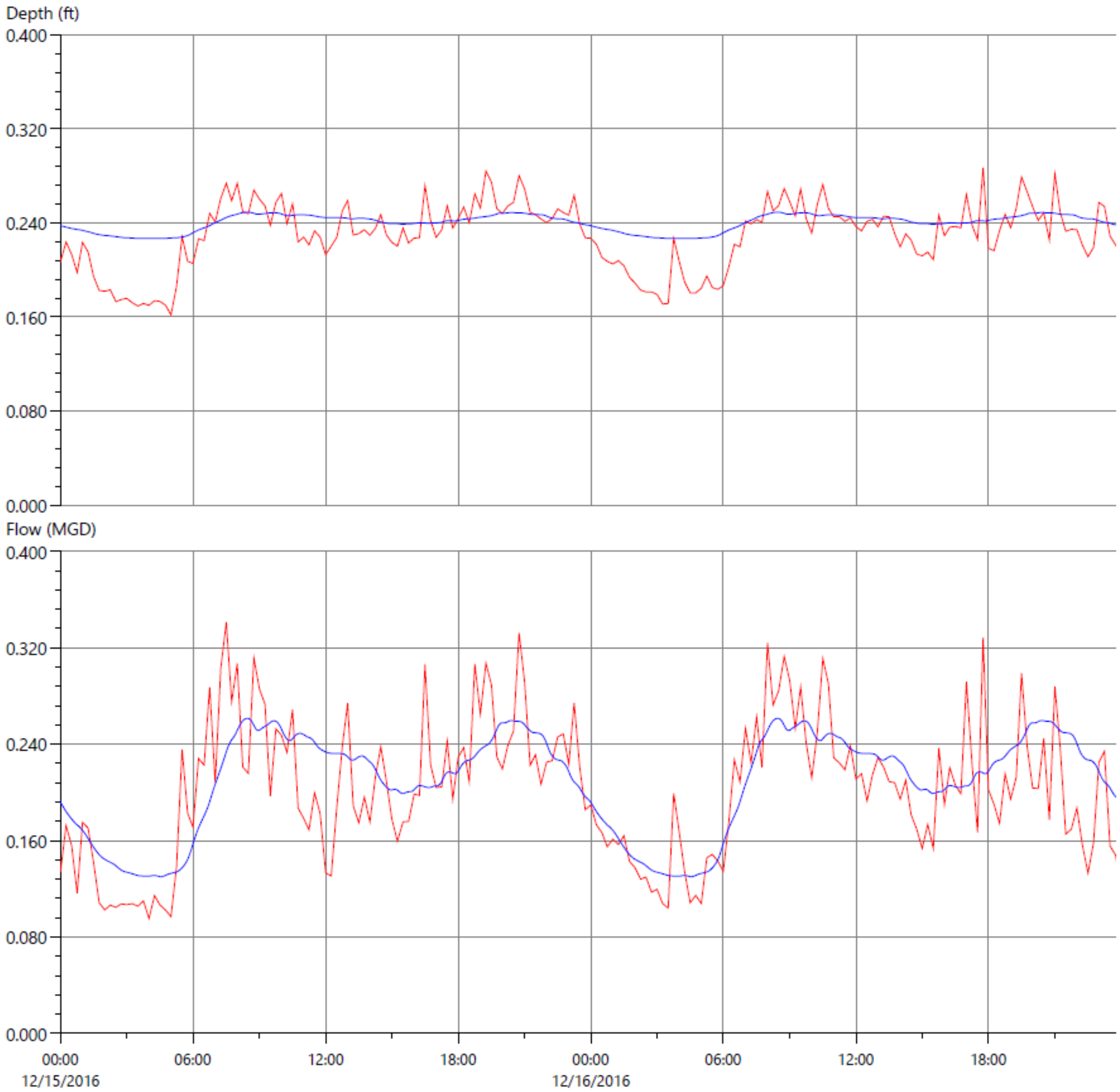
The most downstream model manhole in a continuous run of pipe is referred to as the outlet manhole or "outfall". The outlet is modeled by supplying an assumed water surface elevation. It is important to model the outlet accurately because the level at the outlet can affect levels upstream due to backwater effects. In this case, the outlet is a manhole on the WSACC trunk line. It is our understanding, which is verified by the flow metering data, that the flow level in the WSACC trunk sewer is not currently causing significant backwater effects into Concord's sewer system. Therefore, in general, Gavel & Dorn assumed a water level at each outfall equal to 50 percent of the associated model pipe diameter. However, under planning year 2040 during the 10-year design storm simulation, Gavel & Dorn assumed a water level equal to the model pipe diameter for conservatism.

5.2 Model Calibration

Model calibration to existing conditions is based largely on the temporary flow metering study performed by Concord staff from early November/December 2016 to late April 2017. The flow monitoring period was extended to try to capture additional rainfall. The City installed and maintained thirteen (13) temporary flow meters within their sanitary sewer collection system.

Dry weather modeling results were compared to observed flows at the thirteen-meter locations. The model is calibrated to observed depth, peak flow, and volume. Dry weather model calibration targets for each are noted at the top of Table 2. Table 2 also summarizes the results of the dry weather model calibration. The calibration targets were generally met for dry weather flow within the specified tolerances except at meter locations 183.1110 and 210.2172 which exceed 10%. Meter 183.1110 is located upstream of meter 210.2172. The model is predicting less flow than observed at the upstream meter, and more flow than observed at the downstream meter. Therefore, improving the calibration at one meter causes the other meter's model error to increase. We believe there was a problem with the flow metering data at one or both locations. Table 2 also indicates the final calibrated percent served for each associated model subcatchment, which varied from 25 to 100 percent. An example hydrograph illustrating model calibration under existing dry weather conditions is shown in Figure 4.

Table 2: Dry Weather Flow Model Calibration Data													
					MAX DEPTH (FEET)			PEAK FLOW (MGD)			VOLUME (MG)		
	UP.	EST.	PERCENT	CALIBRATED	Goal: +/- 0.3ft of Observed			Goal: +/- 10% of Observed			Goal: +/- 10% of Observed		
METER	METER	POP.	SERVED	(YES/NO)	OBS.	MODEL	DIFF	OBS.	MODEL	% DIFF	OBS.	MODEL	% DIFF
181.2125	N/A	2,462	91%	YES	0.165	0.238	-0.07	0.239	0.252	5%	0.248	0.272	10%
183.1110	N/A	3,455	100%	NO	0.323	0.262	0.06	0.793	0.355	-55%	0.976	0.475	-51%
209.2100	N/A	1,630	25%	YES	0.129	0.133	0.00	0.040	0.042	5%	0.050	0.055	10%
210.2172	183.1110	2,630	100%	NO	0.538	0.403	0.14	0.932	1.031	11%	1.325	1.698	28%
237.1146	N/A	617	82%	YES	0.181	0.131	0.05	0.042	0.045	7%	0.059	0.064	8%
237.1191	N/A	3,856	90%	YES	0.349	0.353	0.00	0.326	0.336	3%	0.478	0.524	10%
253.4100	N/A	495	100%	YES	0.147	0.140	0.01	0.065	0.062	-5%	0.064	0.066	3%
257.3104	N/A	3,625	61%	YES	0.260	0.245	0.02	0.208	0.217	4%	0.295	0.322	9%
261.2156	N/A	1,104	38%	YES	0.107	0.126	-0.02	0.045	0.048	7%	0.049	0.053	9%
262.3129	N/A	4,207	64%	YES	0.287	0.249	0.04	0.252	0.262	4%	0.378	0.414	10%
262.4115	237.1191	5,061	47%	YES	0.368	0.410	-0.04	0.613	0.632	3%	0.948	1.038	10%
285.4113	N/A	1,772	95%	YES	0.183	0.192	-0.01	0.147	0.154	5%	0.219	0.238	9%
362.2104	N/A	612	100%	YES	0.184	0.148	0.04	0.066	0.063	-5%	0.073	0.073	0%



	Depth		Flow		
	Min (ft)	Max (ft)	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.162	0.287	0.095	0.341	0.403
...ng Conditions DWF	0.227	0.249	0.130	0.261	0.414

Figure 4. Example model calibration to depth and flow. Red line is the flow meter data and the blue line is the model result.

Calibration of the model to wet weather conditions is a more time-consuming iterative process than calibration to dry weather. The model simulates runoff from each subcatchment based on a runoff surface and three triangular unit hydrographs. The method is similar to unit hydrograph methods that are commonly used to simulate flow in stormwater runoff.

The method is based on fitting three triangular unit hydrographs to an actual hydrograph. A unit hydrograph is defined as the flow response that results from one unit of rainfall during one unit of time. A unit hydrograph is fully defined by the following parameters:

1. **R-value** – R is the fraction of rainfall entering the system as rainfall-derived infiltration and inflow (RDII). The sum of the three unit hydrographs must total the observed R value for the given rain event.
2. **T** – is the time to peak of the RDII flow.
3. **K** – is the recession coefficient and is the ratio of the time of recession to the time of peak.

The unit hydrograph concept is illustrated in *Figure 5*. A single unit hydrograph is insufficient to simulate I/I complex response to a unit of rainfall (P). As a result, three unit hydrographs are used as illustrated in *Figure 6*.

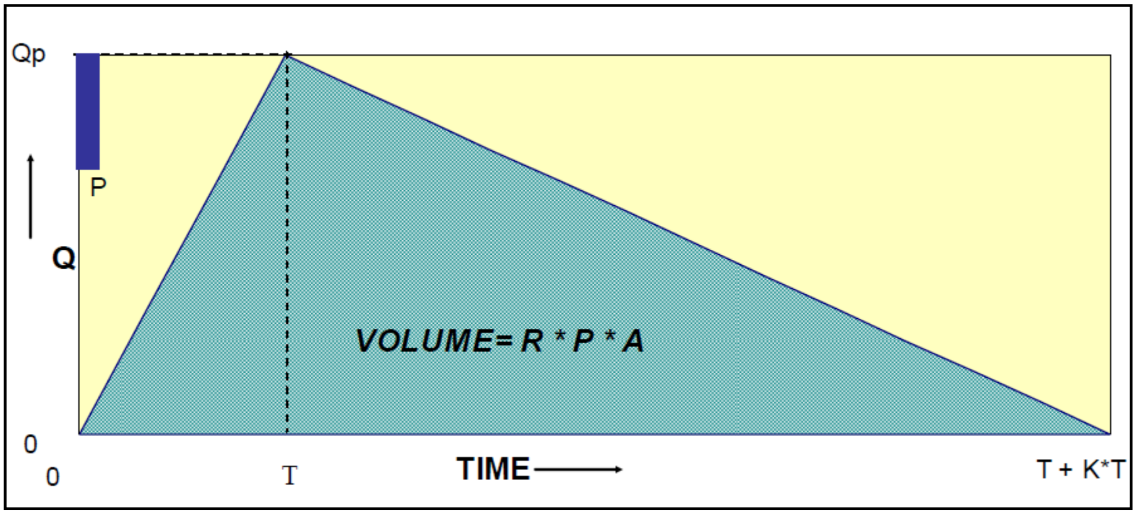


Figure 5. Example of a triangular unit hydrograph (EPA 2007).

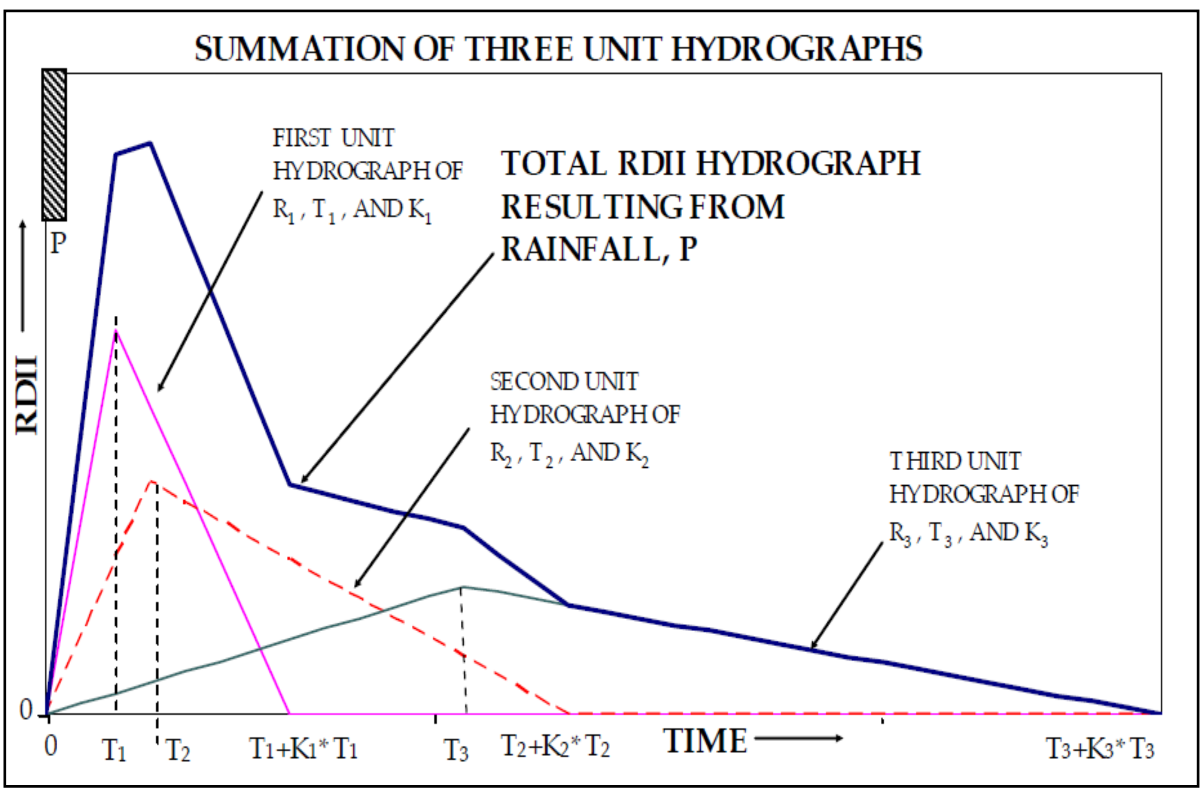


Figure 6. Summation of three unit hydrographs to simulate RDII response to a unit of rainfall in a sewer system (EPA 2007).

Model calibration to wet weather flow, therefore, is a complex process involving the adjustment of the parameters R, T, and K until a satisfactory match to observed conditions is achieved.

The model was calibrated based on a significant rain event that occurred on January 22, 2017, which included antecedent moisture associated with a prior rain event. Model calibration results are presented in Table 3. Wet weather model calibration targets are provided at the top of the Table. In general, the model calibrated to wet weather conditions satisfactorily, except at sites 183.1110 and 210.2172 for the same reasons as discussed above. To achieve model calibration, the R-value was adjusted. Final calibrated R values are also listed in Table 3.

Table 3: Wet Weather Model Calibration Event: 1/22/2017 - 1/24/2017

				MAX DEPTH (FEET)			PEAK FLOW (MGD)			VOLUME (MG)		
				Goal: +/- 0.3ft of Observed			Goal: -15% to +25% of Observed			Goal: -10% to +20% of Observed		
METER	US METER	R TOTAL	CALIBRATED (YES/NO)	OBS.	MODEL	DIFF	OBS.	MODEL	% DIFF	OBS.	MODEL	% DIFF
181.2125	N/A	0.0070	YES	0.260	0.354	0.09	0.775	0.759	-2%	0.820	0.818	0%
183.1110	N/A	0.0240	NO	0.439	0.600	0.16	2.345	2.112	-11%	2.076	1.238	-40%
209.2100	N/A	0.0022	YES	0.303	0.226	0.08	0.270	0.237	-12%	0.167	0.153	-8%
210.2172	183.1110	0.0130	NO	0.565	0.694	0.13	1.474	3.116	111%	2.743	3.475	27%
237.1146	N/A	0.0080	YES	0.330	0.310	0.02	0.308	0.309	0%	0.178	0.160	-10%
237.1191	N/A	0.0225	YES	0.522	0.562	0.04	1.115	1.033	-7%	1.378	1.529	11%
253.4100	N/A	0.0040	YES	0.395	0.377	0.02	0.531	0.511	-4%	0.391	0.362	-7%
257.3104	N/A	0.0070	YES	0.434	0.393	0.04	0.553	0.557	1%	0.861	0.861	0%
261.2156	N/A	0.0084	YES	0.224	0.348	0.12	0.369	0.435	18%	0.217	0.205	-6%
262.3129	N/A	0.0080	YES	0.453	0.389	0.06	0.767	0.786	2%	0.946	1.057	12%
262.4115	237.1191	0.0250	YES	0.761	0.596	0.17	3.409	2.951	-13%	3.754	3.924	5%
285.4113	N/A	0.0040	YES	0.243	0.286	0.04	0.407	0.416	2%	0.534	0.556	4%
362.2104	N/A	0.0006	YES	0.211	0.175	0.04	0.125	0.106	-15%	0.129	0.123	-5%

5.3 Capacity Assessment

The calibrated model of the Concord sanitary sewer system was used to assess the modeled system under various flow conditions. The peak flows result from projected growth and wet weather flows resulting from infiltration and inflow(I/I). This section discusses the capacity assessment of the existing system under existing and future dry and wet weather conditions.

5.3.1 Design Storm Events and Performance Criteria

For existing and 2040 planning conditions, the modeled system was analyzed under peak flows resulting from a large design storm event. The design storm event tests the system's ability to convey peak wet weather flows, and the rainfall frequency provides an indication of how likely a given flow is to occur. For this study, the performance criteria used were to allow the system to surcharge during a 2-year rain event to within 1.5 feet of the rim (i.e.,1.5 feet of freeboard) and to not allow overflows during a 10-year storm. If either condition is violated, improvements or additional assessments are recommended. Design rain event statistics are summarized in Table 4.

Table 4. Design Storm Event Statistics[1]

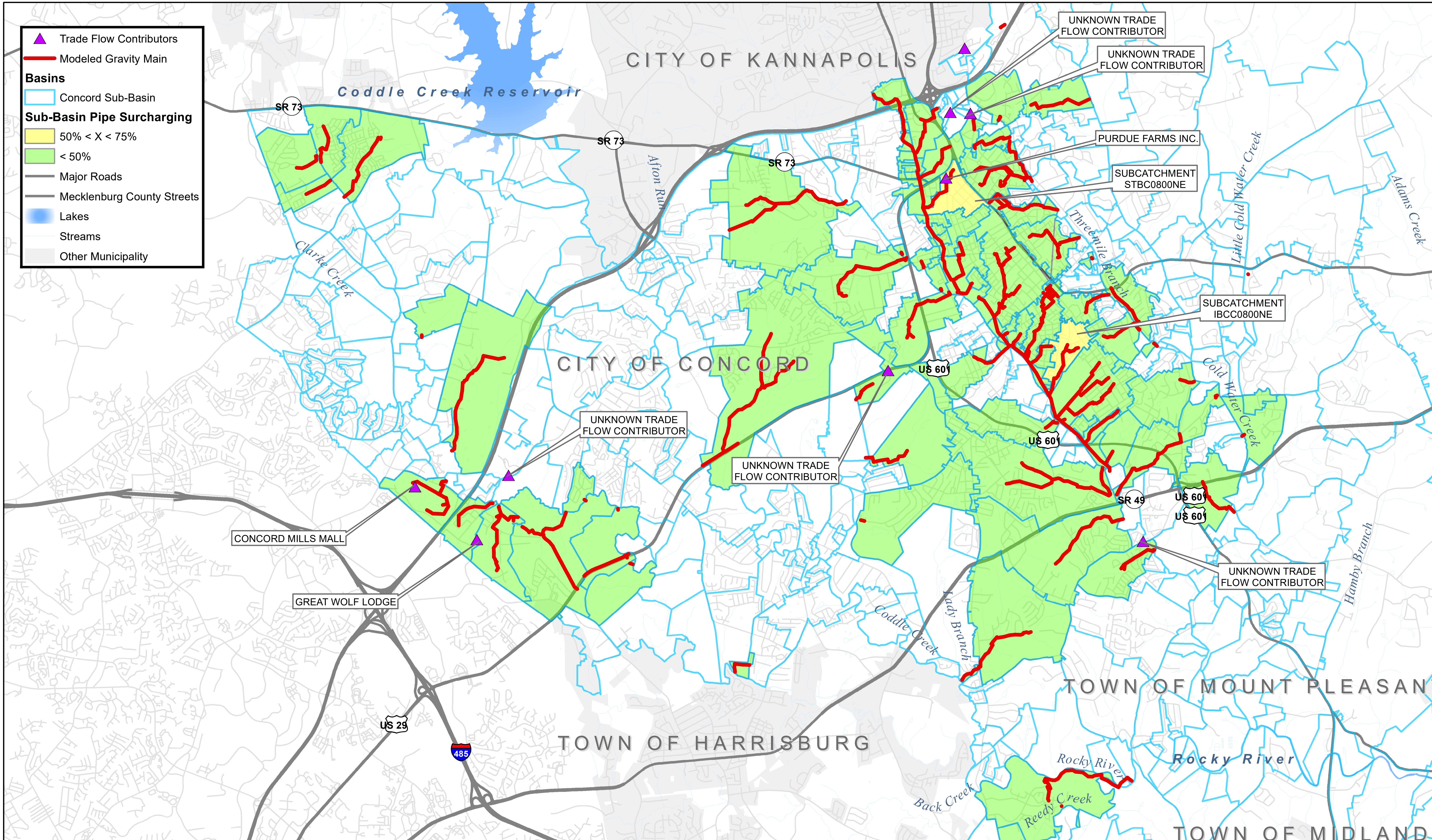
Recurrence Interval	Total Depth (inches)	Peak Intensity (in/hour)	Duration (hours)
2-Year	3.5	2.66	24.0
10-Year	5.1	3.87	24.0

[1] City of Concord Technical Standards Manual, Article 1, Stormwater

5.3.2 Existing Conditions

The developed calibrated model was run under existing conditions for both wet and dry conditions. The results of the dry weather run are summarized in Figure 7. Figure 7 indicates that only two sub-basins contained pipes that were flowing more than 50 percent full under peak dry weather conditions: (1) STBC0800NE and (2) IBCC0800NE. Sub-basin STBC0800NE is predicted to flow more than 50 percent full in multiple 8-inch lines in the vicinity of Purdue Farms, Inc. Purdue (a major industrial user) and was assumed to discharge to manhole 157.3126, which should be confirmed. Sub-basin IBCC0800NE includes both 8-inch and 10-inch diameter pipe and only one of the 8-inch pipes are predicted to flow more than 50 percent full (and less than 75 percent full) during dry weather. The City should perform field work to confirm pipe sizes in this sub-basin.

The results of the wet weather runs are summarized in Figure 8. Table 5 summarizes the sub-basins that were determined to not meet the specified performance criteria under wet weather conditions. These sub-basins correspond to the more built-out areas in the City with the oldest infrastructure.



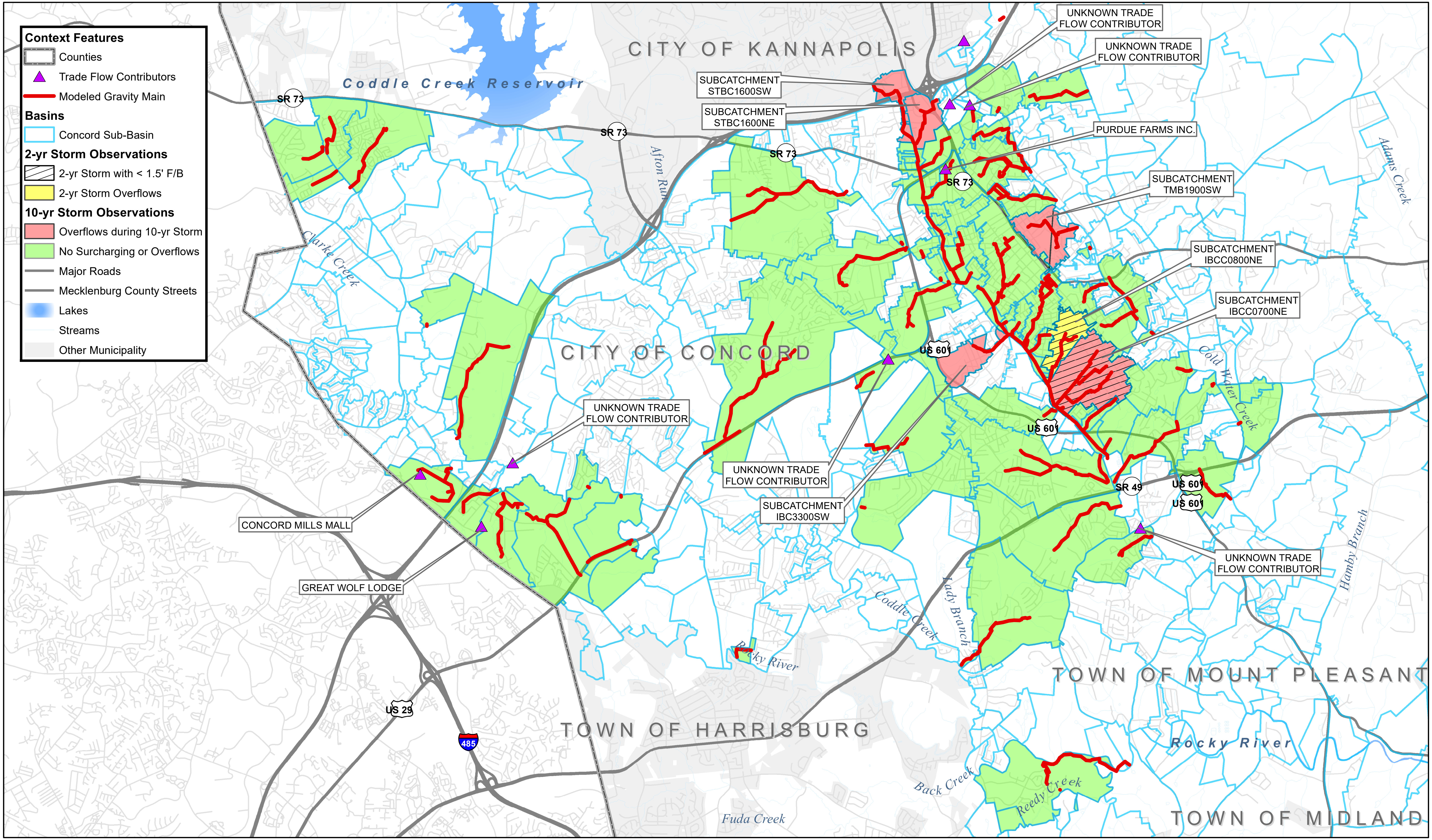
Date: 2/1/2018

FIGURE 7: EXISTING CONDITIONS
DRY WEATHER SURCHARGE MAP
CONCORD, NORTH CAROLINA

N

0 0.45 0.9 1.8 Miles

Disclaimer: This map was created with the best available data, however, it is provided "as is" without warranty of any representation of accuracy, timeliness, reliability or completeness. This map does not represent a legal survey of the land or facilities and is for graphical purposes only. Use of this Data for any purpose should be with acknowlegement of the limitations of the Data, including the fact that the Data is dynamic and is in a constant state of maintenance.



Concord NORTH CAROLINA

Date: 2/1/2018

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Gavel & Dorn Engineering

FIGURE 8: EXISTING CONDITIONS
WET WEATHER OVERFLOW MAP
CONCORD, NORTH CAROLINA

N

0 0.45 0.9 1.8 Miles

Disclaimer: This map was created with the best available data, however, it is provided "as is" without warranty of any representation of accuracy, timeliness, reliability or completeness. This map does not represent a legal survey of the land or facilities and is for graphical purposes only. Use of this Data for any purpose should be with acknowledgement of the limitations of the Data, including the fact that the Data is dynamic and is in a constant state of maintenance.

Gavel & Dorn recommends that the City confirm system inventory in these sub-basins and perform SSES in these areas to identify sources of I/I.

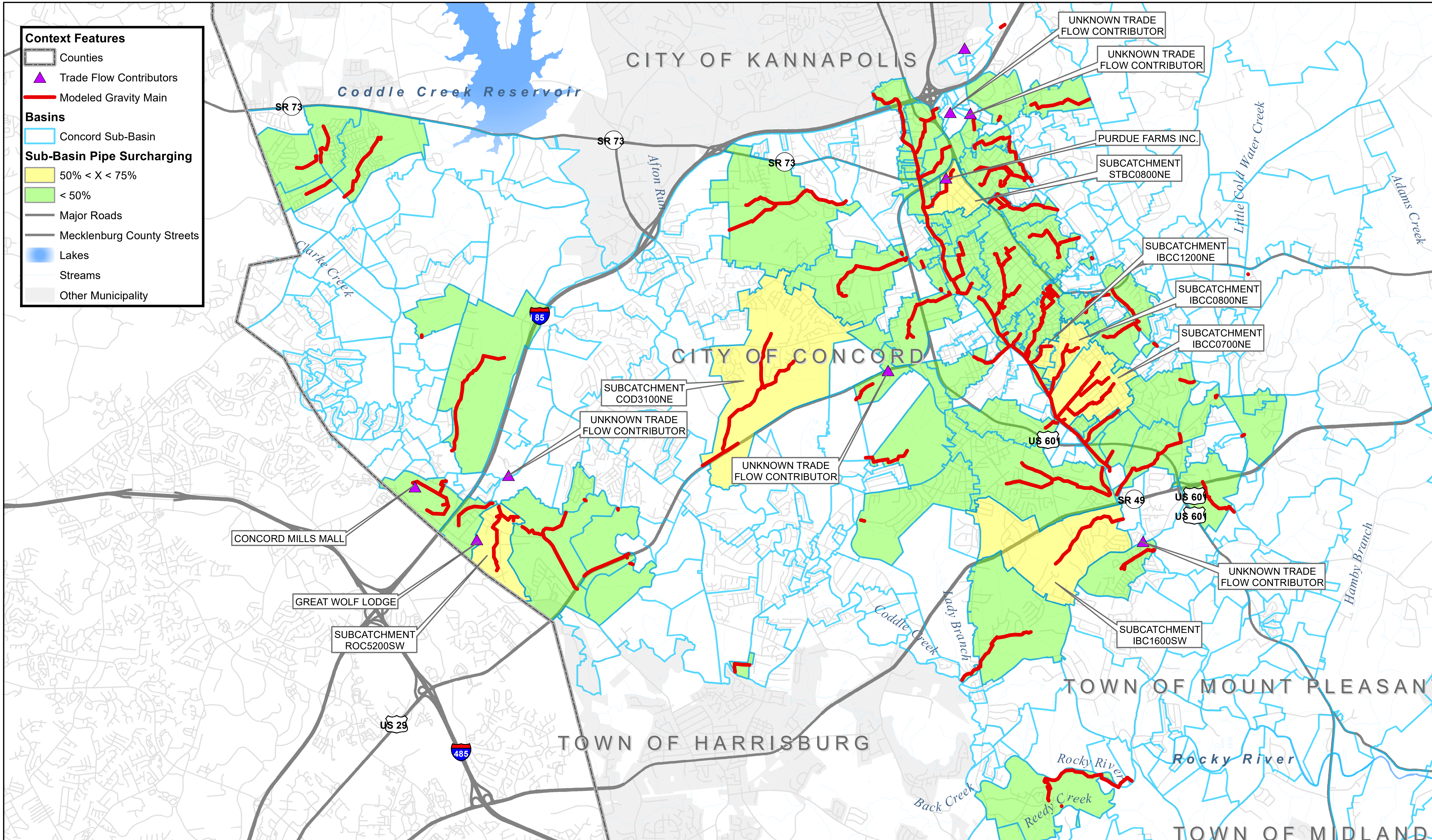
Table 5. Summary of Wet Weather Model Results under Existing Conditions			
Sub-Basin	**2-Year Storm <1.5' of Freeboard**	**2-Year Storm Overflows**	**10-Year Storm Overflows**
STBC1600SW	No	No	Yes
STBC1600NE	No	No	Yes
TMB1900SW	No	No	Yes
IBC3300SW	No	No	Yes
IBCC0800NE	Yes	Yes	Yes
IBCC0700NE	Yes	No	Yes

5.3.3 Planning Year 2040

Peak dry weather flow model results for planning year 2040 are summarized in Figure 9. In addition to the two sub-basins with conduits flowing more than 50 percent full (and less than 75 percent full) identified under existing conditions, four additional sub-basins were found to violate this constraint as summarized in Table 6. Table 6 also indicates the relative severity of the capacity performance criteria violation. Gavel & Dorn recommends monitoring capacity (i.e., including periodic temporary flow metering) in sub-basin COD3100NE to ensure dry weather conveyance capacity does not become limited.

Table 6. Summary of Future Dry Weather Results		
Sub-Basin	**Description**	**Relative Severity**
COD3100NE	Multiple 12-inch diameter pipes throughout flowing more than 50 percent full.	Major
ROC5200SW	Two 12-inch diameter pipes upstream of confluence flowing over 50 percent full.	Minor
IBC1600SW	Two 12-inch diameter pipes upstream of a change in grade are flowing more than 50 percent full.	Minor
IBCC0700NE	One 12-inch diameter pipe at the outlet predicted to flow at more than 50 percent full.	Minor
IBCC1200NE	One 10-inch diameter pipe at the outlet predicted to flow at more than 50 percent full.	Minor

Peak wet weather flow model results for planning year 2040 are summarized in Figure 10. The model results are also summarized in Table 7.

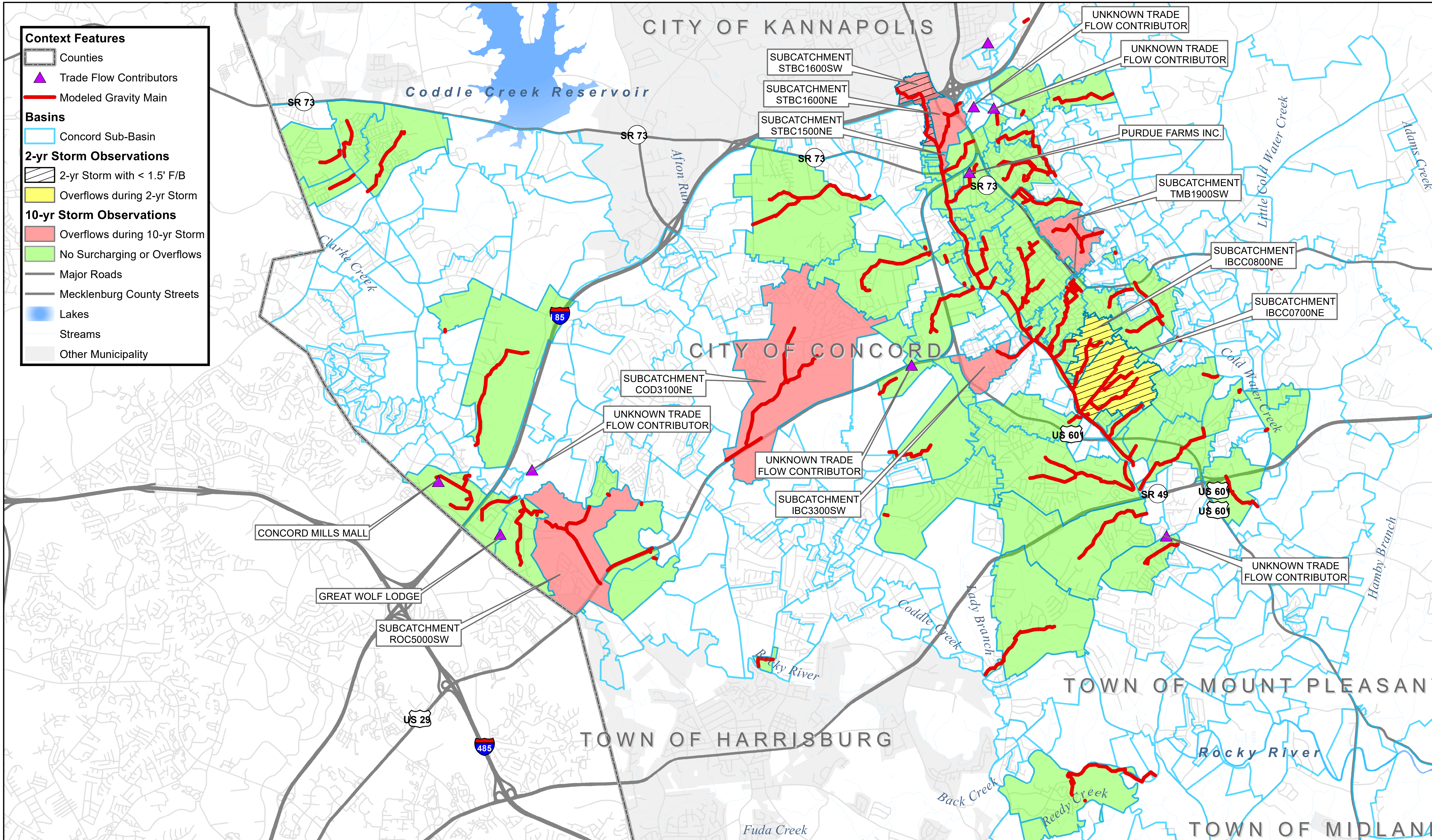


Date: 2/1/2018

FIGURE 9: 2040 DRY WEATHER SURCHARGE MAP

CONCORD, NORTH CAROLINA

Disclaimer: This map was created with the best available data, however, it is provided "as is" without warranty of any representation of accuracy, timeliness, reliability or completeness. This map does not represent a legal survey of the land or facilities and is for graphical purposes only. Use of this Data for any purpose should be with acknowlegement of the limitations of the Data, including the fact that the Data is dynamic and is in a constant state of maintenance.



N
0 0.45 0.9 1.8 Miles

FIGURE 10: 2040 WET WEATHER OVERFLOW MAP

CONCORD, NORTH CAROLINA

Concord NORTH CAROLINA

Date: 2/1/2018

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Table 7. Summary of Wet Weather Model Results under Future Conditions			
Sub-Basin	**2-Year Storm <1.5' of Freeboard**	**2-Year Storm Overflows**	**10-Year Storm Overflows**
STBC1600SW	Yes	No	Yes
STBC1600NE	No	No	Yes
TMB1900SW	No	No	Yes
IBC3300SW	No	No	Yes
IBCC0800NE	Yes	Yes	Yes
IBCC0700NE	Yes	Yes	Yes
STBC1500NE	No	No	Yes
COD3100NE	No	No	Yes
ROC5000SW	No	No	Yes

5.3.4 Conclusions and Recommendations

Table 8 summarizes capacity utilized under the existing and future planning scenarios at each of the temporary flow metering locations (only). Dry weather conveyance capacity constraints do not appear to be prevalent in the modeled Concord collection system. Pipes near Purdue Farms should be inspected to confirm dry weather flow depths and connection location. Asset inventory information should be confirmed in Sub-basin STBC0800NE in Table 8. Under future planning conditions, only sub-basin COD3100NE exhibited extensive potential for dry weather capacity limitations. The City should closely monitor increases in flow in this sub-basin due to growth.

Table 8. Pipe Capacity under Dry Weather Condition at Temporary Flow Meter Locations							
Flow Meter ID	**Subcatchment ID**	**Diameter (inches)**	**Diameter (inches)**	**Existing Peak Dry Flow (MGD)**	**Percent Full Capacity**	**Future Peak Dry Flow (MGD)**	**Percent Full Capacity**
181.2125	IBC5100SW	24	12.02	0.27	2%	0.81	7%
183.111	STBC1000SW	30	15.95	0.36	2%	0.54	3%
209.21	IBC4500SW	12	2.56	0.04	2%	0.18	7%
210.2172	STBC0100NE	36	14.39	1.04	7%	1.29	9%
237.1146	IBC3300SW	10	2.15	0.05	2%	0.07	3%
237.1191	IBCC1400NE	42	20.56	0.34	2%	0.43	2%
253.41	ROC5600NE	12	1.63	0.06	4%	0.14	9%
257.3104	COD3100NE	12	1.37	0.22	16%	0.70	51%
261.2156	IBC2500SW	12	1.63	0.05	3%	0.10	6%
262.3129	IBC2000SW	24	8.6	0.26	3%	0.40	5%
285.4113	IBC1600SW	12	2.64	0.16	6%	0.39	15%
262.4115	IBCC0100NE	42	50.25	0.63	1%	0.93	2%
362.2104	ROC2100SW/ REE0100N	24	8.52	0.06	1%	0.37	4%

Meanwhile, Sub-basin IBCC0800NE exhibited overflows under existing conditions during a 2-year storm event. As a result, according to the model, this sub-basin is the highest priority with respect to wet weather flows and we recommend an SSES to confirm system performance and condition and identify potential sources of I/I. Table 9 summarizes recommendations to address all identified deficiencies under existing and future conditions by sub-basin. Table 9 also includes an indication of the relative priority of each recommendation.

Table 9. Summary of Recommended Improvements to Address Problem Areas			
Sub-basin	**Problem**	**Priority**	**Recommendation**
IBCC0800NE	Overflows in 2-year existing conditions	1	Replace 3,170 LF of 8- and 10-inch diameter pipe with 12-inch
IBCC0700NE	Overflows in 10-year existing conditions	2	Replace 2,260 LF of 12-inch diameter pipe with 15-inch
STB1600SW AND NE	Overflows in 10-year existing conditions	3	Replace 1,950 LF of 15- and 8-inch diameter pipe with 18-inch and 10-inch
IBC3300SW	Overflows in 10-year existing conditions	4	Replace 1,780 LF of 10-inch diameter pipe with 12-inch
TMB1900SW	Overflows in 10-year existing conditions	5	Replace 1,670 LF of 10-inch diameter pipe with 12-inch
COD3100NE	Overflows in 10-year future conditions	6	Replace 5,190 LF of 12-inch diameter pipe with 15-inch
ROC5000SW	Overflows in 10-year future conditions	7	Replace 2,040 LF of 12-inch diameter pipe with 15-inch

5.3.5 Model Limitations

All developed computer models are imperfect representations of reality. The model discussed herein is subject to several limitations. The largest single issue is related to accuracy of the asset inventory information. Future model enhancements should include obtaining survey grade manhole rim and invert elevations before using the developed model for preliminary engineering. Not all of the modeled sub-basins had accurate temporary flow meter data obtained. In addition, meters 210-2172 and 183.1110 were not found to balance hydraulically, so they could not be used for model calibration. Finally, the WSACC trunk sewer was not modeled. As a result, the downstream boundary condition of each connection was based on an assumed depth. An ideal solution would be to merge the model herein with a calibrated model of the WSACC trunk sewers. In lieu of that, additional investigation into the depth of flow in the WSACC trunk sewers under existing and future conditions at key tie-in locations is warranted for future model enhancements.

5.3.6 Model Maintenance

The model was developed for capital planning purposes and to determine available capacity. In general, the model was developed for only those systems containing pipes 12-inches in diameter and greater. Revisions to the model to include additional areas should include temporary flow metering to calibrate the new sub-system(s). The following guidelines should be followed for updating the model:

1. Flow metering data indicating a dry weather flow increase of 10 percent or more at one of the metered locations discussed herein.
2. Operational difficulties, such as sanitary sewer overflows, occur that are not represented in the model.

3. As needed to support various planning or design efforts.
4. Maximum of five (5) years between model updates.

6 Facility Needs

The City of Concord wastewater collection system is generally well maintained and capable of meeting the needs of the existing customers. The modeling efforts undertaken as part of the Master Plan did not reveal any significant deficiencies within the existing collection system and only a few instances where excessive infiltration and inflow (I/I) were detected. These areas can be corrected by the City as part of its normal operations and maintenance.

Likewise, there are relatively few places within the City's collection system that require additional capacity to accommodate moderate future growth. This generally effects the City's practice of sizing collection facilities to meet future needs, a practice which appears to have been well executed. Nonetheless, there are several areas where future development may necessitate additional wastewater capacity, especially in the areas where higher density development may occur.

6.1 Basis of Design

As part of the Master Plan, the Project Team analyzed the normal wastewater flows from current customers. The quantity of wastewater generated by Concord customers was tabulated for each of the drainage sub-basins thereby providing a basis for designing new facilities. In general, the flows experienced in Concord are significantly less than that required by the North Carolina Administrative Code (15A NCAC 02T - Waste Not Discharged to Surface Waters). The Administrative Code specifies that planning for future wastewater facilities be based on specific flow values for each customer class, including the requirement that residential developments utilizes a value of 120 gallons per day (gpd) per bedroom. The quantity of wastewater generated by residential customers in Concord is significantly less making the Administrative Code requirements overly conservative. Nonetheless, future facilities designated in the Capital Improvement Plan are sized based on the requirements of the Administrative Code and the minimum acceptable slope for that size pipe. When compared with the actual anticipated wastewater flow, these facilities will likely be somewhat larger than necessary.

6.2 Facilities to Support Growth in Existing Service Areas

As previously noted, the City's wastewater collection system appears to be adequate for meeting the needs of its existing customers. As part of the modeling effort, several areas were identified within the collection system that are near capacity during wet weather flow. The City has not experienced any particular difficulty during normal operations, but during wet weather events, the sewer appears to surcharge and presents a higher risk of overflow. The majority of these sewers are located in the Irish Buffalo Creek drainage basin and represents some of the oldest portions of the collection system.

For each of these locations, the existing facilities were evaluated and supplemental or replacement sewers are recommended as part of the Capital Improvement Plan.

6.3 New Service Areas

The majority of the recommended future facilities in the Master Plan are for areas that are not currently served by the City of Concord. It is anticipated that development in these areas will likely be driven by private interests. It is important for the City of Concord to have a plan for accommodating these future developments such that the facilities can be constructed in an orderly fashion. In some cases, expansion into these areas will require major infrastructure by WSACC in order to have access to the wastewater transportation and treatment systems.

In these service areas the specific development pattern is not yet known. Based on the wastewater flow projections presented in Section 4, the anticipated flows have been distributed over the sub-basin and the selection of collection system piping is based on the aforementioned design standards.

Since the City of Concord provides wastewater service in the Town of Midland, a similar analysis has been undertaken there. Those facilities recommended for the Town of Midland are presented in a separate section of the Capital Improvement Plan.

The design basis for each of the proposed facilities is summarized in the attached table and further described in the Capital Improvement Plan presented in Section 7.

Sub-Basins Served	Project Code	Estimated Existing Flow (gpd)	Projected Flow (gpd)	Upstream Flow (gpd)	Design Flow per 2T Rules (gpd)	Pipe Size (in)	Pipe Length (ft)
IBCC0800NE	IBC1	16,854	152,063	0	319,332	15	3,170
IBCC0700NE	IBC2	686	224,164	0	470,744	18	2,260
STBC1600SW	IBC4	0	73,296	0	153,922	12	870
STBC1600NE	IBC5	1,065	159,204	73,296	488,252	18	1,090
IBC3300SW	IBC3	483	91,575	0	192,308	12	1,780
TMB1900SW	CWC1	476	149,857	0	314,700	15	1,670
COD3800NE, COD4000NE	CC2	8,005	50,525	94,724	305,025	15	4,900
WMC1500NE, WMC1600NE	CC4	0	66,573	30,107	203,028	12	2,900
COD1800NE, COD2700NE	CC5	15,520	119,017	0	249,936	15	5,000
CWC1500NE	CWC8	0	33,600	150,871	387,391	18	9,900
	MC9	0		10,000	166,000	12	6,700
ROC5000SW	RR1	0	66,321	0	139,274	15	2,040
ROC6300NE	RR2	0	153,519	0	322,390	15	6,700
ROC5500NE, ROC5600NE	RR3	126,716	154,808	0	325,097	15	6,400
COD3100NE	CC1	217,492	500,000	0	1,050,000	24	5,190
COD3100NE	CC3	0	121,762	0	255,700	15	4,700
WMC1400NE	CC6	3,106	100,618	0	211,298	12	4,600
COD0700NE	CC7	13,089	96,426	0	202,495	12	8,500
LCW1200NE	CWC2	0	9,100	0	19,110	8	6,300
LCW1200NE	CWC3	0	9,100	0	19,110	8	5,600
CWC4100NE	CWC4	0	12,698	0	26,666	8	6,000
LCW1100NE	CWC5	0	119,677	0	320,240	15	5,500
LCW0800NE	CWC6	0	55,090	0	115,689	12	5,500
LCW0100NE	CWC7	0	73,282	0	153,892	12	7,200
ROC2100NE	LRR1	0	170,334	0	357,701	12	4,500
REE0800SW, REE0600SW, REE0400SW, REE0300SW,	RC4	0	13,235	121,146	282,209	15	12,000
REE0400SW	RC1	0	27,547	0	57,849	8	5,400
REE0300SW	RC2	0	5,269	0	11,067	8	3,700
REE0100S	RC3	0	88,330	0	185,495	12	3,200
	MC1	0		70,000	350,000	12	18,000
	MC2	0		70,000	350,000	12	7,000
	MC3	0		0	450,000	12	6,600
	MC4	0		0	130,000	12	2,700
	MC5	0		0	217,000	12	4,000
	MC6	0		0	102,000	8	3,800
	MC7	0		0	390,500	18	4,600
	MC8	0		0	90,000	8	2,600

7 Implementation

In order for the City to make best use of the Master Plan, several significant activities should be continued by the City on a regular basis. These activities include:

- Adopt and implement a Capital Improvement Plan.
- Continue flow monitoring throughout the system.
- Continue field evaluations and GIS upgrades.

7.1 Capital Improvement Plan

Perhaps the most useful took produced by the Sewer System Master Plan is development of a Capital Improvement Plan (CIP). The CIP presents a succinct list of recommended improvements necessary to provide continued reliable service to existing customers as well as those facilities that might be needed for additional growth in and around Concord. The CIP is organized into several categories reflecting the relative importance and timing of the various improvement projects. The categories include:

Tier 1 – Improvements to Serve Existing Customers
These improvement projects would provide increased capacity to adequately serve existing customers or to allow for the elimination of existing pump stations.

Tier 2 – Improvements Within the Concord City Limits
These projects would be improvements to the collection system to provide additional capacity to support future developments within the Concord City Limits.

Tier 3 – Improvements Outside the Concord City Limits
These projects would be improvements to the collection system to provide additional capacity to support future developments located outside the Concord City Limits.

Tier 4 – Improvements in the Town of Midland
These improvements would be projects to provide additional capacity for future customers in the Town of Midland service area.

Each of the projects are designated by a Project Code indicating its geographical locations. These codes match the designations found on the attached Capital Improvement Plan Figure. The projects contained in Tier 1 are generally organized in order of their importance as summarized on the attached Capital Improvement Plan. Projects in Tiers 2, 3 and 4 are dependent on future customer demand and are therefore not arranged in priority order. The highest priority projects are those found in the Irish Buffalo Creek area, which represents some of the older portions of the City's collection system. There are also some projects identified in the Cold Water and Coddle Creek drainage basins primarily to eliminate aging pumping stations and allow for orderly expansion in those areas.

The Tier 2 projects would provide for expansion of City services in areas within the Concord City Limits which are not currently serviced by the sewer system. These projects generally consist of expansion within the Rocky River and Coddle Creek basins and would largely be driven by development pressure in those areas.

The projects tabulated in Tiers 3 and 4 represent expansion of the wastewater system outside the City of Concord limits. Some of these projects would require expansion of the WSACC system and are fairly large in scope. They may not be implemented for many years. Likewise, these projects will largely be driven by new developments.

For each of the projects included in the Capital Improvement Plan a separate Project Summary sheet has been prepared, further describing the scope of work to be undertaken and its estimated cost.

7.2 Future Monitoring and Evaluation

The City of Concord maintains a fleet of flow monitoring equipment that is periodically used for short-term flow investigations. Likewise, WSACC maintains a network of permanent flow monitoring stations which it uses to prepare customer bills for each of the member jurisdictions. The continued use of both of these resources will assist the City of Concord in monitoring the flow within its system and can help define areas with excessive infiltration and inflow. During the course of the short-term flow monitoring conducted as part of the Master Plan, several areas appear to be experiencing excessive flow, particularly near the Concord Airport and some of the older areas of the collection system. The City should continue its program of monitoring and addressing I/I issues, and may wish to implement a more formalized plan for flow monitoring and capacity assurance.

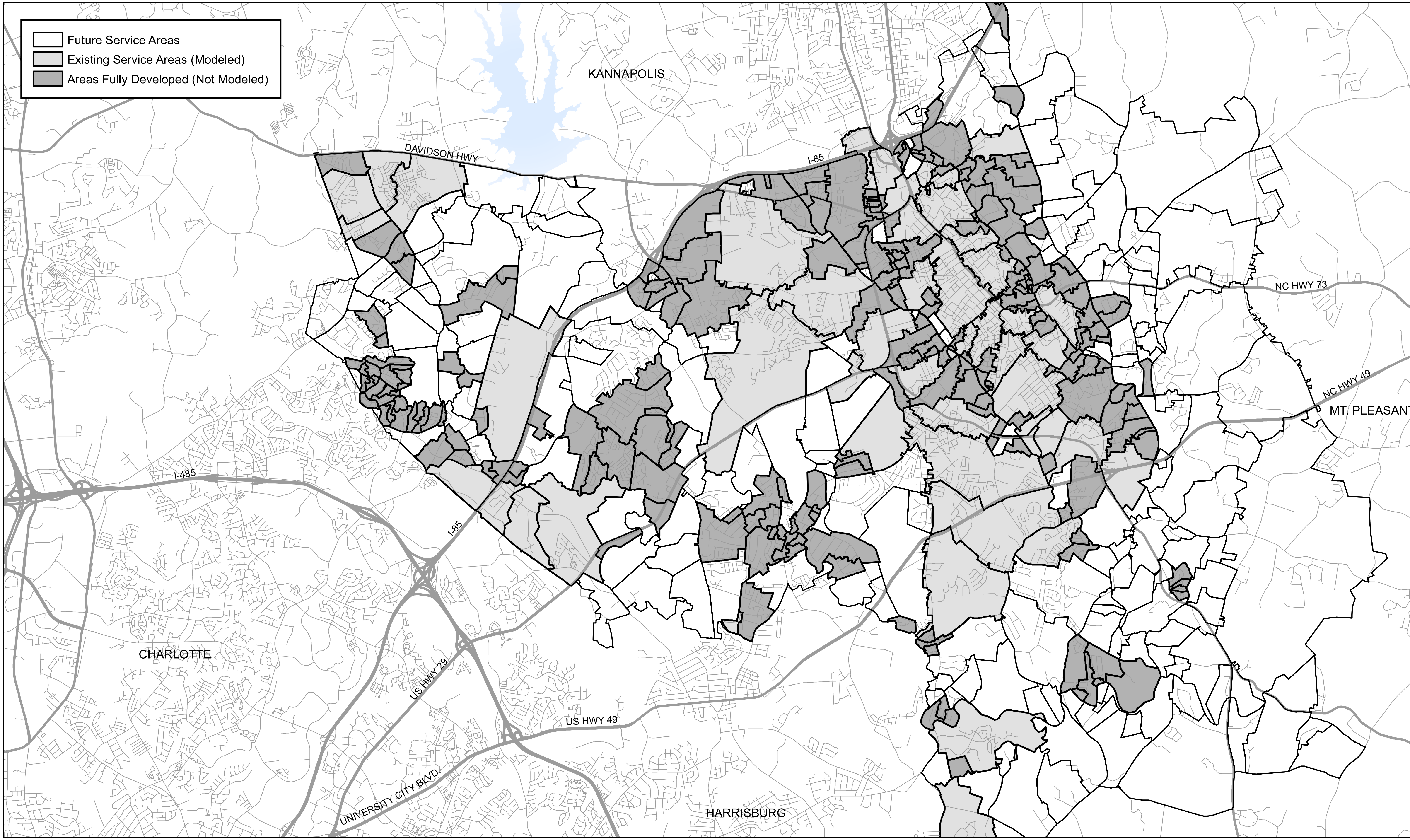
7.3 GIS and Data Management

As part of the Master Plan effort, it became apparent that portions of the City's GIS system data are not as accurate as previously thought. The City undertook a substantial effort in field surveying portions of the collection system in order to provide sufficient information for the wastewater modeling. These efforts should continue, and the City should seek to improve the quality of its GIS database. This information will be useful in future modeling efforts and is essential for maintaining the integrity of the City's Capacity Assurance Program.

7.4 Summary of Action Items

For the City's convenience, various recommendations noted in this Master Plan have been summarized on the attached tabulation of action items.

Table 1. Summary of Action Items		
Item No.	**Description**	**Reference**
1	Performing sanitary sewer evaluation survey (SSES) upstream of metering location 253.4100 to determine source of inflow.	Section 3.4, Paragraph 2
2	Collect survey grade asset inventory to refine the model.	Section 5.1.1, Paragraph 2
3	Confirm system inventory in sub-basins and perform SSES to identify sources of I/I.	Section 5.3.2, Paragraph 2, Table 5
4	Conduct flow metering to monitor capacity in sub-basin COD3100NE.	Section 5.3.3, Paragraph 1
5	Inspect pipes near Purdue Farms to confirm dry weather flow depths and connection locations.	Section 5.3.4, Paragraph 1
6	Confirm asset inventory information in sub-basin STBC0800NE.	Section 5.3.4, Paragraph 1
7	Monitor increases in flow in sub-basin COD3100NE.	Section 5.3.4, Paragraph 1
8	Perform SSES to confirm system performance and condition and identify potential sources of I/I in sub-basin IBCC0800NE.	Section 5.3.4, Paragraph 2
9	Conduct improvements to system to address deficiencies.	Section 5.3.4, Paragraph 2, Table 9
10	Develop formalized plan of monitoring and addressing I/I issues for flow monitoring and capacity assurance.	Section 7.2, Paragraph 1
11	Continue field surveying to update and improve the quality of the GIS database.	Section 7.3, Paragraph 1



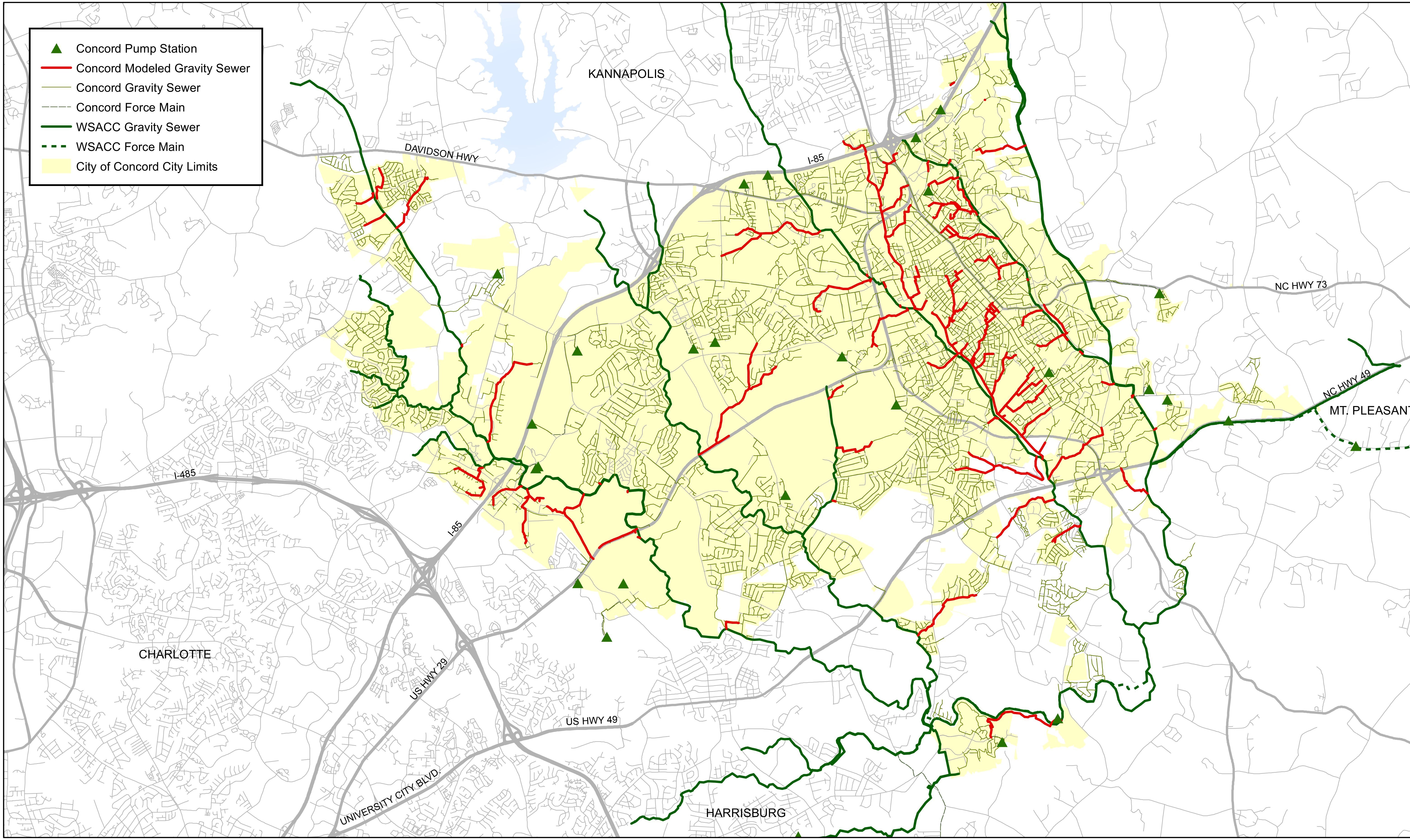
Date: 2/1/2018

FIGURE 1

PLANNING AREA

CONCORD, NORTH CAROLINA

Disclaimer: This map was created with the best available data, however, it is provided "as is" without warranty of any representation of accuracy, timeliness, reliability or completeness. This map does not represent a legal survey of the land or facilities and is for graphical purposes only. Use of this Data for any purpose should be with acknowlegement of the limitations of the Data, including the fact that the Data is dynamic and is in a constant state of maintenance.



Concord NORTH CAROLINA

Date: 1/23/2018

willis ENGINEERS

LandDesign

Gavel & Dorn Engineering

FIGURE 2

EXISTING FACILITIES

CONCORD, NORTH CAROLINA

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0 0.5 1 2 Miles

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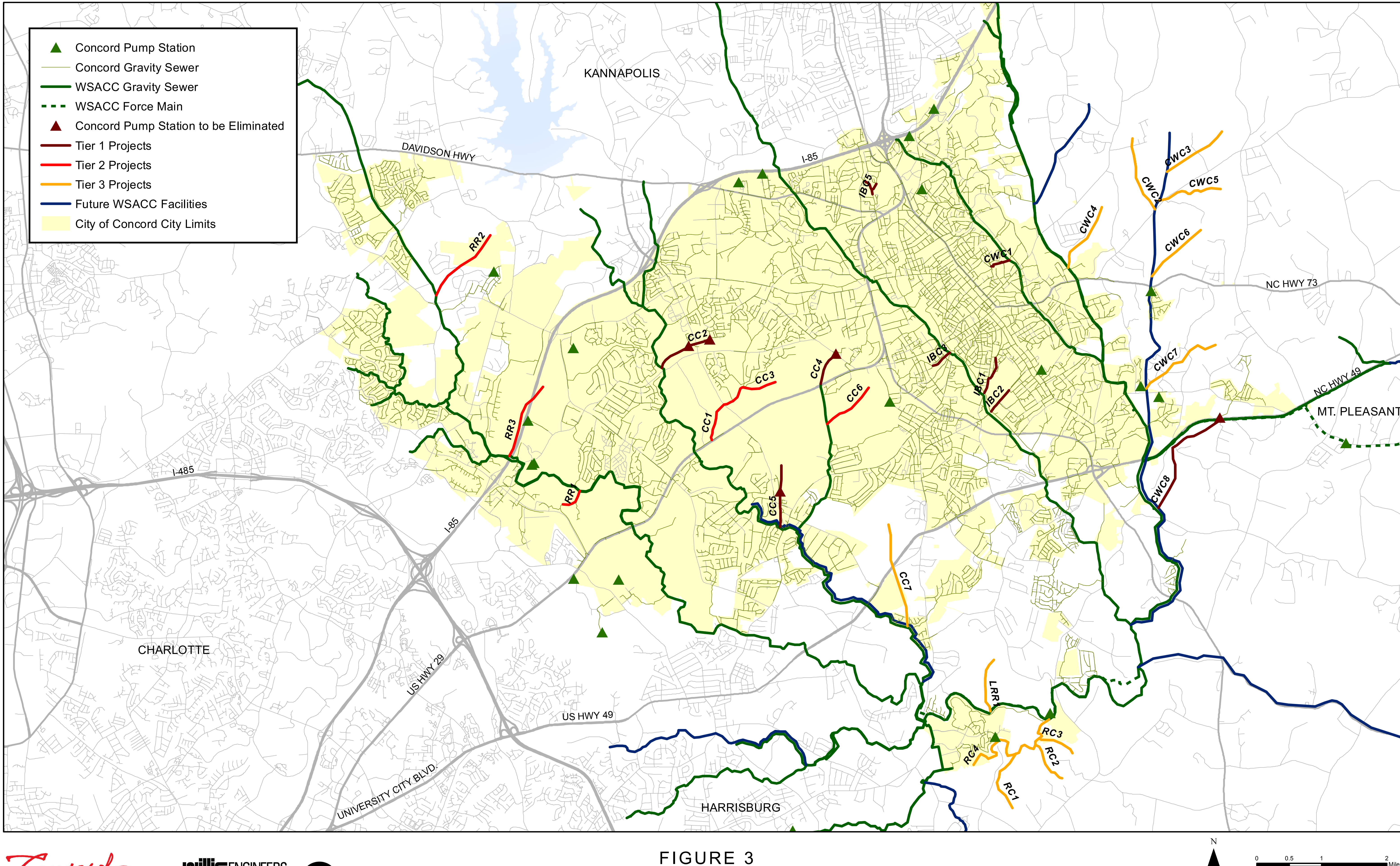
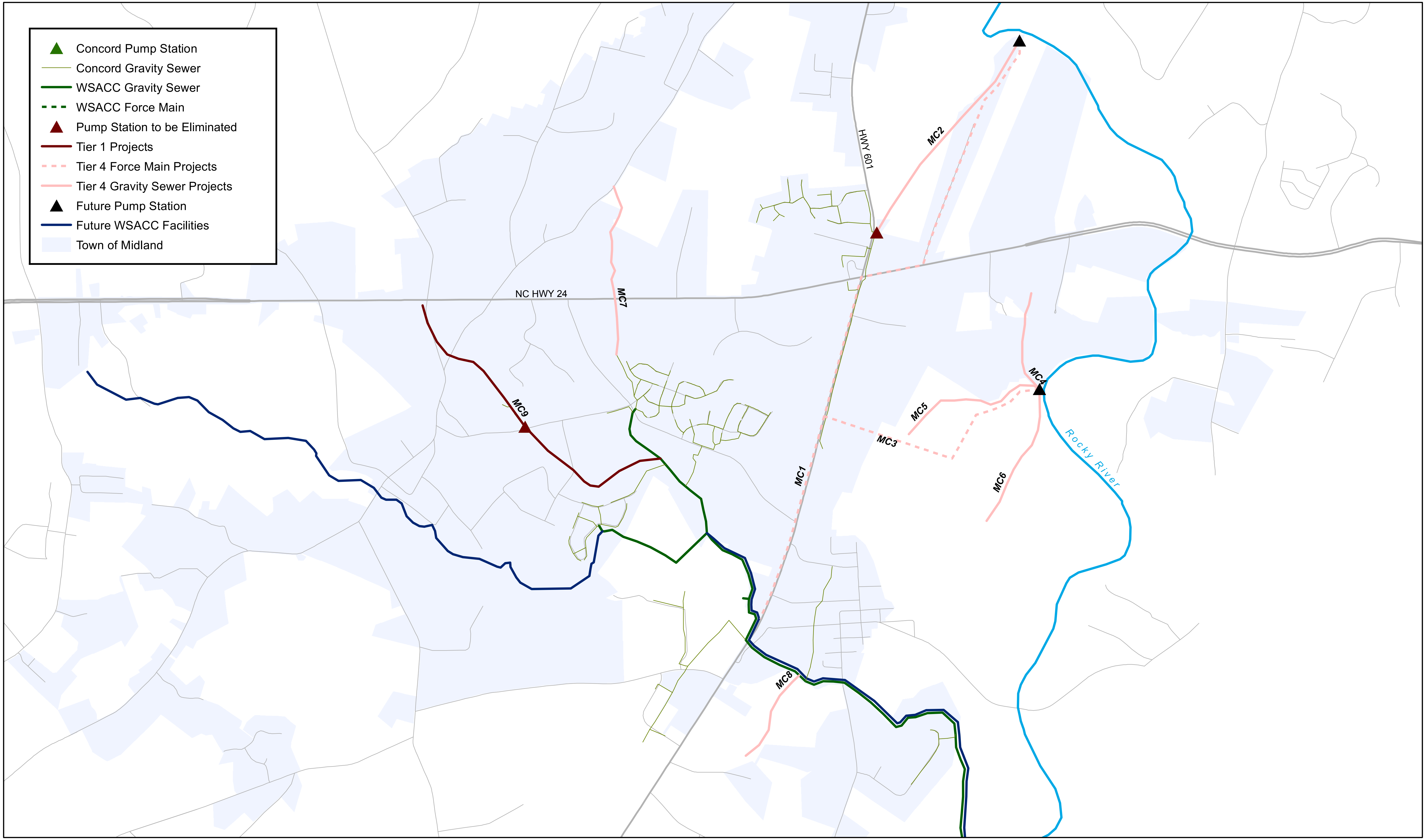
Drainage Basin	Project Code	Design Flow (gpd)	Size (in)	Length (ft)	Estimated Cost	Notes
Tier 1 - Improvements to adequately serve existing customers or to allow for elimination of an existing pump station						
Irish Buffalo	IBC1	319,332	15	3,170	$1,347,250	Provides additional wet weather capacity
	IBC2	470,744	18	2,260	$1,130,000	Provides additional wet weather capacity
	IBC4	153,922	12	870	$282,750	Provides additional wet weather capacity
	IBC5	488,252	18	1,090	$545,000	Provides additional wet weather capacity
	IBC3	192,308	12	1,780	$578,500	Provides additional wet weather capacity
Cold Water Creek	CWC1	314,700	15	1,670	$709,750	Provides additional wet weather capacity
Coddle Creek	CC2	305,025	15	4,900	$2,382,500	Eliminates Provence Green and Laurel Park Pump Stations
	CC4	203,028	12	2,900	$942,500	Eliminates Crossbow Circle Pump Station
	CC5	249,936	15	5,000	$2,125,000	Eliminates Roberta Woods Pump Station
Cold Water Creek	CWC8	387,391	18	9,900	$4,950,000	Eliminates Racoon Hollow Pump Station
Muddy Creek	MC9	166,000	12	6,700	$2,177,500	Eliminates Bethel School Pump Station
Tier 2 - Improvements to support future development within the Concord City Limits						
Rocky River	RR1	139,274	15	2,040	$867,000	Additional capacity for future flows
	RR2	322,390	15	6,700	$2,847,500	Expansion of Service Area
	RR3	325,097	15	6,400	$3,170,000	Expansion of Service Area
Coddle Creek	CC1	1,050,000	24	5,190	$3,154,500	Additional capacity for future flows
	CC3	255,700	15	4,700	$1,997,500	Expansion of Service Area
	CC6	211,298	12	4,600	$1,495,000	Expansion of Service Area
Tier 3 - Improvements to support future development outside of the Concord City Limits						
Coddle Creek	CC7	202,495	12	8,500	$3,062,500	Expansion of Service Area
Cold Water Creek	CWC2	19,110	8	6,300	$1,890,000	Expansion of Service Area
	CWC3	19,110	8	5,600	$1,680,000	Expansion of Service Area
	CWC4	26,666	8	6,000	$1,800,000	Expansion of Service Area
	CWC5	320,240	15	5,500	$2,337,500	Expansion of Service Area
	CWC6	115,689	12	5,500	$1,787,500	Expansion of Service Area
	CWC7	153,892	12	7,200	$2,340,000	Expansion of Service Area
Lower Rocky River	LRR1	357,701	12	4,500	$1,462,500	Expansion of Service Area
Reedy Creek	RC4	282,209	15	12,000	$5,100,000	Expansion of Service Area. RC1, RC2 and RC3 would be tributary to this gravity sewer
	RC1	57,849	8	5,400	$1,620,000	Expansion of Service Area
	RC2	11,067	8	3,700	$1,110,000	Expansion of Service Area
	RC3	185,495	12	3,200	$1,040,000	Expansion of Service Area
Tier 4 - Improvements to support future development in the Town of Midland						
Muddy Creek	MC1	350,000	12	18,000	$2,300,000	Anderson Creek Pump Station and Force Main
	MC2	350,000	12	7,000	$2,275,000	To support future development along Anderson Creek
	MC3	450,000	12	6,600	$1,160,000	Rocky River Pump Station and Force Main
	MC4	130,000	12	2,700	$877,500	Expansion of Service Area
	MC5	217,000	12	4,000	$1,300,000	Expansion of Service Area
	MC6	102,000	8	3,800	$1,140,000	Expansion of Service Area
	MC7	390,500	18	4,600	$2,300,000	Expansion of Service Area
	MC8	90,000	8	2,600	$780,000	Expansion of Service Area
Total Improvement Cost					**$68,064,750**	



Date: 4/20/2018

FIGURE 3
CAPITAL IMPROVEMENT PLAN
CONCORD, NORTH CAROLINA



Concord NORTH CAROLINA

Date: 11/17/2017

willis ENGINEERS

LandDesign

Gavel & Dorn Engineering

FIGURE 4

CAPITAL IMPROVEMENT PLAN

MIDLAND, NORTH CAROLINA

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0 0.15 0.3 0.6 Miles

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Tier 1 Projects
Irish Buffalo Improvements

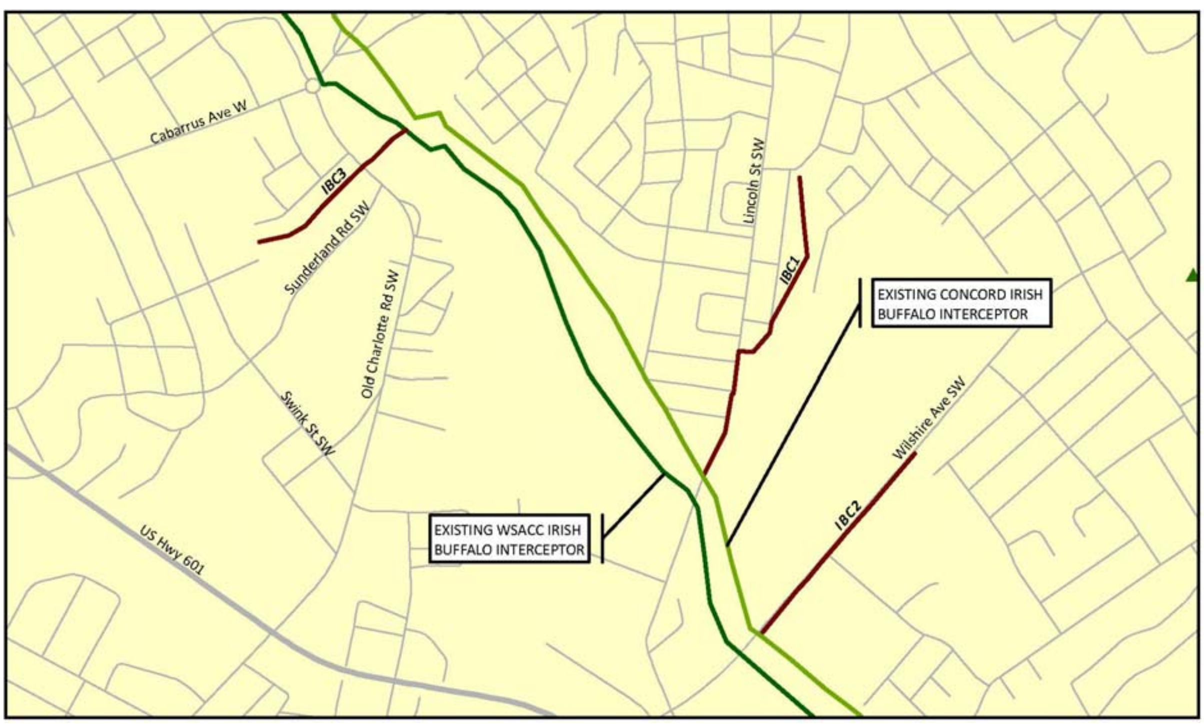
Project Codes – IBC1, IBC2, IBC3

Description – These projects consist of multiple improvements in the Irish Buffalo Basin. The improvements include replacement of an existing 8-inch and 10-inch diameter sewer along Lincoln Street with a 15-inch diameter sewer (IBC1). The improvements also include replacement of a 12-inch diameter sewer along Wilshire Avenue with an 18-inch diameter sewer (IBC2). Both gravity sewers discharge into the existing Concord Irish Buffalo Creek Interceptor. An existing 10-inch diameter sewer parallel to Meadowview Avenue would be replaced with a 12-inch diameter sewer (IBC3). This gravity sewer discharges into the WSACC Irish Buffalo Creek Interceptor.

Justification – These projects would replace existing infrastructure that does not appear to have sufficient capacity to accommodate existing wet weather flows. The future facilities would be sufficient to meet existing and future projected wastewater flows from the tributary subcatchments.

Priority – These projects would address existing deficiencies in the City's sewer system and are therefore rated as Tier 1 projects. The anticipated cost for this work is approximately $3,055,750 as tabulated below.

Project Code	Size	Length	Estimated Cost
IBC1	15	3,170	$1,347,250
IBC2	18	2,260	$1,130,000
IBC3	12	1,780	$578,500
Total Estimated Cost			**$3,055,750**



Irish Buffalo Improvements

Project Codes – IBC4, IBC5

Description – This project consists of replacement of approximately 1,950 feet 8-inch and 15-inch diameter gravity sewer in the Irish Buffalo Basin with 12-inch (IBC4) and 18-inch (IBC5) diameter sewer.

Justification – This project would replace existing infrastructure that does not appear to have sufficient capacity to accommodate existing wet weather flows. The future facilities would be sufficient to meet existing and future projected wastewater flows from the tributary subcatchments.

Priority – This project would address existing deficiencies in the City's sewer system and is therefore listed as a Tier 1 project. The anticipated cost for this work is approximately $827,750 as tabulated below.

Project Code	Size	Length	Estimated Cost
IBC4	12	870	$282,750
IBC5	18	1,090	$545,000
Total Estimated Cost			**$827,750**

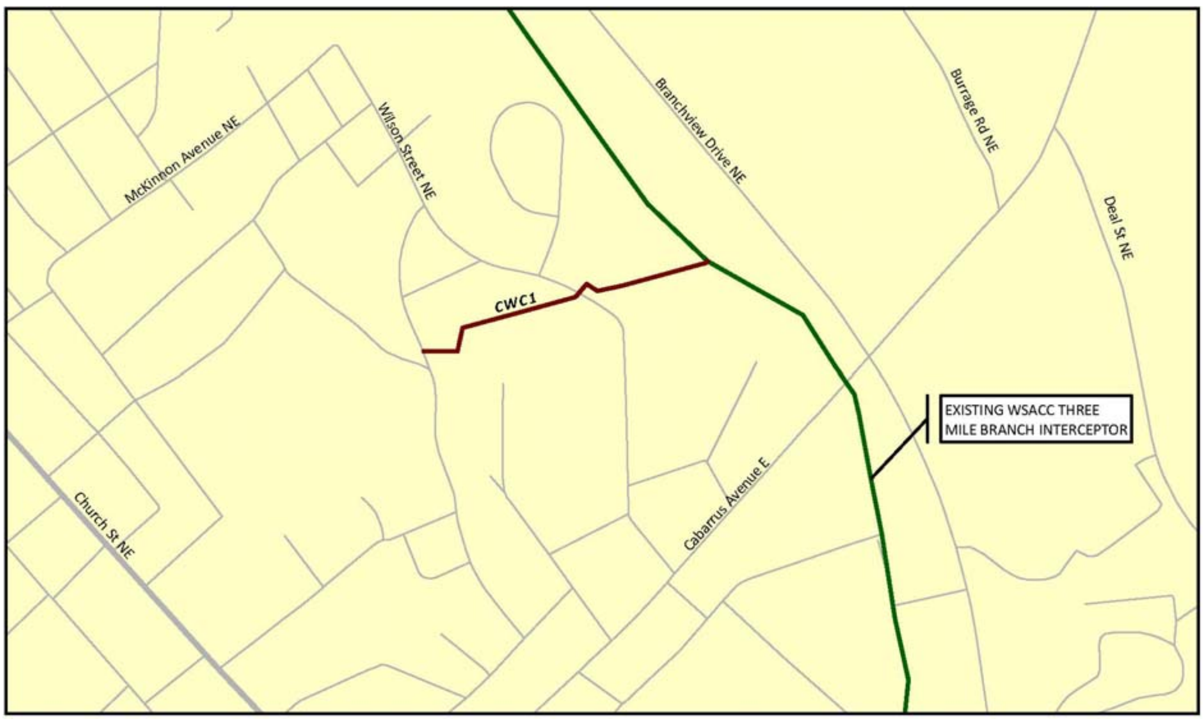
Tier 1 Projects
Cold Water Creek Improvements

Project Codes – CWC1

Description – This project consists of replacement of approximately 1,670 feet of 10-inch diameter sewer in the Cold Water Creek Basin with a 15-inch diameter gravity sewer. The project begins from the existing Three Mile Branch Interceptor and extends west towards Shamrock Street.

Justification – This project would replace an existing gravity sewer that does not appear to have sufficient capacity to accommodate existing wet weather flows. The future facilities would be sufficient to meet existing and future projected wastewater flows from the tributary subcatchments.

Priority – This project would address an existing deficiency in the City's sewer system and is therefore rated as a Tier 1 project. The anticipated cost for this work is approximately $709,750.

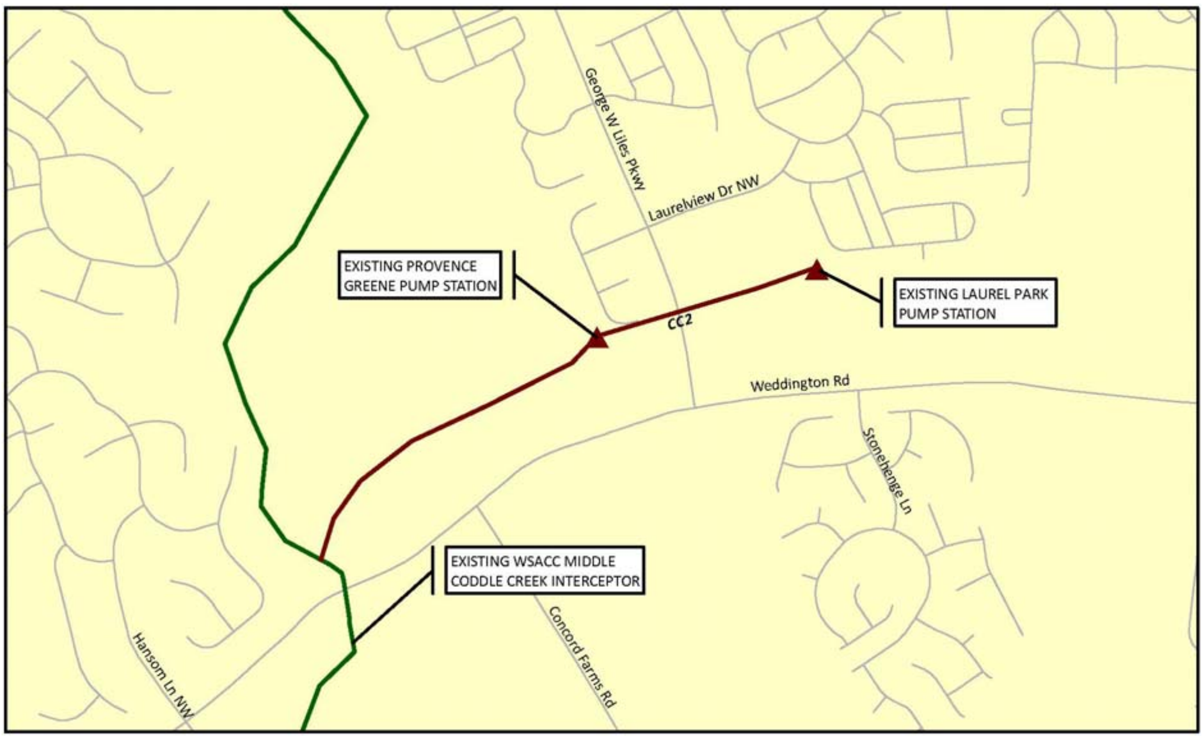


Project Code – CC2

Description – This project consists of approximately 4,900 feet of 15-inch gravity sewer to serve future development in the Coddle Creek Basin. The project begins at the existing WSACC Middle Coddle Creek Interceptor and extends northeast to the Laurel Park Pump Station. This project would eliminate the Laurel Park Pump Station as well as the Providence Greene Pump Station.

Justification – There is currently very little development within these subcatchments of Coddle Creek. This project would provide service to anticipated development in the area. In addition, the Laurel Park and Providence Greene Pump Stations would be eliminated.

Priority – The purpose of this project is to support future development within the City of Concord city limits. Since this project would eliminate two pump stations it is rated as Tier 1 project. The anticipated cost for this work is approximately $2,382,500.



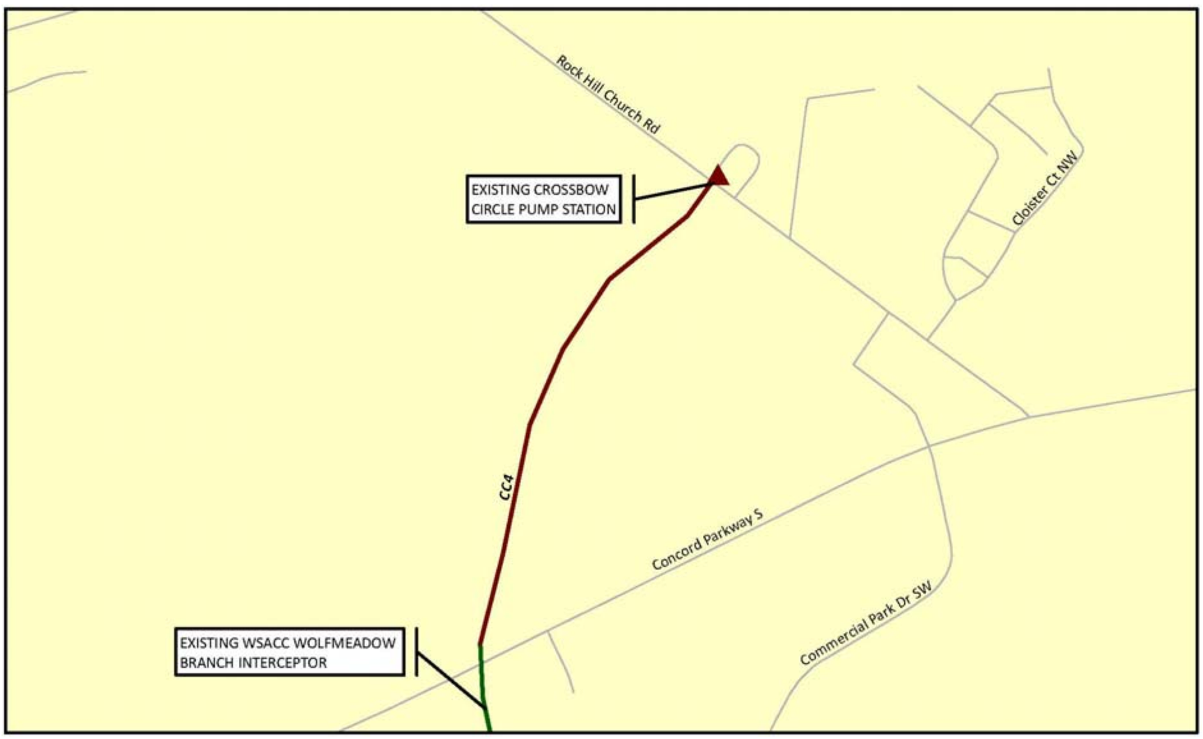
Tier 1 Projects
Coddle Creek Facilities

Project Code – CC4

Description – This project consists of approximately 2,900 feet of 12-inch gravity sewer to serve future development in the Coddle Creek Basin. The project begins at the existing WSACC Wolfmeadow Branch Interceptor and extends north to the existing Crossbow Circle Pump Station. This project would eliminate the Crossbow Circle Pump Station.

Justification – There is currently very little development within this subcatchment of Coddle Creek. This project would provide service to anticipated development in the area. In addition, the Crossbow Circle Pump Station would be eliminated.

Priority – The purpose of this project is to support future development within the City of Concord city limits. Since this project would eliminate a pump station it is rated as a Tier 1 project. The anticipated cost for this work is approximately $942,500.



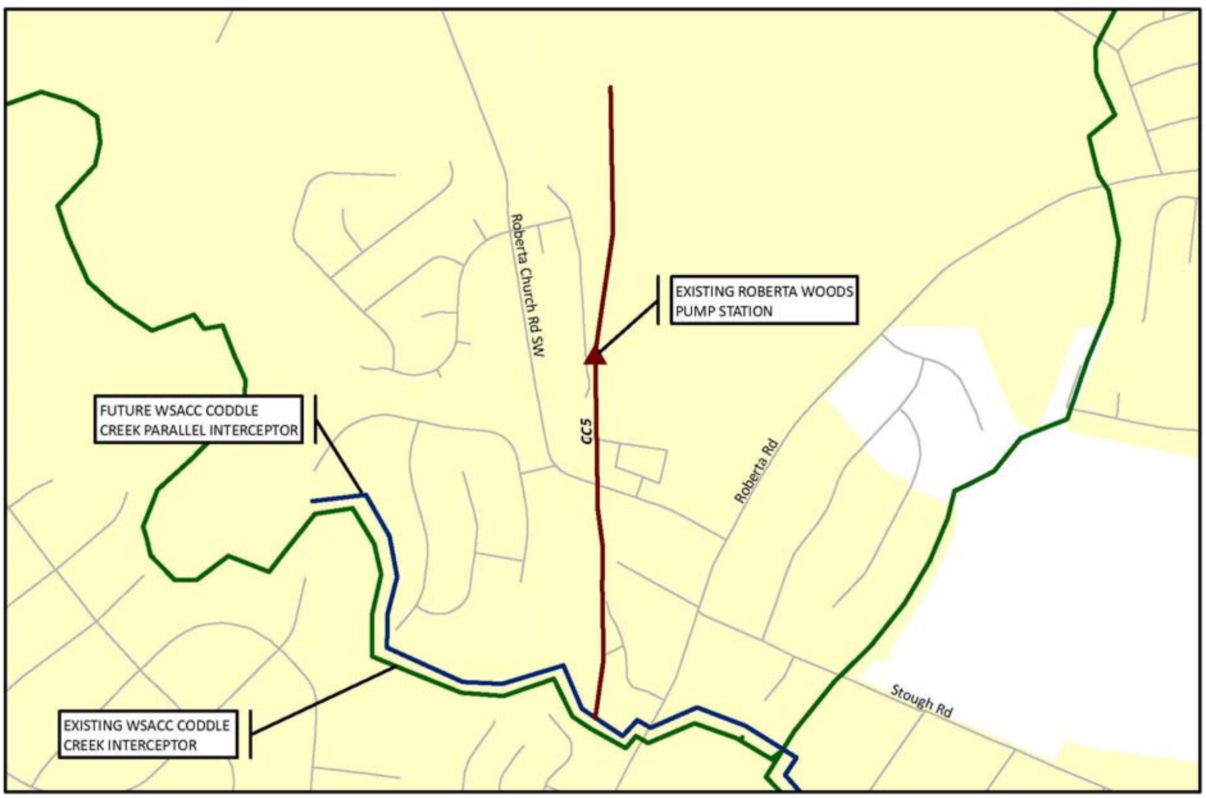
Tier 1 Projects
Coddle Creek Facilities

Project Code – CC5

Description – This project consists of approximately 5,000 feet of 15-inch gravity sewer to serve future development in the Coddle Creek Basin. The project begins at the future WSACC Coddle Creek Parallel Interceptor and extends north parallel to Roberta Church Road. This project would eliminate the Roberta Woods Pump Station.

Justification – There is currently very little development within this subcatchment of Coddle Creek. This project would provide service to anticipated development in the area. In addition, the Roberta Woods Pump Station would be eliminated.

Priority – The purpose of this project is to support future development within the City of Concord city limits. Since this project would eliminate a pump station it is rated as a Tier 1 project. The anticipated cost for this work is approximately $2,125,000.



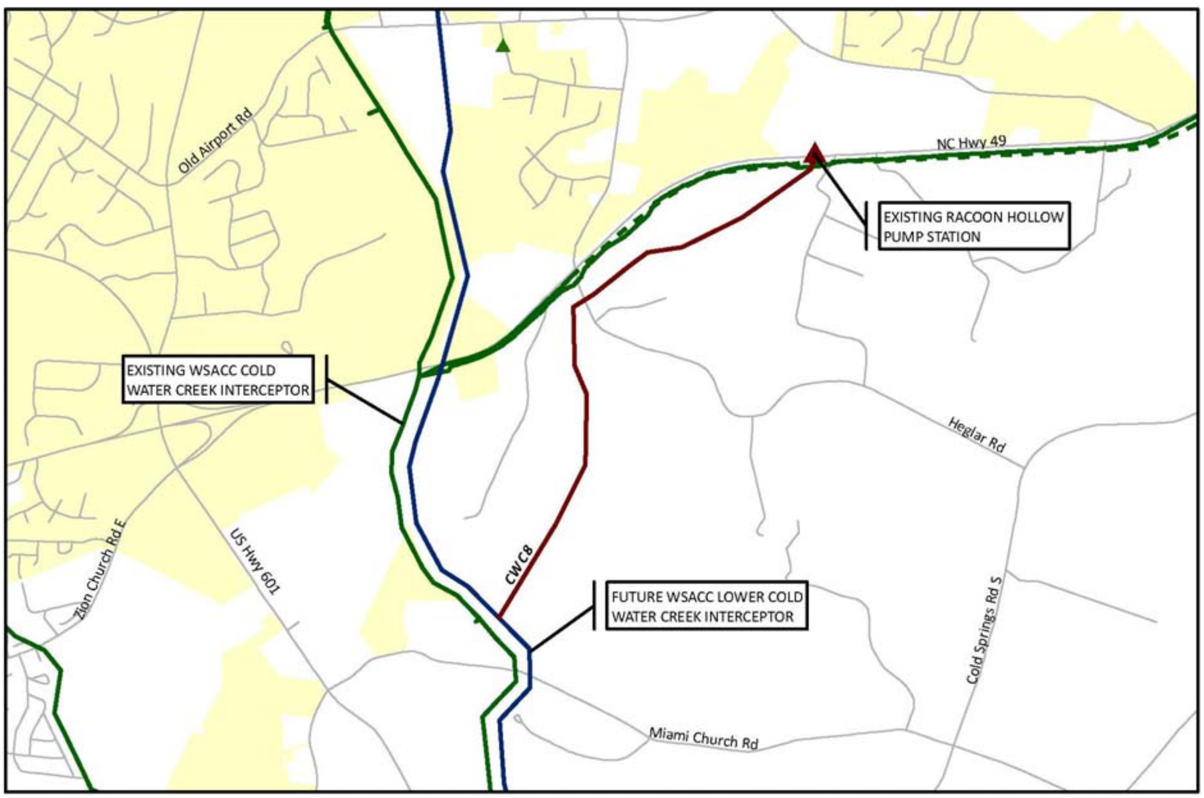
Tier 1 Projects
Cold Water Creek Facilities

Project Code – CWC8

Description – This project consists of approximately 9,900 feet of 18-inch gravity sewer to serve future development in the Cold Water Creek Basin. The project begins at the WSACC Lower Cold Water Creek Interceptors and extends northeast to the existing Concord Racoon Hollow Pump Station. This project would eliminate the Racoon Hollow Pump Station.

Justification – There is currently very little development within this subcatchment of Cold Water Creek. This project would provide service to anticipated development in the area. In addition, the Racoon Hollow Pump Station would be eliminated.

Priority – The purpose of this project is to support future development outside the City of Concord city limits. Since this project would eliminate a pump station it is rated as a Tier 1 project. The anticipated cost for this work is approximately $4,950,000.



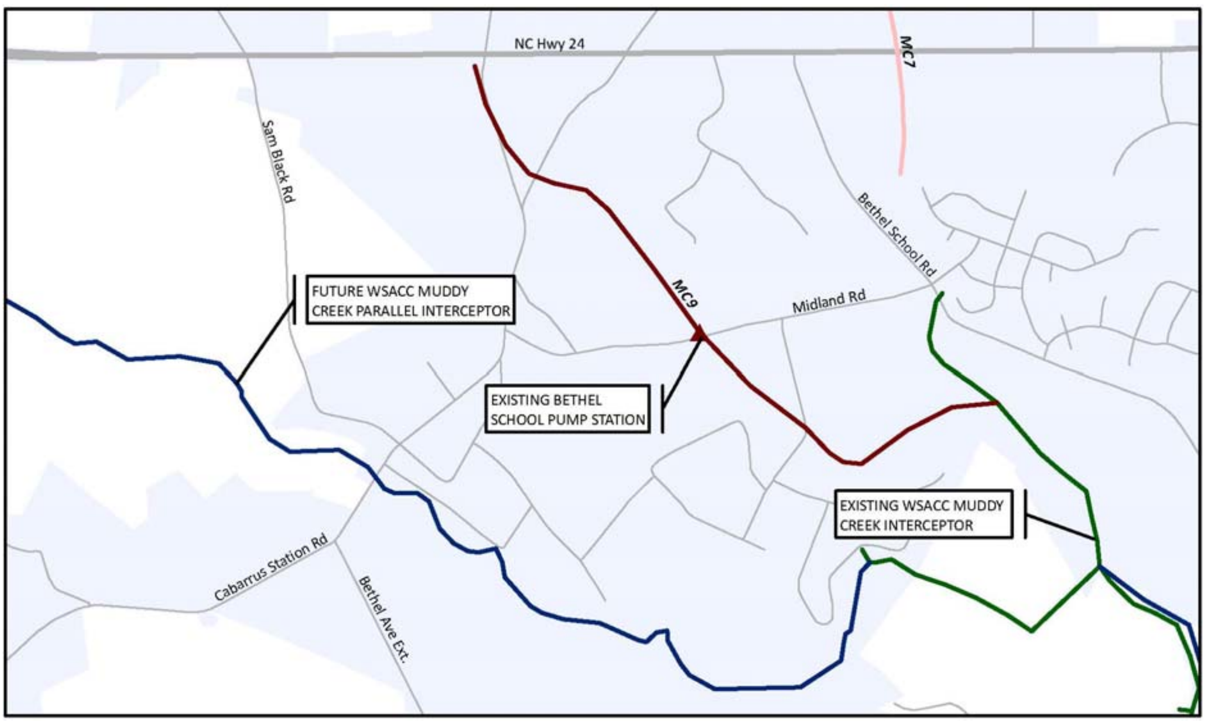
Tier 1 Projects
Coddle Creek Facilities

Project Code – MC9

Description – This project consists of approximately 6,700 feet of 12-inch gravity sewer to serve future development in the Muddy Creek Basin. The project begins at the existing WSACC Muddy Creek Interceptor and extends northwest to NC Highway 24. This project would eliminate the Bethel School Pump Station.

Justification – There is currently very little development within this area of the Muddy Creek Basin. This project would provide service to anticipated development in the area. In addition, the Bethel School Pump Station would be eliminated.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits. Since this project would eliminate a pump station it is rated as a Tier 1 project. The anticipated cost for this work is approximately $2,177,500.



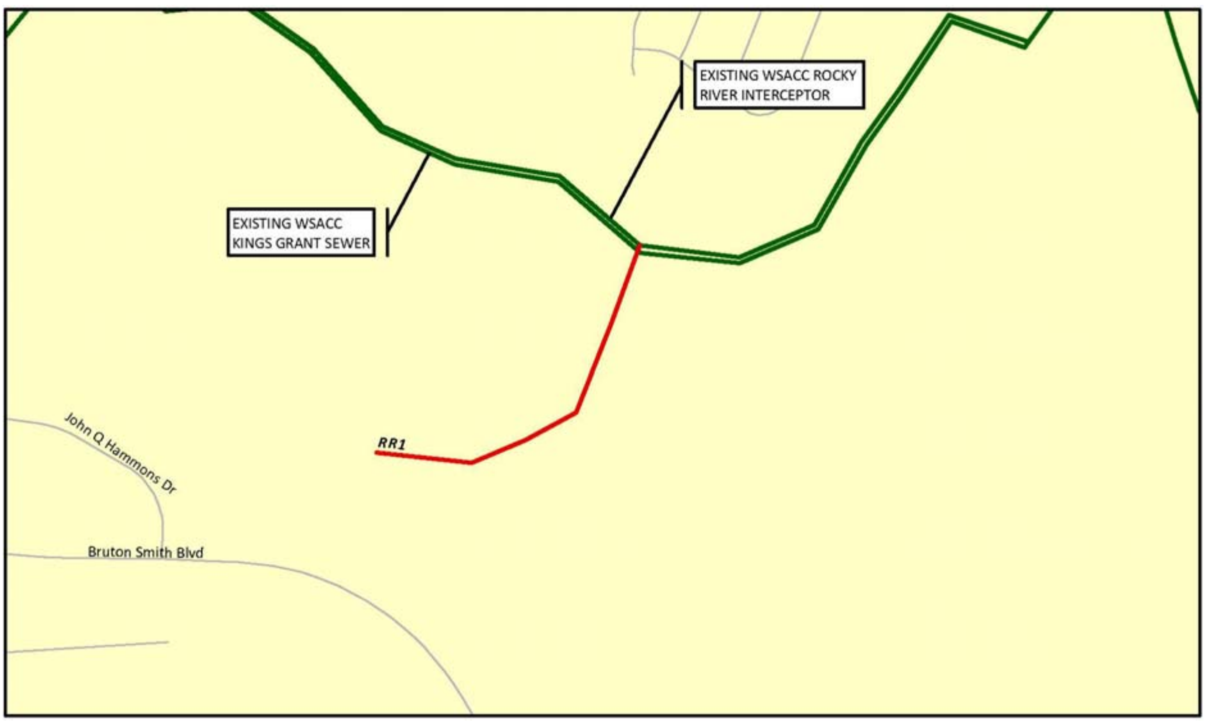
Tier 2 Projects
Rocky River Improvements

Project Code – RR1

Description – This project consists of replacement of approximately 2,040 feet of 12-inch diameter gravity sewer in the Rocky River Basin with a 15-inch diameter sewer. The project begins at the existing Rocky River Interceptor and extend southwest towards Bruton Smith Boulevard.

Justification – This project would replace existing infrastructure that does not appear to have sufficient capacity to accommodate future projected wastewater flows near the Charlotte Motor Speedway in Concord. The future facilities would be sufficient to meet future projected wastewater flows from the tributary subcatchment.

Priority – This project is dependent on future development and is therefore rated as a Tier 2 project. The anticipated cost for this work is approximately $867,000.



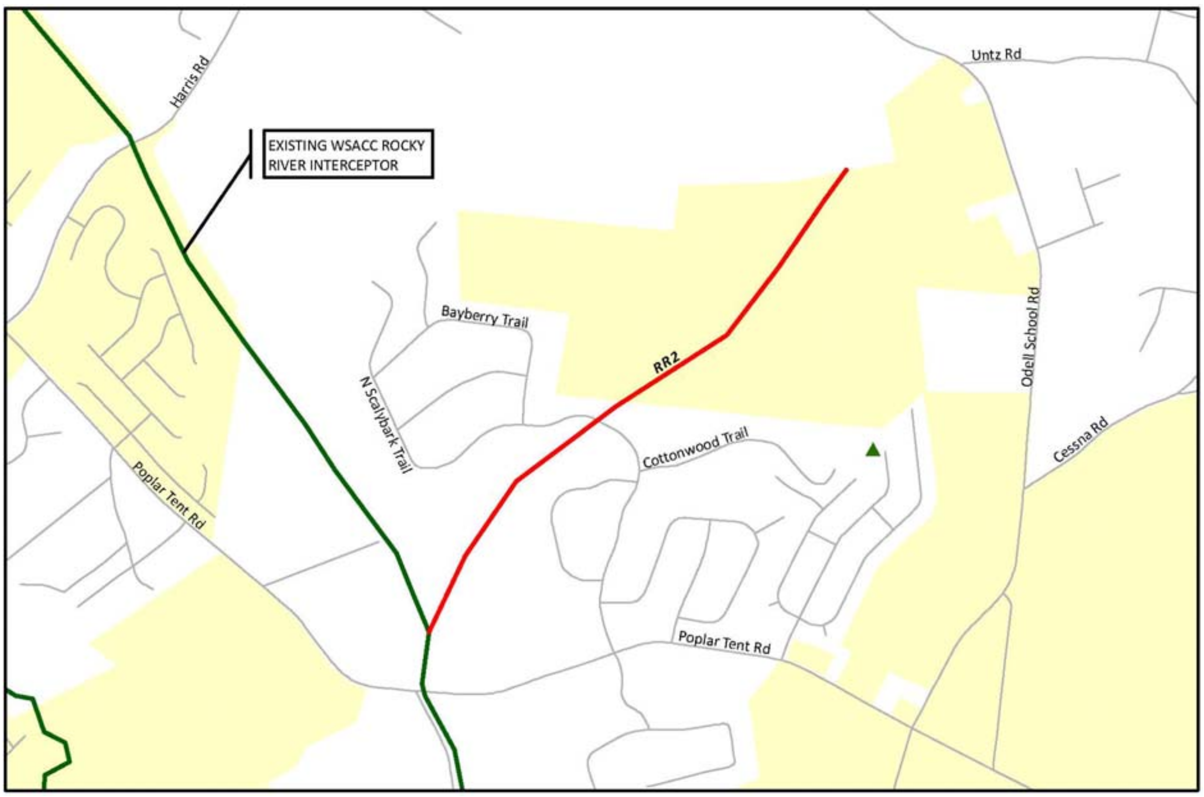
Tier 2 Projects
Rocky River Facilities

Project Code – RR2

Description – This project consists of approximately 6,700 feet of 15-inch gravity sewer to serve future development in the Rocky River Basin. The project begins at the existing WSACC Rocky River Interceptor and extends northeast towards Odell School Road.

Justification – There is currently very little development within this subcatchment of Rocky River. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development within the City of Concord city limits and is therefore rated as a Tier 2 project. The anticipated cost for this work is approximately $2,847,500.

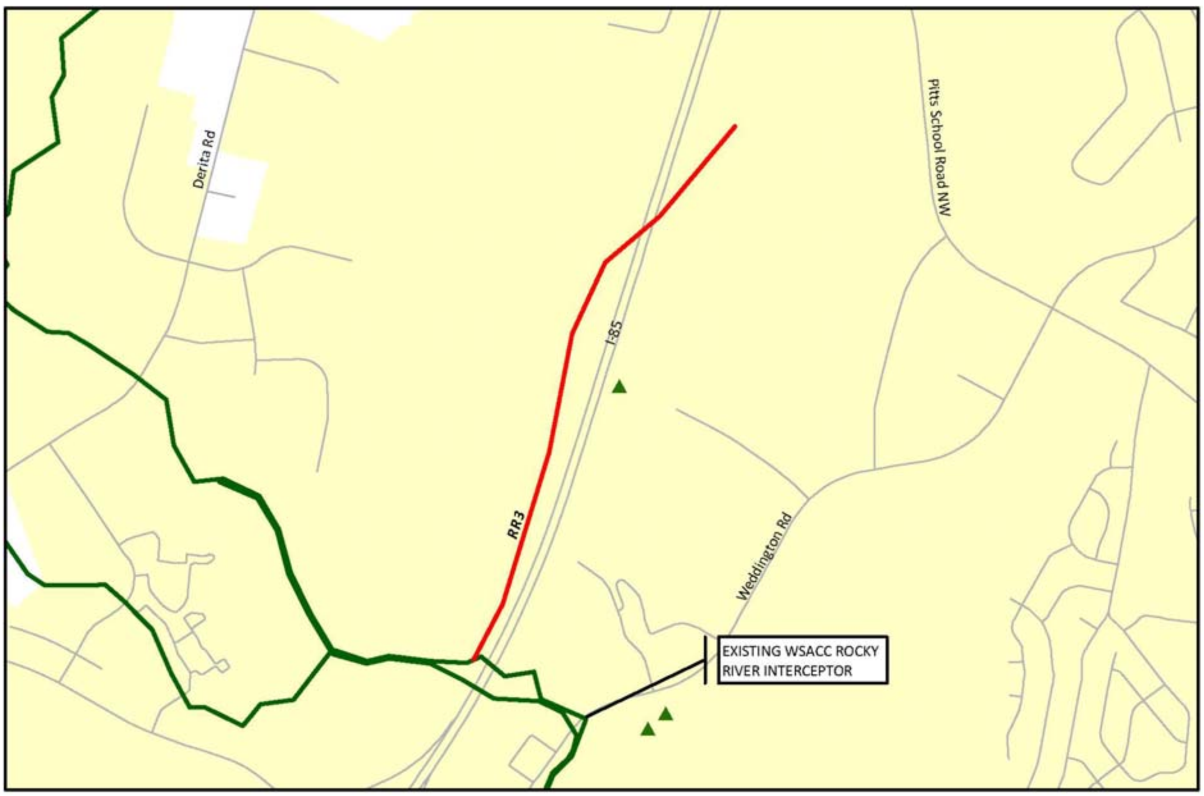


Project Code – RR3

Description – This project consists of approximately 6,400 feet of 15-inch gravity sewer to serve future development in the Rocky River Basin. The project begins at the existing WSACC Rocky River Interceptor and extends north, parallel to I-85.

Justification – There is currently very little development within this subcatchment of Rocky River. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development within the City of Concord city limits and is therefore rated as a Tier 2 project. The anticipated cost for this work is approximately $3,170,000.



Tier 2 Projects
Coddle Creek Improvements

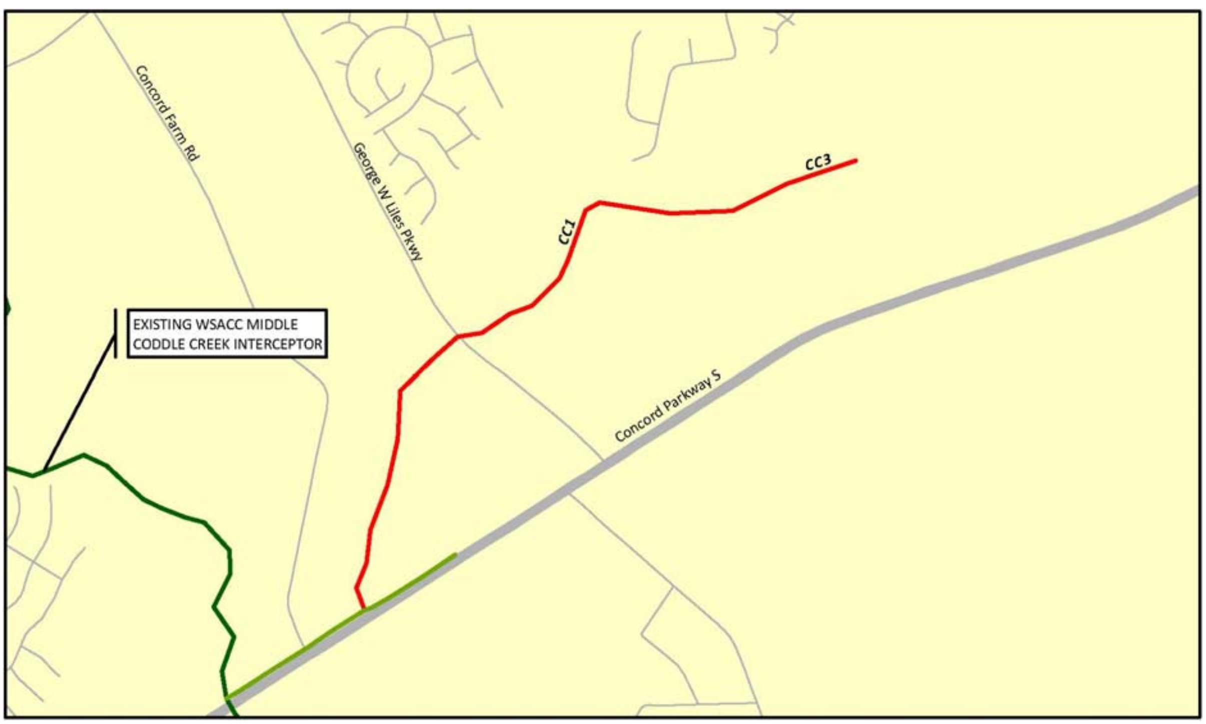
Project Code – CC1, CC3

Description – These projects consist of multiple improvements in the Coddle Creek Basin. The improvements include replacement of an existing 12-inch diameter gravity sewer with a 24-inch diameter sewer (CC1). The improvements also include approximately 4,700 feet of 15-inch gravity sewer to serve future development in the subcatchment (CC3).

Justification – The purpose of section CC1 is to replace existing infrastructure that does not appear to have sufficient capacity to accommodate future projected wastewater flows. Section CC3 would extend the service area to future development in the subcatchment.

Priority – These projects are dependent on future development and are therefore rated as Tier 2 projects. The anticipated cost for this work is approximately $5,152,000 as tabulated below.

Project Code	Size	Length	Estimated Cost
CC1	24	5,190	$3,154,500
CC3	15	4,700	$1,997,500
Total Estimated Cost			**$5,152,000**



Project Code – CC6

Description – This project consists of approximately 4,600 feet of 12-inch gravity sewer to serve future development in the Coddle Creek Basin. The project begins at the existing WSACC Wolfmeadow Branch Interceptor and extends north towards Union Cemetery Road.

Justification – There is currently very little development within this subcatchment of Coddle Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development within the City of Concord city limits and is therefore rated as a Tier 2 project. The anticipated cost for this work is approximately $1,495,000.

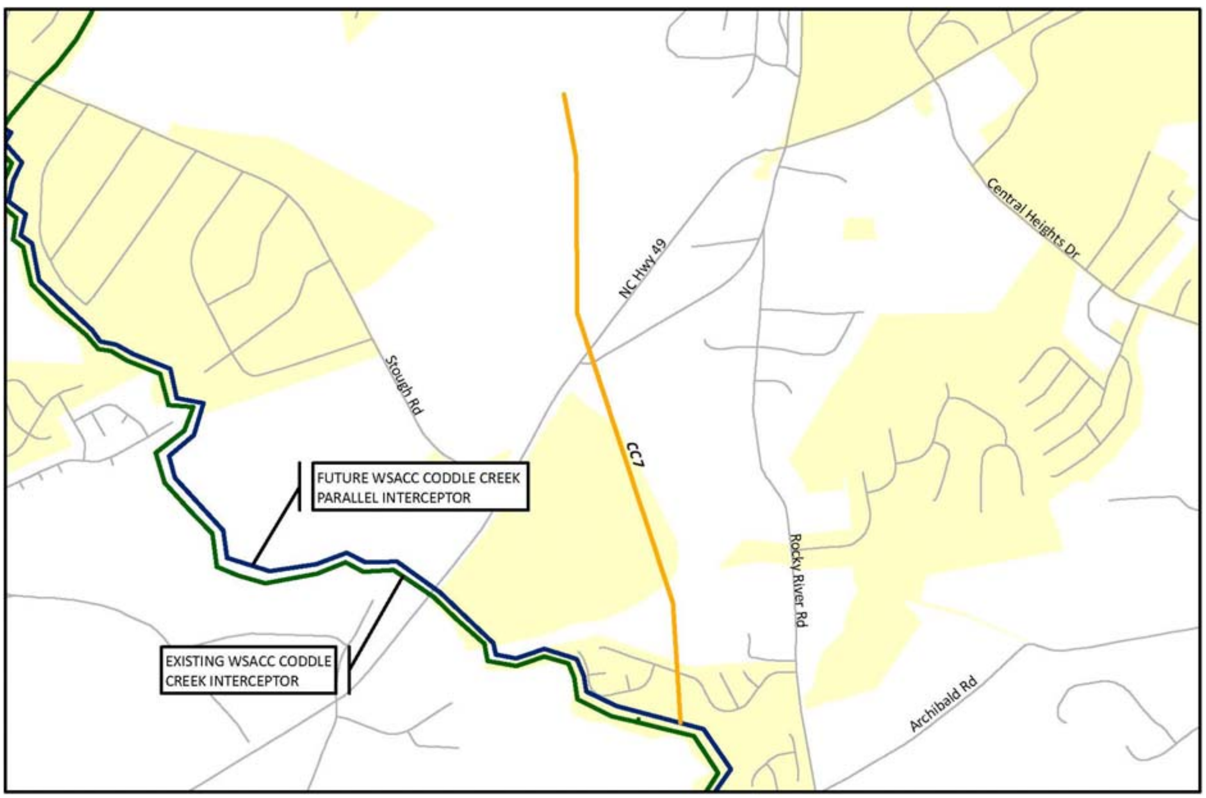
Tier 3 Project
Coddle Creek Facilities

Project Code – CC7

Description – This project consists of approximately 8,500 feet of 12-inch gravity sewer to serve future development in the Coddle Creek Basin. The project begins at the WSACC Coddle Creek Parallel Interceptors and extends north, crossing over NC Highway 49.

Justification – There is currently very little development within this subcatchment of Coddle Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as a Tier 3 project. The anticipated cost for this work is approximately $3,062,500.



Tier 3 Projects
Cold Water Creek Facilities

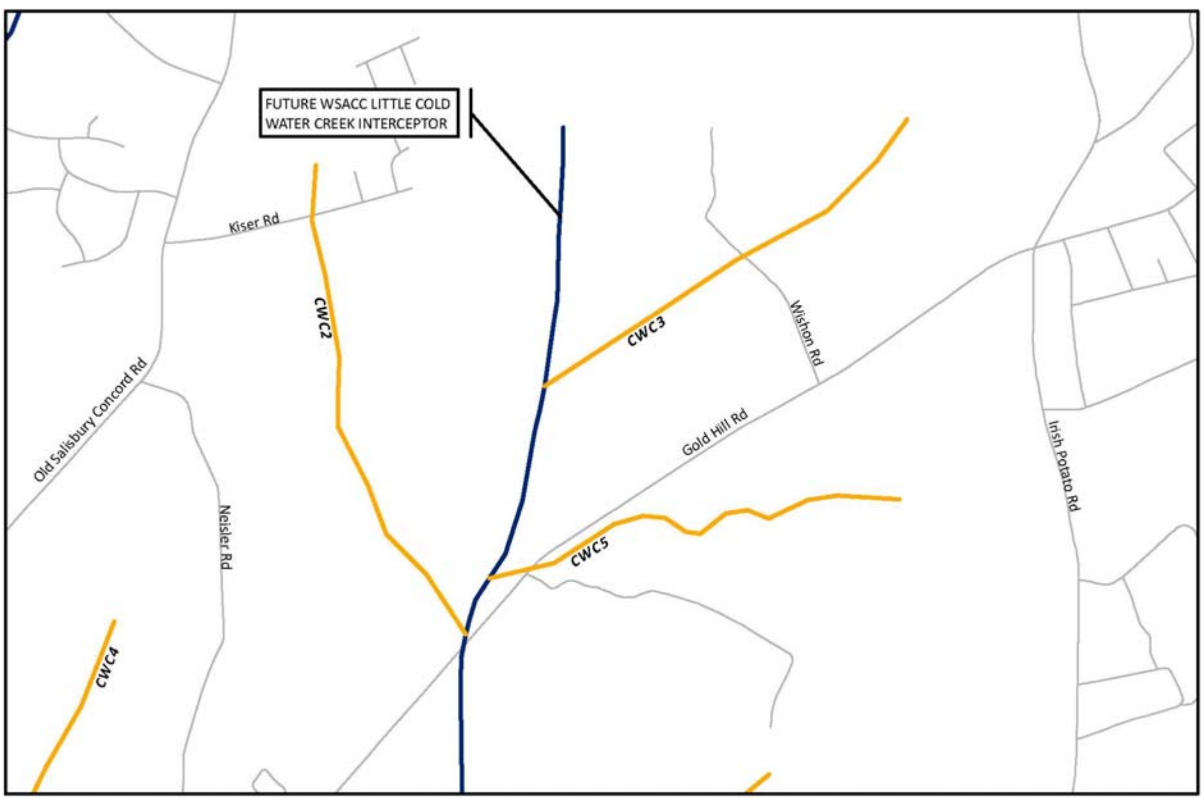
Project Code – CWC2, CWC3, CWC5

Description – These projects consists of several new gravity sewers to serve future development in the Cold Water Creek Basin. The projects include two 8-inch gravity sewers and a 15-inch gravity sewer, all of which discharge into the future WSACC Little Cold Water Creek Interceptor.

Justification – There is currently very little development within these subcatchments of Cold Water Creek. These projects would provide service to anticipated development in the area.

Priority – The purpose of these projects is to support future development outside of the City of Concord city limits and they are therefore rated as Tier 3 projects. These projects are dependent on the future WSACC Little Cold Water Creek Interceptor. The anticipated cost for this work is approximately $5,907,500 as tabulated below.

Project Code	Size	Length	Estimated Cost
CWC2	8	6,300	$1,890,000
CWC3	8	5,600	$1,680,000
CWC5	15	5,500	$2,337,500
Total Estimated Cost			**$5,907,500**



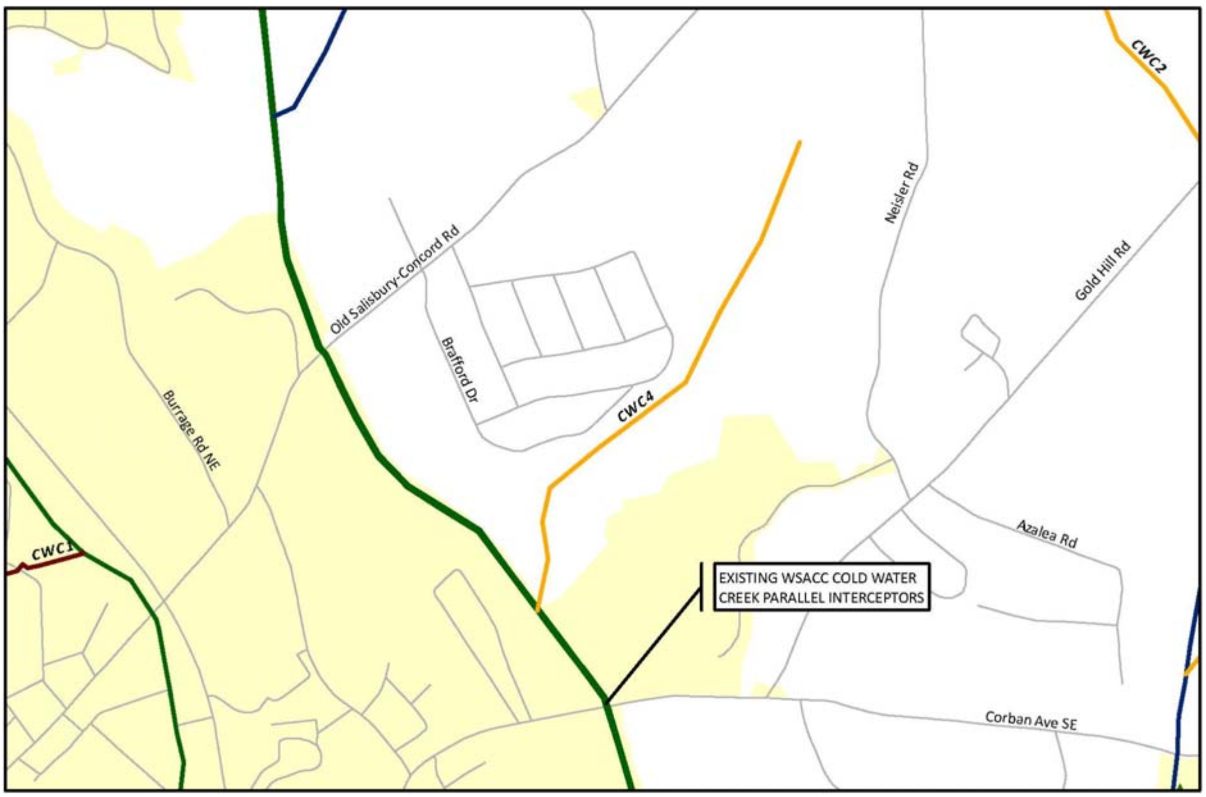
Tier 3 Projects
Cold Water Creek Facilities

Project Code – CWC4

Description – This project consists of approximately 6,000 feet of 8-inch gravity sewer to serve future development in the Cold Water Creek Basin. The project begins at the existing WSACC Cold Water Creek Interceptor and extends northeast towards Neisler Road.

Justification – There is currently very little development within these subcatchments of Cold Water Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as a Tier 3 project. The anticipated cost for this work is approximately $1,800,000.



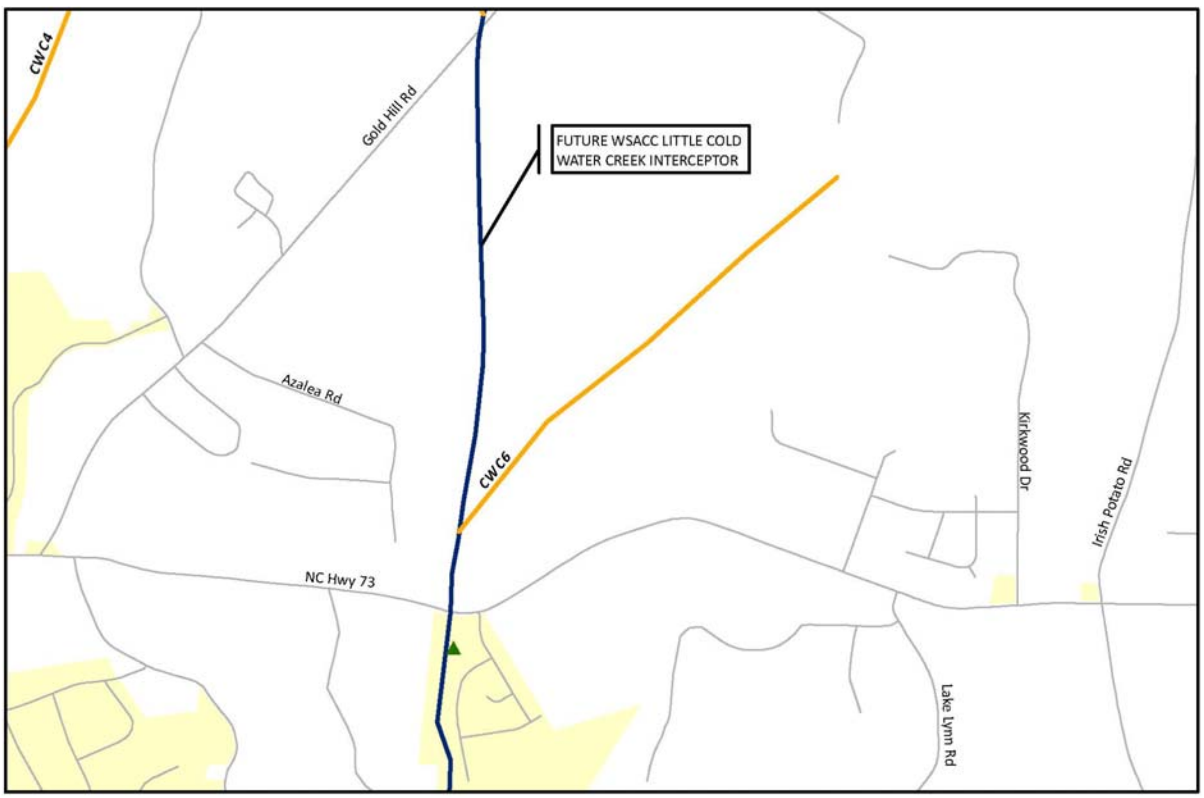
Tier 3 Projects
Cold Water Creek Facilities

Project Code – CWC6

Description – This project approximately 5,500 feet of 12-inch gravity sewer to serve future development in the Cold Water Creek Basin. The project begins at the future WSACC Little Cold Water Creek Interceptor and extends northeast.

Justification – There is currently very little development within these subcatchments of Cold Water Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as a Tier 3 project. This project is dependent on the future WSACC Little Cold Water Creek Interceptor. The anticipated cost for this work is approximately $1,787,500.



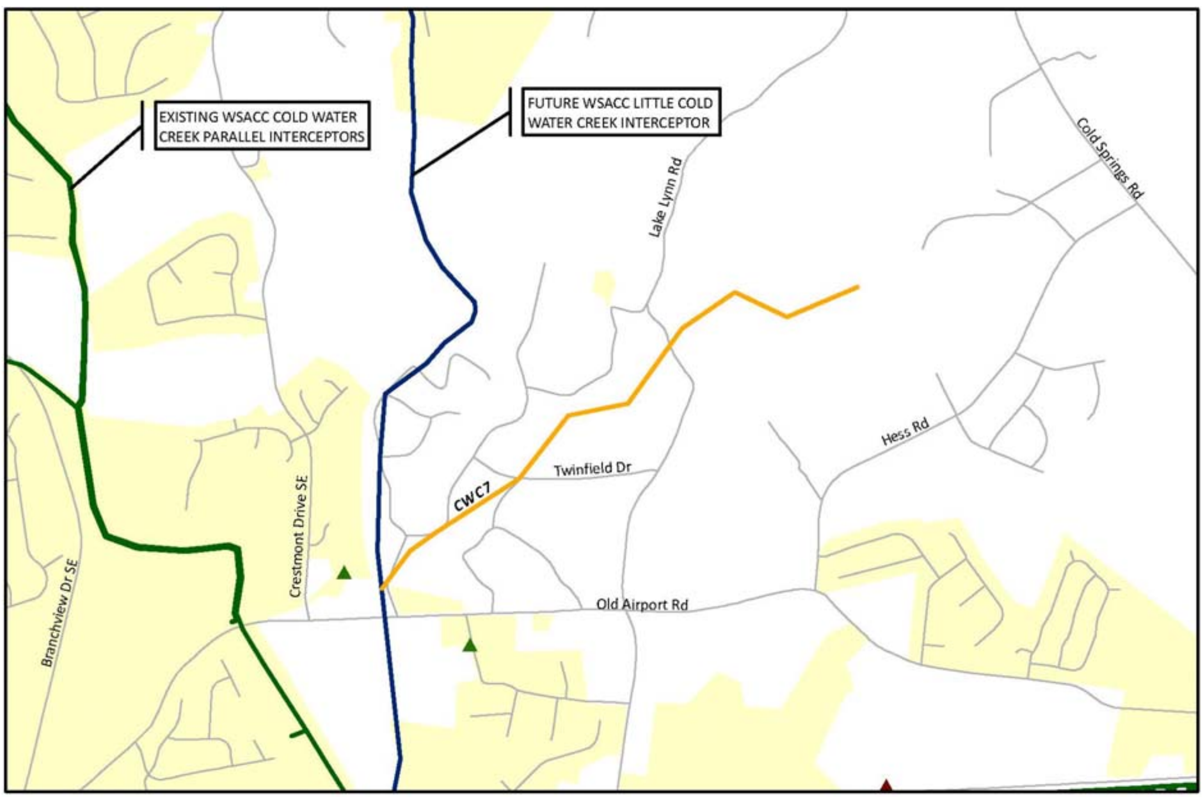
Tier 3 Projects
Cold Water Creek Facilities

Project Code – CWC7

Description – This project consists of approximately 7,200 feet of 12-inch gravity sewer to serve future development in the Cold Water Creek Basin. The project begins at the future WSACC Little Cold Water Creek Interceptor and extends northeast towards Lake Lynn.

Justification – There is currently very little development within this subcatchment of Cold Water Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as Tier 3 project. This project is dependent on the future WSACC Little Cold Water Creek Interceptor. The anticipated cost for this work is approximately $2,340,000.



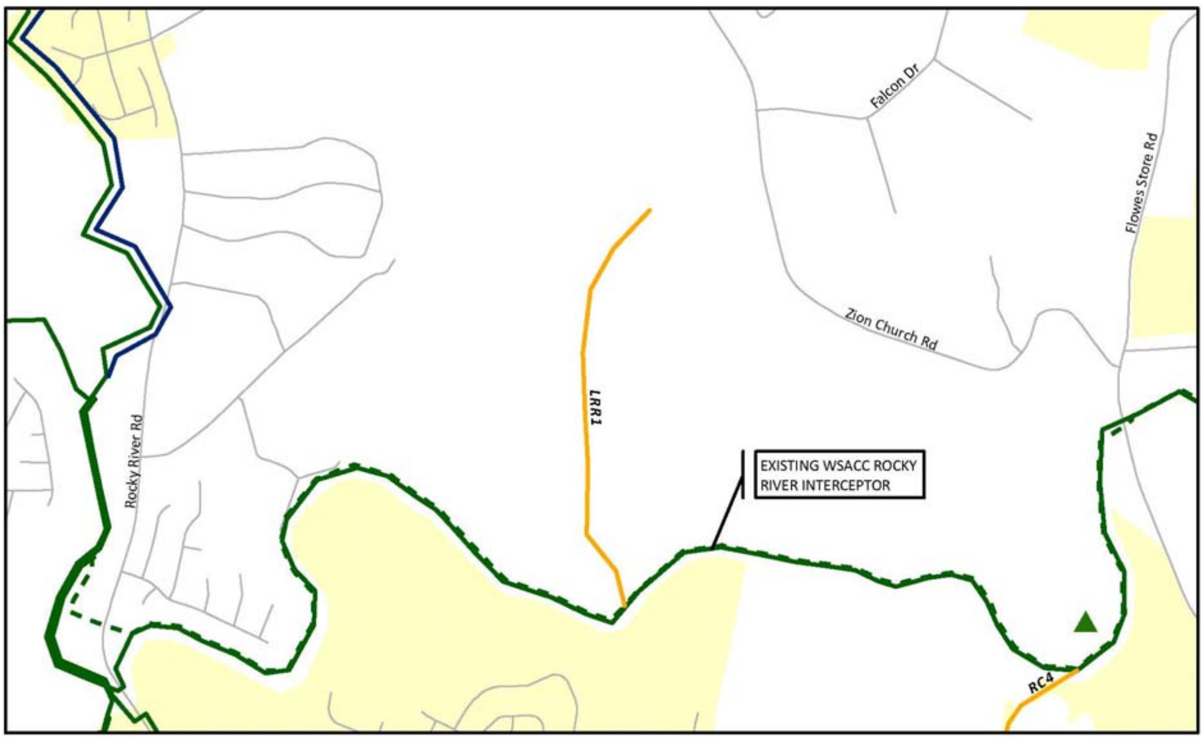
Tier 3 Projects
Lower Rocky River Facilities

Project Code – LRR1

Description – This project consists of approximately 4,500 feet of 12-inch gravity sewer to serve future development in the Lower Rocky River Basin. The project begins at the existing WSACC Rocky River Interceptor and extends north towards Zion Church Road.

Justification – There is currently very little development within this subcatchment of Cold Water Creek. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development within the City of Concord city limits and is therefore rated a Tier 3 project. The anticipated cost for this work is approximately $1,462,500.



Tier 3 Projects
Reedy Creek Facilities

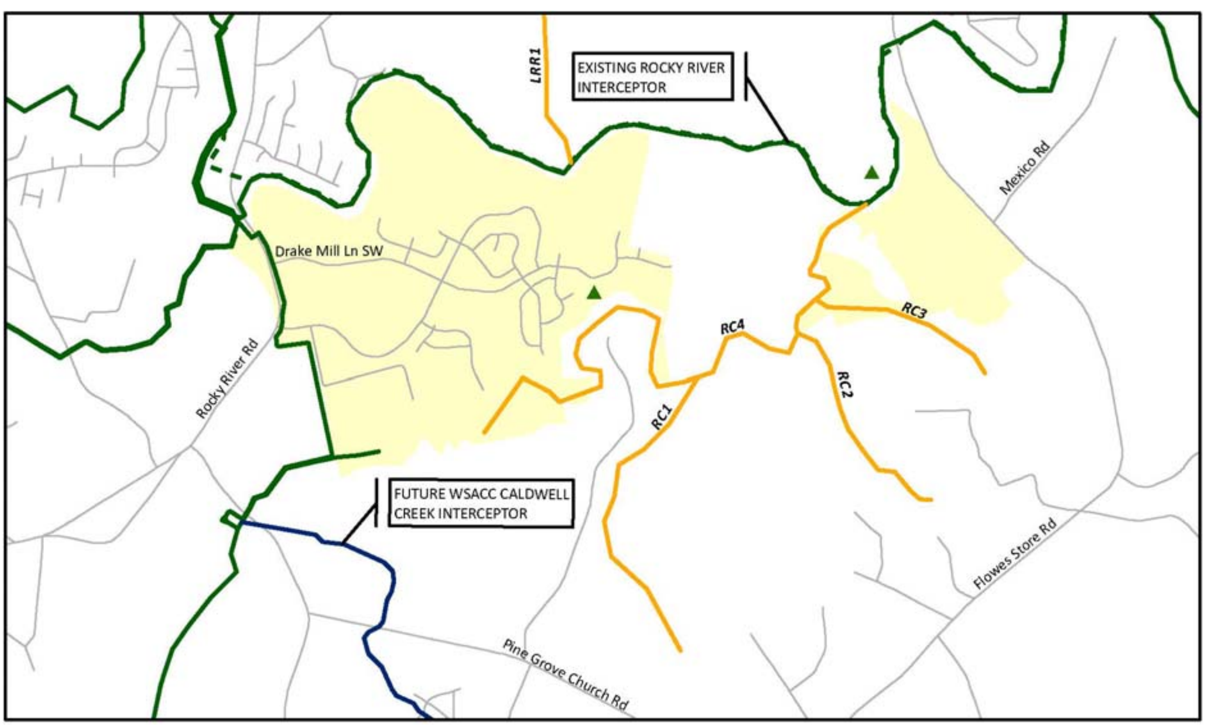
Project Codes – RC1, RC2, RC3, RC4

Description – These projects include several new gravity sewers to serve future development in the Reedy Creek basin. The projects include approximately 12,000 feet of 15-inch gravity sewer that begins at the existing WSACC owned Rocky River Interceptor at the confluence of Reedy Creek and Rocky River and extends southwest along Reedy Creek. The projects also include two 8-inch gravity sewers and a 12-inch gravity sewer which would discharge into the new 15-inch sewer.

Justification – There is currently very little development within these subcatchments of Reedy Creek. These projects would provide service to anticipated development in the area.

Priority – The purpose of these projects is to support future development outside of the City of Concord city limits. Segment RC4 would be required before any development could occur. These projects are rated as Tier 3 projects. The anticipated cost for this work is approximately $8,870,000 as tabulated below.

Project Code	Size	Length	Estimated Cost
RC1	8	5,400	$1,620,000
RC2	8	3,700	$1,110,000
RC3	12	3,200	$1,040,000
RC4	15	12,000	$5,100,000
Total Estimated Cost			**$8,870,000**



Tier 4 Projects
Muddy Creek Improvements

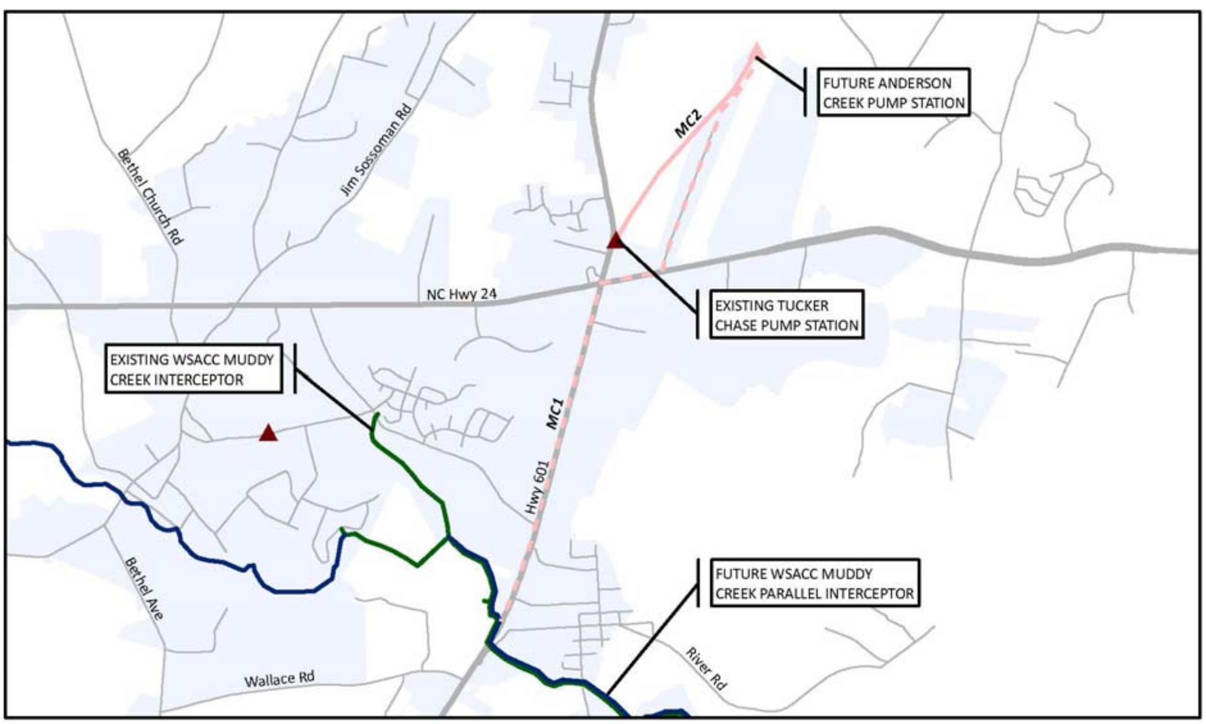
Project Codes – MC1, MC2

Description – These projects consist of multiple improvements to serve future development in the Muddy Creek Basin. The projects include approximately 7,000 feet of 12-inch gravity sewer extending from the existing Tucker Chase Pump Station to the future Anderson Creek Pump Station (MC2). The project also includes approximately 18,000 feet of 12-inch force main extending from the 850 gpm Anderson Creek Pump Station and discharging into the WSACC Muddy Creek Parallel Interceptors (MC1). The Tucker Chase Pump Station would be eliminated as part of these projects.

Justification – There is currently very little development within this area of the Muddy Creek Basin. These projects would provide service to anticipated development in the area. In addition, the Tucker Chase Pump Station would be eliminated.

Priority – The purpose of these projects is to support future development outside of the City of Concord city limits and they are therefore rated as Tier 4 projects. The anticipated cost for this work is approximately $4,575,000 as tabulated below.

Project Code	Size	Length	Estimated Cost
MC1	12	18,000	$2,300,000
MC2	12	7,000	$2,275,000
Total Estimated Cost			**$4,575,000**



Tier 4 Projects
Muddy Creek Improvements

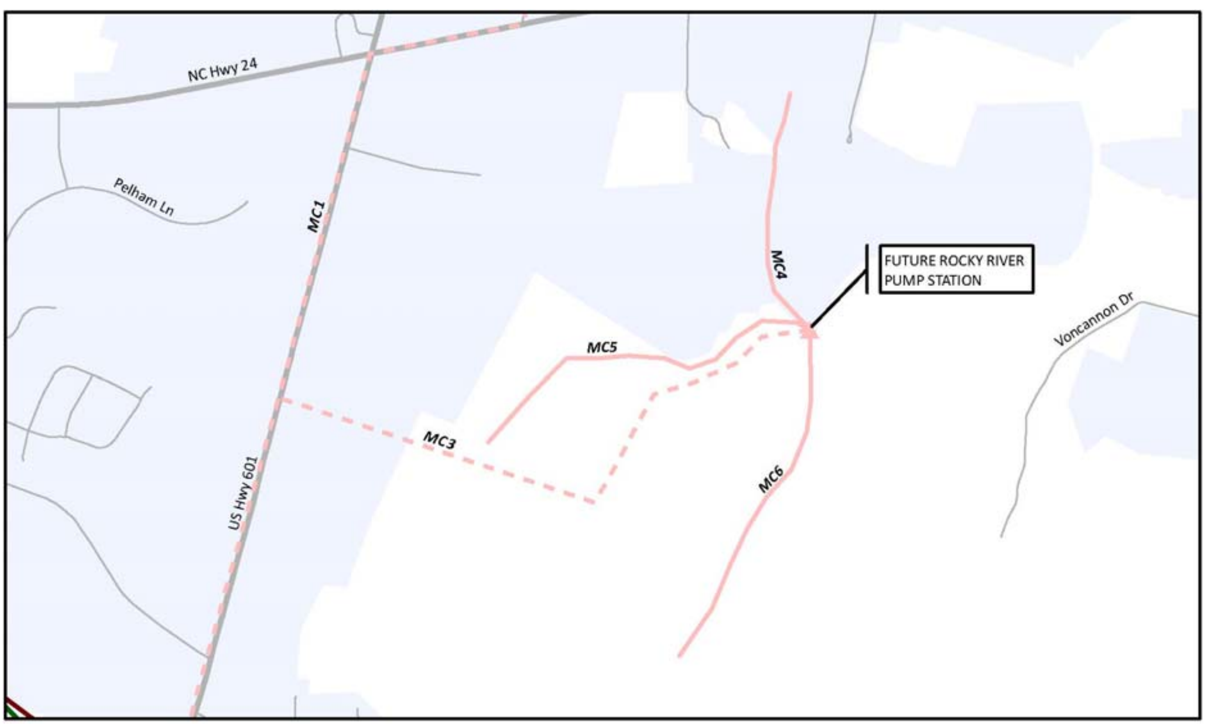
Project Codes – MC3, MC4, MC5, MC6

Description – These projects consist of multiple improvements to serve future development in the Muddy Creek Basin. The projects include multiple gravity sewers that convey wastewater to a future Rocky River Pump Station located at Rocky River. The project also includes approximately 6,600 feet of 12-inch diameter force main extending from the new 1,100 gpm Rocky River Pump Station to the future force main on Highway 601 (MC3).

Justification – There is currently very little development within this area of the Muddy Creek Basin. These projects would provide service to anticipated development in the area.

Priority – The purpose of these projects is to support future development outside of the City of Concord city limits and they are therefore rated as Tier 4 projects. The anticipated cost for this work is approximately $4,477,500 as tabulated below.

Project Code	Size	Length	Estimated Cost
MC3	12	6,600	$1,160,000
MC4	12	2,700	$877,500
MC5	12	4,000	$1,300,000
MC6	8	3,800	$1,140,000
Total Estimated Cost			**$4,477,500**



Tier 4 Projects
Muddy Creek Improvements

Project Codes – MC7

Description – This project consists of approximately 4,600 feet of 18-inch gravity sewer to serve future development in the Muddy Creek Basin. The project begins at an existing gravity sewer near Hill Pine Road and extends north to Jim Sossoman Road.

Justification – There is currently very little development within this area of the Muddy Creek Basin. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as a Tier 4 project. The anticipated cost for this work is approximately $2,300,000.

Tier 4 Projects
Muddy Creek Improvements

Project Codes – MC8

Description – This project consists of approximately 2,600 feet of 8-inch gravity sewer to serve future development in the Muddy Creek Basin. The project begins at the existing WSACC Muddy Creek Interceptor and extends south towards Whitley Road.

Justification – There is currently very little development within this area of the Muddy Creek Basin. This project would provide service to anticipated development in the area.

Priority – The purpose of this project is to support future development outside of the City of Concord city limits and is therefore rated as a Tier 4 project. The anticipated cost for this work is approximately $780,000.