



# TOWN OF SOUTHERN PINES SEWER SYSTEM ASSET MANAGEMENT PLAN

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*Prepared for:*



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## LIST OF ABBREVIATIONS

AMP	-	Asset Management Plan
CI	-	Cast Iron Pipe
CIP	-	Capital Improvement Plan
CIPP	-	Cured in Place Pipe
DIP	-	Ductile Iron Pipe
FY	-	Fiscal Year
GIS	-	Geographic Information System
GPM	-	Gallons per Minute
LF	-	Linear Feet
LOS	-	Level of Service
MGD	-	Million Gallons per Day
NCAC	-	North Carolina Administrative Code
NCDEQ	-	North Carolina Department of Environmental Quality
O&M	-	Operation and Maintenance
PVC	-	Polyvinyl Chloride Pipe
RPT	-	Reinforced Plastic Truss
SSO	-	Sanitary Sewer Overflow
VCP	-	Vitrified Clay Pipe
WWTP	-	Wastewater Treatment Plant

# 1 Executive Summary

## 1.1 Introduction

The Town of Southern Pines, with the assistance of WithersRavenel, developed a comprehensive Asset Management Plan (AMP) for its sewer collection system assets. The AMP for the collection system is funded through the North Carolina Division of Environmental Quality (NCDEQ) Asset Inventory and Assessment (AIA) Grant program.

The scope of the Asset Management Plan is shown in Table 1 below, which outlines the Town's core collection system assets assessed, and included in this AMP.

*Table 1 - Town's Core Collection System Infrastructure Assets*

Asset Category	Asset Types
Collection System	Gravity Mains, Manholes, Force Mains, Lift Stations

## 1.2 Project Purpose

The purpose of this AMP is to deliver a near- and long-term roadmap for proactive management of the Town's wastewater assets and provide data driven insights for the Town to make informed decisions for capital planning and to maximize value of existing infrastructure in the most cost-effective manner, all while ensuring enhanced levels of service for its residents.

The AMP is a compilation of four (4) key components:

1. Asset Inventory
2. Condition Assessment Results
3. Capital Improvements Plan (CIP) with projected cost estimates
4. Operation and Maintenance (O&M) Plan

## 1.3 Key Findings

### 1.3.1 Inventory of Assets

Table 2 below summarizes inventory of the Town's collection system assets assessed as a part of the project and their replacement values.

*Table 2 - Collection System Inventory*

Collection System Inventory		
Asset Type	Quantity	Replacement Value
Gravity Mains	796,649 LF	\$ 205,264,168
Force Mains	65,850 LF	\$ 9,025,098
Manholes	3,743	\$8,740,215
Lift Stations <sup>1</sup>	19	-

<sup>1</sup> Lift stations were not assessed for their replacement values

### 1.3.2 Risk Assessment Summary

Figure 1 below illustrates the Risk across each asset category.

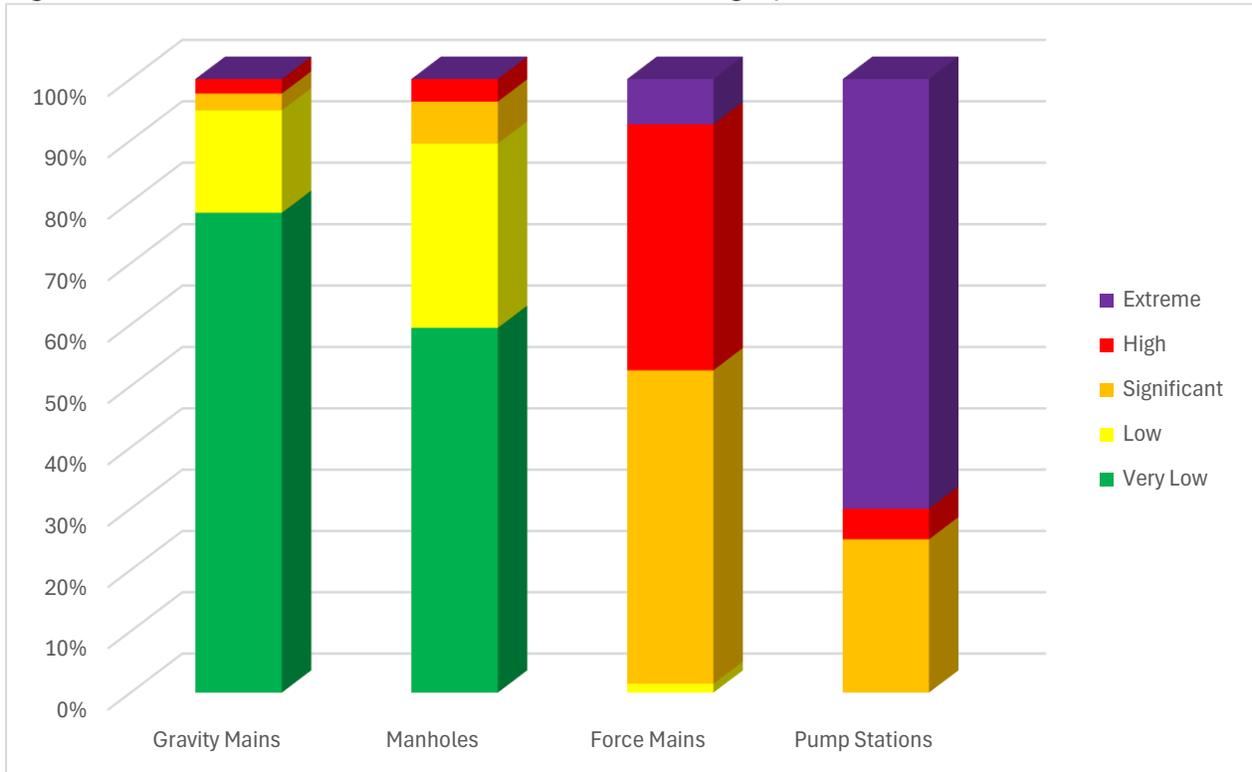


Figure 1 - Summary of Sewer System Assets by Risk

### 1.3.3 10-Year Capital Improvements Plan (CIP)

The list shown here is a summary of the project list showing on the Capital Improvements Plan in Section 7.

- Gravity Sewer System - Annual Rehabilitation (Wastewater Project #8)
- Longleaf Dam Sewer Relocation (Wastewater Project #7)
- Sewer Lift Station Emergency Backups (Wastewater Project #5)
- Warrior Woods Pump Station Upgrade Phases IB, II, III (Wastewater Projects #1-3)

### 1.3.4 Operation and Maintenance (O&M) Plan

Table 3 provides an O&M list prepared as a part of the project. See Table 21 for a more comprehensive list of O&M recommendations.

*Table 3 - Operation and Maintenance Schedule*

Operation and Maintenance Schedule		
Asset	Recommendation	Frequency
Gravity Mains	Clean and video inspect at least 10% of the gravity mains	Annually
	Document all SSOs	As Needed
	Break Evaluation Log	As Needed
Force Mains	Break Evaluation Log	As Needed
	Pressure Checks	Monthly
	Exercise and Inspect Valves	Monthly
Manholes	Visual Inspections (10% of system)	Annually
Laterals	Inspect laterals for damage and missing clean out caps (10% each year)	Annually
Lift Stations	Maintenance, Safety, Structural, and Security Inspection	Annually
	Drawdown testing	Per Permit Requirement
	Start/Stop Control Alarm testing	Per Permit Requirement
	Telemetry Verification	Per Permit Requirement
	Practice Emergency Response	Per Permit Requirement
Emergency Plan	Review System Operations Plan	Annual

## 2 Background and System Overview

### 2.1 Background

The Town of Southern Pines is in eastern North Carolina in Moore County, approximately 30 miles west of Fayetteville. The population of the Town is approximately 16,052 and accounts for approximately 15% of the total population in Moore County.

The Town received an AIA grant award of \$200,000 to study its sewer collection system in the Fall 2022 funding cycle. The Town, with the help of WithersRavenel, reviewed its sewer system assets by performing a Geographic Information System (GIS) data review and populating manhole attribute information. Data collected from this review was used to classify critical assets, perform flow monitoring including rainfall derived infiltration and inflow analysis, calibrate a hydraulic model, assess utility easement for tree cover and, perform a risk assessment, identify critical projects to include in the Town's Capital Improvements Plan (CIP), and determine operation and maintenance strategies to mitigate future risk of failure. This study resulted in the development of this AMP. The elements of the AMP framework include:

- Level of Service (LOS) Statement
- Asset Inventory
- Risk Analysis using Likelihood of Failure (LoF) and Consequences of Failure (CoF)
- Operation and Maintenance (O&M) Plan
- 10-Year Capital Improvements Plan (CIP)
- Utility Assessment

This AMP is intended to be a living document that is updated regularly. It is recommended that the data stored within the Town's GIS database be continually validated and updated to ensure that the most relevant and accurate representations of the current system are captured.

### 2.2 System Overview

The sewer collection system is a combination of gravity mains and pumping stations to collect wastewater from 6,940 customers and convey it to the Moore County Wastewater Treatment Plant (WWTP) where it is treated and discharged into Aberdeen Creek. The plant has a permitted capacity of 0.48 million gallons per day (MGD) operating under Permit No. NCG590018. References for this data can be found in Appendix III.

The sewer system assets include:

- Approximately 150 miles of Gravity Mains
- Approximately 12.5 miles of Force Mains
- 3,743 Manholes
- 19 Lift Stations

The sewer system inventories are stored and maintained in the Town's GIS database. The following sections break down the current state of the inventory, and maps of sewer assets can be found in Appendix I.

### 3 Level of Service

Level of Service (LOS) criteria define the goals and standards the Town will strive to attain. LOS criteria reflect the mission of the Town and are expressed in terms of quality, quantity, reliability, responsiveness, cost, and environmental impact. Taking all these considerations into account, the Town is adopting the following LOS criteria:

Table 4 - Southern Pines, NC Level of Service Criteria

Category	Level of Service	Performance Measure	Target
Performance	<b>1. Residential Back-ups and SSOs</b> No adverse events will cause residential sewer back-ups and sanitary sewer overflows (SSOs)	Number of violations per year	0 events/year
	<b>2. Sewer System Performance</b>	Main break frequency per year	≤ 15/100 miles
		CCTV inspection	10% every year
Customer Service	<b>3. Response Time</b> Respond to customer complaints/requests in a timely manner	Emergency (breaks)	1-2 hours
		Leaks	1-2 hours
	<b>4. Communication</b> Notification of planned shutdown will be provided	Number of days	≥ 72 Hours
Financial	<b>5. Financial Capability</b> Rates are reviewed on an annual basis and revised as needed to ensure full cost recovery	Revise, review rates	Once/year

With the LOS criteria developed, the Town must establish sustainable business processes to ensure information required for measuring LOS is readily available and cost effective. The processes for collecting the information must be integrated into existing workflows.

#### 3.1 Design Standards

The prevention of residential sewer back-ups and sanitary sewer overflows were designated as important metrics for the sewer system analysis, and Figure 5 summarizes the sewer system design standards per North Carolina Administrative Code (NCAC). These standards were used to identify assets within the collection system that require updates to become compliant.

Table 5 - Sewer System Design Standards per NCAC

System Parameter	Evaluation Criterion	Value	Design Standard/Guideline
Design Capacity	Daily Flow	Various <sup>1</sup>	15A NCAC 02T.0114
Minimum Separation	Storm Sewer	18 inches	15A NCAC 02T.0305
	Water Mains - Vertical	18 inches	
	Water Mains - Horizontal	10 feet	
	Reclaimed Water Lines - Vertical	18 inches	
	Reclaimed Water Lines - Horizontal	2 feet	
	Drinking Water Source	100 feet	
	Classified Waters <sup>2</sup> or Wetlands <sup>3</sup>	50 feet	
	Stream, Lake, Impoundment, Wetlands <sup>4</sup> , Waters <sup>5</sup>	10 feet	
	Building Foundation	5 feet	
	Basement	10 feet	
	Top slope <sup>6</sup>	10 feet	
	Drainage System	5 feet	
	Swimming Pool	10 feet	
	Final Earth Grade	36 inches	
Minimum Nominal Diameter	Public Gravity	8-inch	15A NCAC 02T.0305
	Private Gravity	6-inch	
Minimum Slope, in feet/100 feet, by Diameter of Gravity Pipe <sup>7</sup>	6-inch	0.6	15A NCAC 02T.0305
	8-inch	0.4	
	10-inch	0.28	
	12-inch	0.22	
	14-inch	0.17	
	16-inch	0.15	
	18-inch	0.14	
	21-inch	0.1	
	24-inch	0.08	
	27-inch	0.07	
	30-inch	0.06	
	36-inch	0.05	
Manholes	Maximum Distance	425 feet	15A NCAC 02T.0305
	Minimum Diameter	4 feet	
	Minimum Bench Slope	4%	
Force Mains	Minimum Nominal Diameter	4-inch	15A NCAC 02T.0305
	Air Release Valves for Vertical Distance	> 10 feet	
Easements	Full Easement Width	Various <sup>8</sup>	15A NCAC 02T .0403

1. Refer to NCAC Standard for detailed list of values.
2. Classified WS-II, WS-III, WS-IV, B, SA, ORW, HQW, SB from normal high water or tide elevation.
3. Classified as UWL or SWL or directly abutting the waters classified above.
4. Classified as WL.
5. Classified as C, SC, or WS-V, or ground water lowering and surface drainage ditches.
6. Embankment or cuts of 2 feet or more vertical height.
7. Based upon a mean velocity of 2.0 feet per second and Manning's "n" of 0.0013.
8. Right-of-ways and easements shall be maintained in the full easement width for personnel and equipment accessibility

## 4 Sewer System Inventory

### 4.1 Gravity Mains

The Town's sewer collection system consists of approximately 150 miles of gravity mains, serving approximately 6,940 sewer customers which includes residential, commercial, and institutional classifications.

Gravity main diameters range from 4 to 24 inches and materials include cast Iron (CI), cured in place (CIPP), ductile iron (DIP), polyvinyl chloride (PVC), and reinforced plastic truss (RPT), and vitrified clay pipe (VCP).

Table 6 provides a summary of the diameter and materials of gravity main pipes in the system.

*Table 6 - Gravity Mains by Diameter and Material (summarized by length in feet)*

Material/ Diameter	CI	CIPP	DIP	PVC	RPT	VCP	Unknown	Total	Percent of Total
4 Inch	-	-	-	750	-	-	-	750	0.09%
6 Inch	-	-	686	9,083	-	40,805	-	50,574	6.36%
8 Inch	11	442	51,870	408,045	5,623	218,680	2,167	686,838	86.36%
10 Inch	-	250	976	1,816	404	19,223	-	22,669	2.85%
12 Inch	-	224	885	16,809	329	7,553	-	25,800	3.24%
16 Inch	118	-	23	-	-	365	-	506	0.06%
18 Inch	1,305	701	-	-	-	4,836	-	6,842	0.86%
24 Inch	-	567	-	-	-	132	-	699	0.09%
Unknown	-	-	407	-	-	-	234	641	0.08%
<b>Total</b>	<b>1,434</b>	<b>2,183</b>	<b>54,847</b>	<b>436,503</b>	<b>6,356</b>	<b>291,594</b>	<b>2,401</b>	<b>795,318</b>	
<b>Percent of Total</b>	<b>0.18%</b>	<b>0.27%</b>	<b>6.90%</b>	<b>54.88%</b>	<b>0.80%</b>	<b>36.66%</b>	<b>0.29%</b>		

More than 99% of the system has known material and diameter. The most common material in the system is PVC, representing approximately 55%, followed by approximately 37% of VCP pipe. The most common diameter across the system is 8 inches, representing approximately 86% of the system.

Figure 2 below illustrates gravity mains by pipe sizes and materials summarized by length in feet.

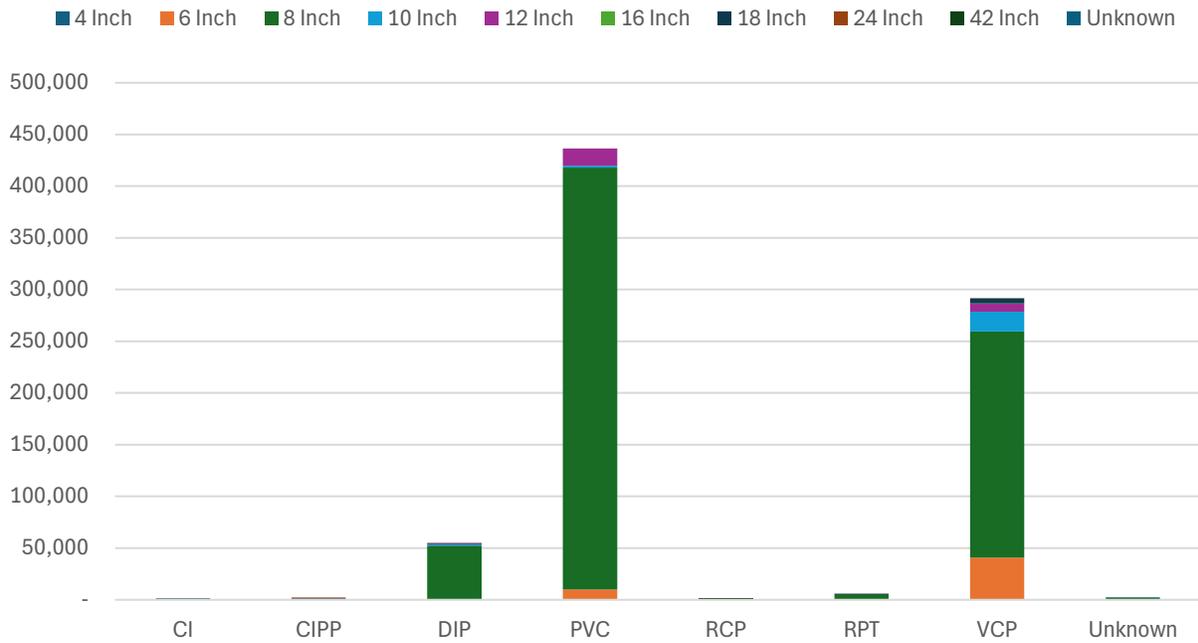


Figure 2 - Distribution of Gravity Mains by Diameter and Material (summarized by length in feet)

## 4.2 Force Mains

The Town's collection system consists of approximately twelve (12) miles of force mains. Force main diameters range from 2 to 14 inches and materials include cast iron (CI), ductile iron (DIP), polyvinyl chloride (PVC), and steel.

Table 7 provides a summary of the diameter and materials of the force main pipes in the system.

*Table 7 - Force Mains by Diameter and Material (summarized by length in feet)*

Material/ Diameter	CI	DIP	PVC	Steel	Total	Percent of Total
2 Inch	-	56	743	-	799	1%
2.5 Inch	-	-	2,063	-	2,063	3%
3 Inch	-	-	675	-	675	1%
4 Inch	1,608	4,111	6,490	1,690	13,899	21%
6 Inch	1,969	8,518	-	-	10,487	16%
8 Inch	-	8,946	15,592	-	24,538	37%
10 Inch	-	64	1,565	-	1,629	2%
12 Inch	-	91	1,476	-	1,567	2%
14 Inch	-	-	10,192	-	10,192	15%
Total	3,577	21,787	38,796	1,690	65,850	
Percent of Total	5%	33%	59%	3%		

Figure 3 below illustrates force mains by pipe sizes and materials summarized by length in feet.

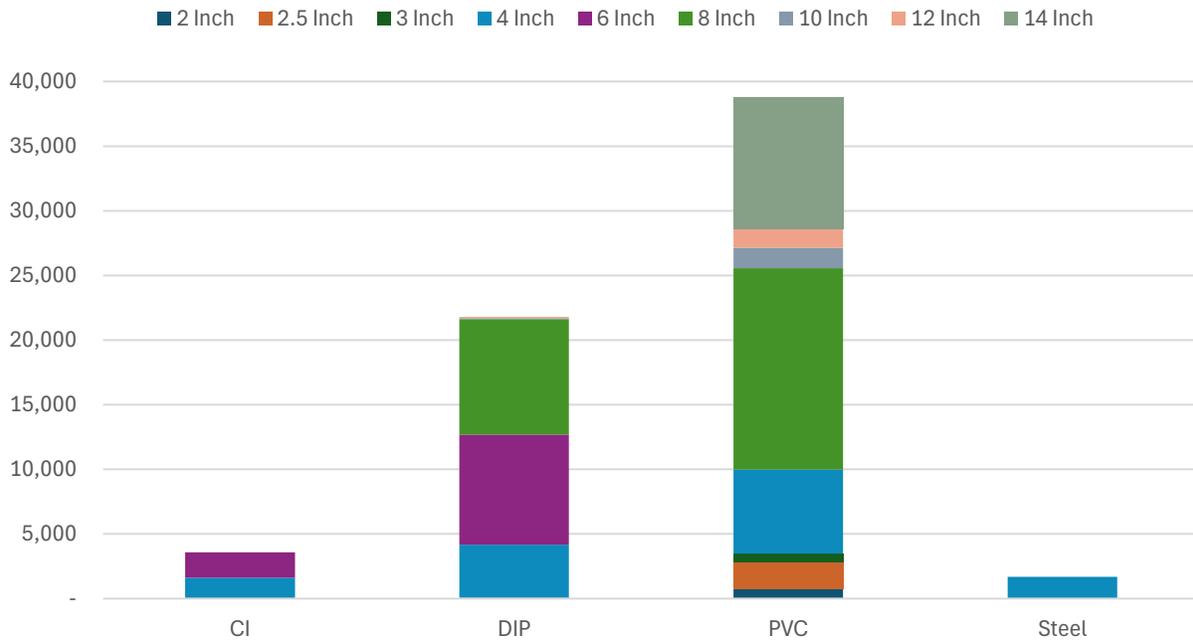


Figure 3 - Distribution of Force Main by Pipe Size and Material (summarized by length in feet)

### 4.3 Manholes

The collection system contains 3,743 manholes, ranging in approximate depth from 1.3 to 31.4 feet and materials including brick, concrete non reinforced, and concrete reinforced.

Table 8 provides a summary of the material of the manholes in the system. Approximately 88% of manholes have unknown material.

Table 8 - Manholes by Material and Depth (summarized by count)

Depth/Material	Less than 5 Feet	5 to 10 Feet	10 to 20 Feet	20 to 30 Feet	More than 30 Feet	Unknown	Total	Percent of Total
Concrete reinforced	178	1,360	492	18	2	4	2,054	55%
Concrete non reinforced	14	50	8	-	-	-	72	2%
Brick	89	442	71	2	-	1	605	16%
Cement Lined	13	140	32	1	-	2	188	5%
Unknown	15	41	17	1	-	750	824	22%
Total	309	2,033	620	22	2	757	3,743	
Percent of Total	8%	54%	17%	1%	0%	20%		

## 4.4 Lift Stations

The collection system contains nineteen (19) lift stations that are an integral part of the conveyance of wastewater to the Town of Southern Pines WWTP. Table 9 gives a summary of number of pumps, installation date, design capacity, and force main diameter.

*Table 9 - Lift Station Information*

Facility Name	# Of Pumps	Installation Date	Design Capacity (GPM)	Force Main Diameter (Inches)
Aiken Road	2	1979	100	4
ARO Corporation	2	-	185	6
Bellemeade	2	1998	45	8
Bethesda & Maples	2	1979	180	4
Bethesda & Ridgeview	2	2002	80	4
Caropines	2	2016	320	8
Cypress Creek	2	2010	100	4
Forest Creek	2	2007	80	4
McDeeds Creek	2	2019	275	6
Middleton Place	2	1984	44	2
Muster Branch	2	1994	46	2
Nicks Creek	3	1999	400	8
Pee Dee Road	2	2017	140	4
South Ridge St	2	2002	180	6
Spring & Country Club Cir	2	1997	78	4
Spring & S. Valley	2	1997	83	4
Talamore	2	2000	50	2.5
Warrior Woods	3	1995	925	10
Weymouth Pines	2	1981	80	4

## 5 Risk Assessment

As infrastructure ages, it becomes increasingly more challenging to assign limited capital expenditures to the repair, rehabilitation, or replacement of the assets. This section describes how the Town's risk model was used in decision making and preparing the Town's capital improvement programs for the prioritization for wastewater infrastructure.

The intent of the risk model is to answer questions, such as "which sewer mains will have the greatest impact if a failure is to occur?". This allows staff to focus resources and effort on these assets before they fail.

The risk associated with a given asset failing can be determined by multiplying Likelihood of Failure (LoF) based on condition and the Consequence of Failure (CoF) also known as criticality.

$$\text{Risk} = \text{LoF} \times \text{CoF}$$

The following summarizes the LoF and CoF criteria and methodologies used to calculate risk and project prioritization. The results of the risk analysis can be found in the GIS database created as a part of this asset inventory assessment.

### 5.1 Likelihood of Failure (LoF)

LoF is a numerical representation that denotes the probability of an asset's failure based on its condition from known metrics such as asset age, condition inspections, work order history, staff input, etc.

For the purposes of this project, LoF was determined using a condition rating system informed by asset age, CCTV inspection results, and work order history, depending on the asset type and data availability. The estimated useful life for each asset was established using NCDEQ-recommended lifespans for various pipe materials, as shown in Table 10. These values were used to calculate the percentage of remaining useful life for gravity mains, force mains, and manholes.

Condition ratings were developed separately for each asset category—gravity mains, force mains, and manholes—and are summarized in Table 11, Table 12, and Table 13, respectively. Gravity main condition scoring incorporated a weighted evaluation of age, CCTV inspection findings, and work order history. When CCTV data was available, weights of 20% for age, 70% for CCTV defects, and 10% for work orders were applied; when CCTV data was not available, the weighting shifted to 80% for age and 20% for work orders. Force main condition ratings were based solely on remaining useful life, using a 100% age-based weighting. Manhole condition ratings used an 80% weight on age and 20% on work order history.

Table 10 - Pipe Life Expectancy by Material Type

Material	Life Expectancy (years)
Concrete (Reinforced)	100
Ductile Iron	100
Polyvinyl Chloride	80
Reinforced Plastic Truss (RPT)	100
Vitrified Clay	50
Cast Iron	60
Cured in Place (CIPP)	50
Unknown	60

Reference: Recommended Life Spans, sourced from 2022 AMP DWI Guidance Document

Table 11 - Condition Based Criteria for Gravity Mains

Condition Rating	Age	CCTV	Work Order
<b>Weights</b>	<b>20%, if no CCTV 80%</b>	<b>70%, if no CCTV 0%</b>	<b>10%, if no CCTV 20%</b>
5	<5% Remaining Useful Life. Very poor. Requires complete rehabilitation	Multiple Grade 5 Structural Defects	>= 5 work orders mentioning Keywords from work order descriptions (Main, Main Repair, Main Break, Repaired, Cross, Roots, Tree)
4	>=5 and <15% Remaining Useful Life. Poor, Unable to meet level of service	Single Grade 5 Structural Defect	
3	>=15 and <50% Remaining Useful Life. Fair, Major wear, impacting level of service	Grade 4 or 3 Structural Defects	>= 3 work orders mentioning Keywords
2	>=50 and <95% Remaining Useful Life, Good, Minor wear	Grade 2 or 1 Structural Defect	
1	>=95%, Very Good, New or nearly new	No Structural Defects Located	>= 1 work order mentioning Keywords

Table 12 - Condition Based Criteria for Force Mains and Lift Stations

Condition Rating	Age
<b>Weights</b>	<b>100%</b>
5	<5% Remaining Useful Life. Very poor. Requires complete rehabilitation
4	5-15% Remaining Useful Life. Poor, Unable to meet level of service
3	15-50% Remaining Useful Life. Fair, Major wear, impacting level of service
2	50-95% Remaining Useful Life, Good, Minor wear
1	>95%, Very Good, New or nearly new

Table 13 - Condition Based Criteria for Manholes

Condition Rating	Age	Work Order
<b>Weights</b>	<b>80%</b>	<b>20%</b>
5	<5% Remaining Useful Life. Very poor. Requires complete rehabilitation	>= 5 work orders mentioning main breaks or repairs (Keywords: Roots, Main, Grease)
4	>=5 and <15% Remaining Useful Life. Poor, Unable to meet level of service	
3	>=15 and <50% Remaining Useful Life. Fair, Major wear, impacting level of service	>= 3 work orders mentioning main breaks or repairs (Keywords: Roots, Main, Grease)
2	>=50 and <95% Remaining Useful Life, Good, Minor wear	
1	>=95%, Very Good, New or nearly new	>= 1 work order mentioning main breaks or repairs (Keywords: Roots, Main, Grease)

Condition Ratings of 1 through 5 contributed to an overall likelihood of failure score for each asset. As described above,

Table 11, Table 12 and Table 13 summarize the condition criteria for each asset category on a scale of 1 through 5 with 1 being the lowest LoF and 5 being the highest.

Using these categories, each sewer main, force main, and manhole in the system were assigned a condition score. A summary of the overall condition score of each asset category is listed in Table 14 below and stored in the Town’s GIS database.

Table 14 - Summary of Condition Ratings for Sewer System Assets

Asset / Condition	5 - Very Poor	4 - Poor	3 - Fair	2 - Good	1 - Very Good
Gravity Mains	6,325 (1%)	78,750 (10%)	44,018 (6%)	153,790 (19%)	512,434 (64%)
Force Mains	1,588 (2%)	3,273 (5%)	26,368 (40%)	33,669 (51%)	952 (2%)
Manholes	8 (0%)	351 (9%)	618 (17%)	2,766 (74%)	-
Lift Stations	13 (68%)	-	2 (11%)	4 (21%)	-

Table 14 shows approximately 11% of gravity mains, 7% of force mains, 9% of manholes, and 68% of lift stations were given a rating of 4 “Poor” or above, indicating major wear that would impact the level of service in the immediate future. These respective assets were considered for rehabilitation/replacement projects on the CIP, discussed in Section 7.

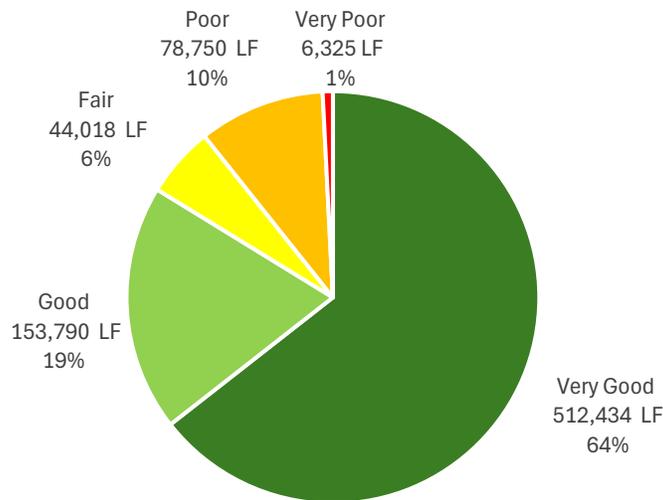


Figure 4 - Summary of Gravity Mains by Condition (summarized by length in feet)

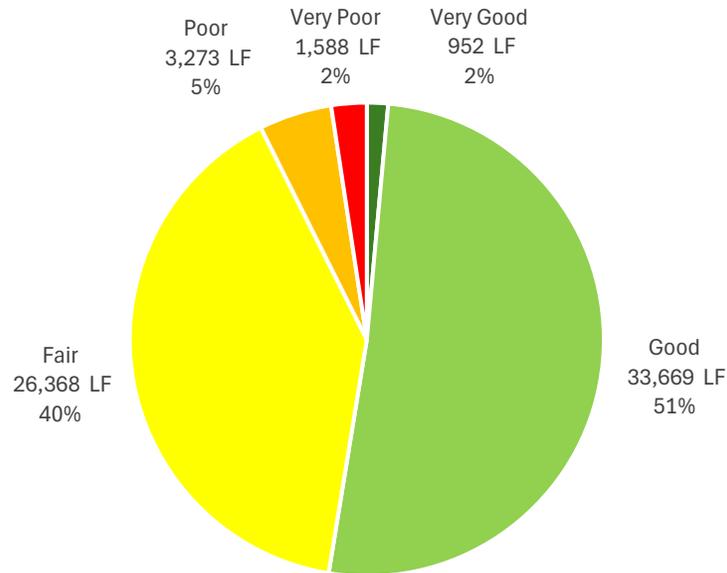


Figure 5 - Summary of Force Mains by Condition (summarized by length in feet)

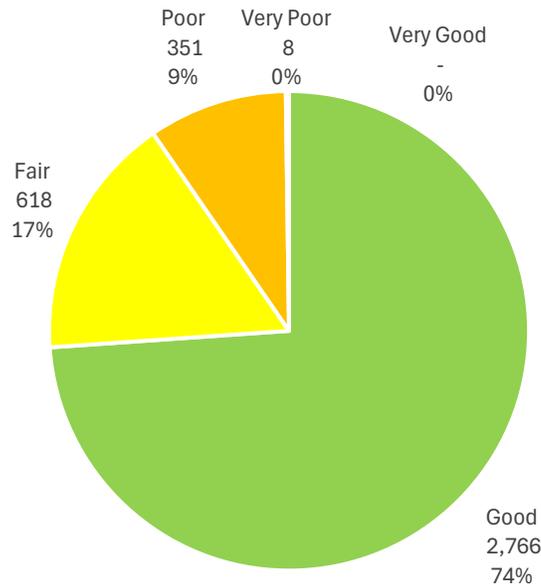


Figure 6 - Summary of Manholes by Condition (summarized by count)

### 5.1.1 Asset Capacity and Performance Assessment

The hydraulic model developed for the Town provides a detailed, one-to-one representation of the sewer system’s performance under a range of dry- and wet-weather conditions. The model was calibrated and validated using flow monitoring data and pump station operational records to

ensure that simulated system behavior closely reflects actual field conditions. Through this calibration process, the model identified areas where the system may be vulnerable during design storm events, including locations with anticipated surcharging, limited capacity, or elevated inflow and infiltration. The hydraulic model results were used to support the asset capacity evaluation and performance assessment described in this section.

Model outputs—including depth-to-diameter ratios, predicted surcharging, and freeboard limitations—were directly incorporated into the capacity scoring framework for gravity mains and manholes. This integration helped with both condition and hydraulic performance assessment when evaluating the overall risk of each asset.

Asset capacity was assessed for both gravity mains and manholes. Each inventoried asset was assigned a capacity rating based on the criteria summarized in Table 15 and Table 16. Gravity mains were evaluated using maximum depth relative to full pipe depth, while manhole capacity was based on the amount of freeboard available during modeled peak flow conditions.

Asset capacity was also assessed for gravity mains and manholes. The gravity mains and manholes inventoried were assigned a capacity rating based on the criteria listed in Table 15 and Table 16 below.

*Table 15 - Capacity Based Criteria for Gravity Mains*

Capacity Rating	Description
5	Max/Full Depth: > 0.99
4	Max/Full Depth: > 0.75 and <= 0.99
3	-
2	Max/Full Depth: > 0.5 and <= 0.75
1	Max/Full Depth: <= 0.5

*Table 16 - Capacity Based Criteria for Manholes*

Capacity Rating	Description
5	Minimum freeboard < 2
4	-
3	-
2	-
1	Minimum freeboard >= 2

Using these criteria, each sewer main and manhole in the system was assigned a capacity score. A summary of the results, shown in Table 17, indicates that the vast majority of gravity mains and manholes operate with sufficient hydraulic capacity under modeled conditions. These results have been stored in the Town's GIS database for future planning and operational use.

The full hydraulic modeling process—including data collection, calibration, model development, and system-wide capacity analysis results and recommendations—is documented in the Hydraulic Model Report included in Appendix II.

The findings and recommendations from the hydraulic model, condition assessment, and capacity evaluation were directly integrated into the Town’s CIP, so that projects are addressing the most critical structural and hydraulic needs and prioritized accordingly.

Table 17 - Summary of Capacity Ratings for Sewer System Assets

Asset / Capacity	5 - Very Poor	4 - Poor	3 - Fair	2 - Good	1 - Very Good	Unknown
Gravity Mains	17,236 LF (2.17%)	9,247 LF (1.16%)	-	40,945 LF (5.15%)	727,629 LF (91.49%)	261 (0.03%)
Manholes	54 (1.44%)	-	-	-	3,635 (97.11%)	54 (1.44%)

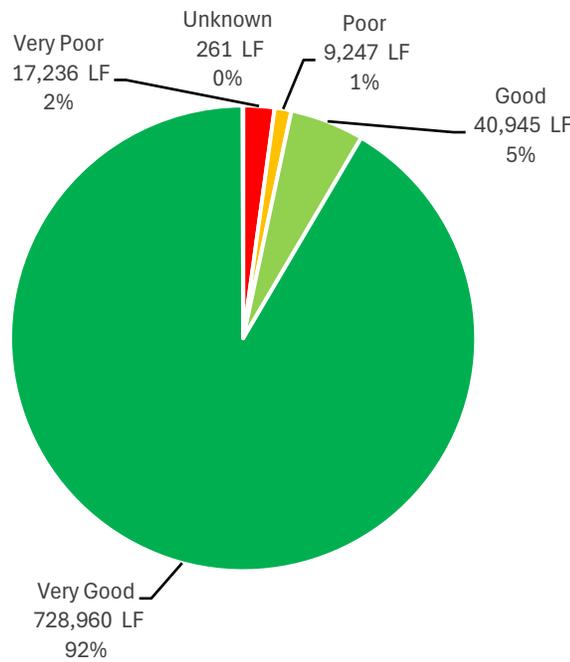


Figure 7 - Summary of Gravity Mains by Capacity (summarized by length in feet)

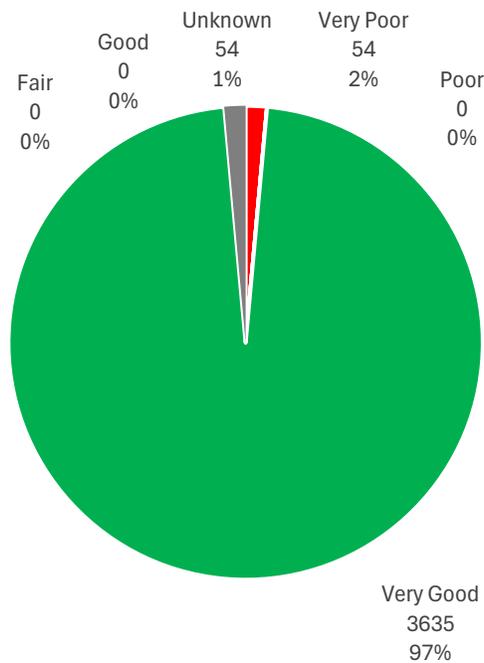


Figure 8 - Summary of Manholes by Capacity (summarized by count)

### 5.1.2 Additional Assessment Recommendations

The forecasted state of the sewer asset condition assessment is focused on increasing the known condition information of the collection system assets.

#### Closed-Circuit Television (CCTV) Inspection

Performing CCTV inspections on the collection system would provide condition information used to prioritize rehabilitation and replacement needs. Regular CCTV inspections to gather updated condition information would help the Town prevent residential back-ups and sanitary sewer overflows (SSOs) by rehabilitating or replacing assets before they fail.

#### Manhole Inspection

Manhole inspections are typically performed along with CCTV inspection initiatives. Regular manhole inspections would help the Town identify corrosion, inflow and infiltration, fat and grease build up, and other issues that could cause residential back-ups, SSOs or clogs in the collection system.

#### Lift Station Assessment

For the purposes of this project, lift station information was gathered from the Town. Pump drawdown testing would provide the existing capacity for each pump to compare to the design capacity, allowing the Town to determine the remaining efficiency of the pump. Complete lift station assessment would also provide condition information for the pumps and pump accessories

within the lift stations, and help the Town identify maintenance, rehabilitation, and replacement needs.

## 5.2 Consequence of Failure (CoF)

CoF is a numerical representation of the impact of an asset’s failure to the community. Assets with higher CoF scores can be considered the most critical components of the Town’s wastewater system in terms of maintaining the performance and integrity of the entire system.

The CoF scores were determined using economic, social, and environmental impacts as described in Table 18 below. Various CoF criteria were presented to the Town, and the selected ones are listed below based on their applicability to the Town’s system. The weighting for each category was equally distributed among the five (5) criteria selected.

Table 18 - Consequence of Failure Criteria for Gravity Mains, Force Mains, and Manholes

Asset Category	Criticality Rating	Description
Proximity to Critical Infrastructure	5	<50 ft of railroad or NCDOT state road, significant impact on traffic flow and access issue
	4	50-100 ft of railroad or NCDOT state road, major impact on traffic flow and access issue
	3	100-150 ft of railroad or NCDOT state road, moderate impact on traffic flow, some access issue
	2	150-200 ft of railroad or NCDOT state road, minimal impact on traffic flow, easy access for repair
	1	>200 ft of railroad or NCDOT state road, no/minimal impact on traffic flow, easy access for repair
Critical Users	5	Health and Safety, Public Utilities (Hospitals, Schools, Treatment Plant, etc.)
	4	Public Services/ Administration (Town Office)
	3	Industrial/ Commercial
	2	Businesses
	1	Residential
Proximity to a water body	5	<25 ft of a water body or crossing
	4	25-50 ft of a water body or crossing
	3	50-100 ft of a water body or crossing
	2	100-150 ft of a water body or crossing
	1	>150 ft of a water body or crossing

- Critical Infrastructure selected for analysis includes: Talamore Dr, Murray Hill Rd, Carlisle St, Pinehurst Ave, Bethesda Rd, Broad S, Knoll Rd, Airport Rd, NC HWY 22, Camp Easter Rd, Pee Dee Rd, Aro Rd, Felton Capel Ln, Sandhills Blvd, May St, E Indiana Ave, N Poplar St, NC HWY 15, Midland Rd, E Connecticut Ave, Brucewood Rd, Central Dr
- Critical Users selected for analysis include: Southern Pines Fire Department, FirstHealth Convenient Care, Pinehurst Medical Clinic Walk in Clinic, FastMed Urgent Care, Med First Primary & Urgent Care, Magnolia Gardens, St Joseph of the Pines Assisted Living, Aberdeen Fire Department, Southern Middle School, Southern Pines Elementary, Pinecrest Highschool, Southern Pines Administration, Southern Pines Golf Club, Mid Pines Inn & Golf, Pine Needles

*Lodge & Golf, Harbour Laundry Systems, Soapy Bubbles Laundromat, Target, Lowe's, Walmart, Sheetz, Lowes Food, The Fresh Market, Food Lion, Food Lion, Moore County Airport*

Using the above criteria, each sewer asset was assigned a CoF rating, which is stored in the GIS geodatabase. The results were summarized by linear foot for gravity and force mains and by asset count for manholes. Lift station criticality was not assessed as a part of this project.

*Table 19 - Summary of Criticality Ratings for Sewer System Assets*

<b>Asset / Criticality</b>	<b>5 - Very High</b>	<b>4 - High</b>	<b>3 - Medium</b>	<b>2 - Low</b>	<b>1 - Very Low</b>
<b>Gravity Mains</b>	1,561 (0.20%)	11,741 (1.48%)	205,498 (25.84%)	96,210 (12.10%)	480,309 (60.39%)
<b>Force Mains</b>	65,850 (100%)	-	-	-	-
<b>Manholes</b>	6 (0.16%)	35 (0.94%)	886 (23.67%)	391 (10.45%)	2,425 (64.79%)
<b>Lift Stations</b>	19 (100%)	-	-	-	-

Table 19 shows approximately 2% of gravity mains, 100% of force mains, 1% of manholes, and 100% of lift stations were given a criticality rating of “High”, or above, indicating that the consequence of the assets failing will be highly impactful to Town operations. These respective assets were used to prioritize rehabilitation/replacement projects on the CIP, discussed in Section 7.

## 5.2.1 Additional Analysis Recommendations

### *Regulatory Considerations*

NCDEQ adopted the Minimum Design Criteria for the permitting of Gravity Sewers in February 1996 and updated the design criteria to the 15A NCAC 2T Regulations in March 2008. NCDEQ adopted the Minimum Design Criteria for the permitting of lift stations and force mains in June 2000. The purpose of the standards described in these regulations is to protect the health and safety of the community and environment. Table 7 contains a summary of these NCAC sewer system design standards. Using these standards, the collection system assets could be evaluated to determine the assets that are not in compliance with these NCAC design standards. As the collection system assets are upgraded, rehabilitated, or replaced, the new assets are required to comply with these standards.

### 5.3 Risk Score Analysis

The quantification of risk using LoF and CoF scores was used to identify priority projects for preparation of the Town’s Capital Improvements Plan (CIP). The combining of the LoF and CoF scores for each asset was jointly analyzed in the risk matrix shown in Figure 9 below.

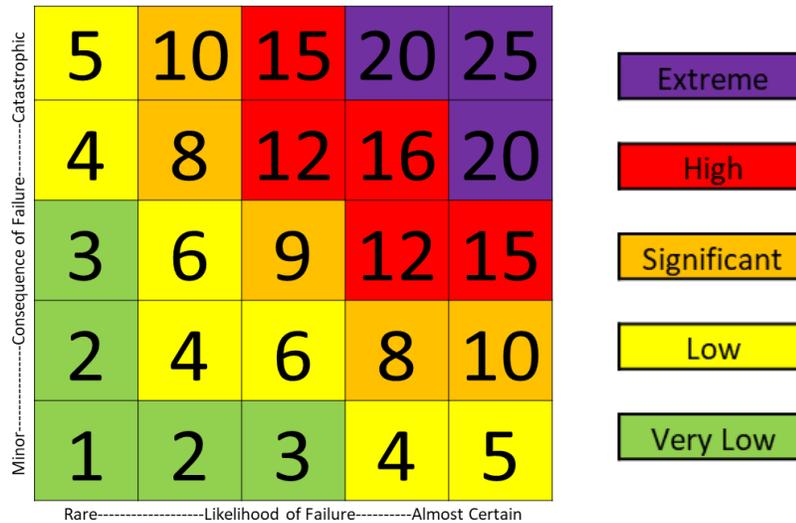


Figure 9 - Risk Score Matrix

Although hydraulic capacity was evaluated as a separate component of asset performance, capacity ratings were not used directly in calculating the LoF × CoF risk score. Instead, capacity limitations—such as anticipated surcharging, insufficient freeboard, or limited remaining depth—were incorporated into the Town’s Capital Improvement Plan (CIP) recommendations to make sure that projects address not only condition-based risks but also hydraulic performance constraints (see Section 5.4 below).

Assets with a high likelihood of failure based on condition, combined with a high consequence of failure based on criticality, fall within the extreme risk category. These assets were prioritized for rehabilitation or replacement in the Town’s CIP. Assets with very low to moderate risk were assigned lower priority and may be scheduled for future-year projects or addressed through routine operation and maintenance activities.

Appendix I includes a map with assets identified based on their risk scores.

Table 20 - Summary of Risk Scores for Sewer System Assets

Asset / Risk	Extreme	High	Significant	Low	Very Low
Gravity Mains	- (0%)	18,924 (2.38%)	21,741 (2.73%)	132,669 (16.68%)	621,984 (78.21%)
Force Mains	4,861 (7.38%)	26,368 (40.04%)	33,669 (51.13%)	952 (1.45%)	- (0%)
Manholes	- (0%)	138 (3.69%)	256 (6.84%)	1,123 (30.00%)	2,226 (59.47%)
Lift Stations	13 (68%)	2 (11%)	4 (21%)	-	-

Table 20 shows approximately 2% of gravity mains, 47% of force mains, 4% of manholes, and 79% of lift stations were given at least a high risk value, indicating that the consequence of the assets failing will be highly impactful to Town operations. These respective assets were used to prioritize rehabilitation/replacement projects on the CIP, discussed in Section 7. Lift stations were not recommended for CIP prioritization projects as they are considered for replacement based on Town staff input.

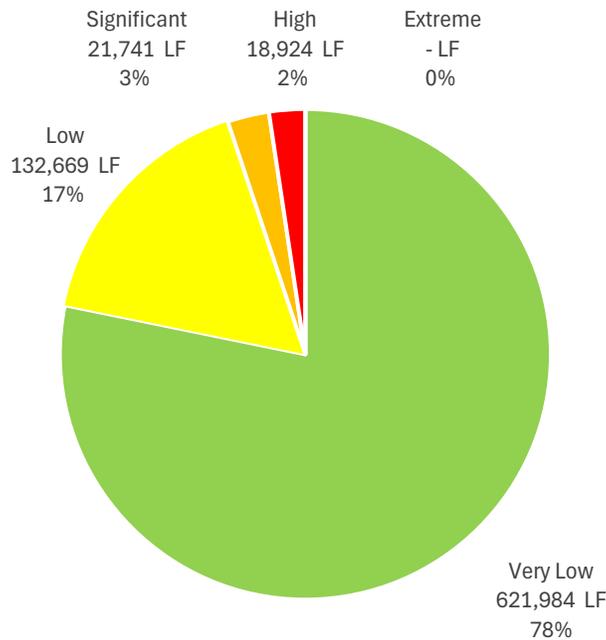


Figure 10 - Summary of Gravity Mains by Risk (summarized by length in feet)

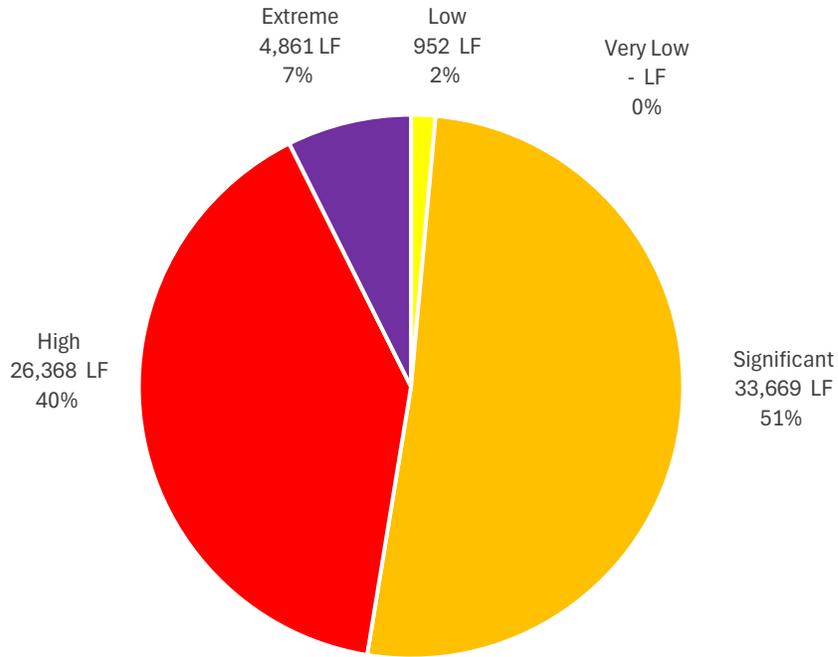


Figure 11 - Summary of Force Mains by Risk (summarized by length in feet)

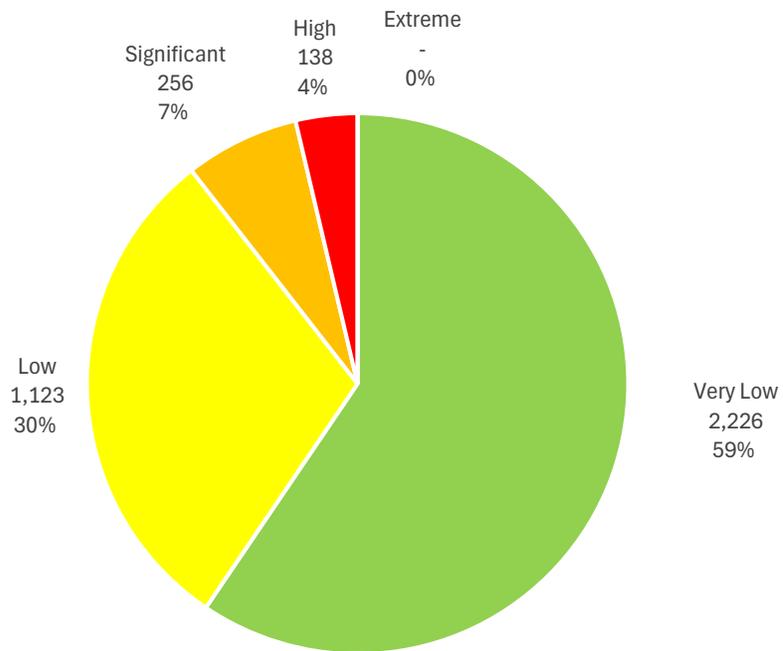


Figure 12 - Summary of Manholes by Risk (summarized by count)

## 5.4 CIP Prioritization and Decision Making

To translate the results of the condition, risk, and capacity assessments into actionable capital planning, the Town developed a tiered CIP Prioritization and Decision-Making Framework. This framework combines condition ratings and capacity ratings to determine the priority level for each asset. Assets that rank poorly in both categories receive the highest priority, while assets with adequate condition and capacity fall into lower tiers.

Town staff input was incorporated throughout this process to ensure that operational experience, maintenance history, and local knowledge informed prioritization decisions.

The prioritization criteria and recommended actions for each tier are summarized in Table 21 below.

Table 21 – CIP Prioritization and Decision Making

Tier	Criteria	Description	Action
4	Condition > 4, Capacity > 4	Physically failing and hydraulically overloaded	Immediate inspection & rehab (CCTV if Age-based, Rehab if CCTV-based); I/I Study/Capacity Alleviation
3	4-5 in one category, 1-3 in other	High risk driven by Condition or Capacity	Prioritized Rehab/Inspection; note driver
2	Both Condition & Capacity = 3-4	Moderate wear, near hydraulic limit	Routine monitoring; staged inspections/rehab
1	Both Condition & Capacity = 1-3	New or lightly loaded	Routine monitoring

This integrated prioritization approach builds the CIP recommendations to address both structural condition and hydraulic performance, supporting long-term system sustainability of the system.

The resulting priority projects are listed in Table 18 and recommended for funding within the Town's 10-year Capital Improvements Plan.

## 6 Operation and Maintenance (O&M) Plan

Operation and Maintenance (O&M) for the wastewater system focuses on upkeep of the gravity mains, force mains, manholes, and lift stations. Maintenance consists of “Emergency Maintenance,” which is corrective action needed quickly to keep the system operational, and “Preventative Maintenance,” which is routine, scheduled tasks to prevent problems before they arise. The items below represent routine maintenance items performed throughout the collection system.

Table 21 - Summary of Operation and Maintenance Recommendations

Collection System Maintenance		
Asset	Maintenance	Frequency
Collection System	Clean and video inspect at least 10% of the collection system. Record the date, location of cleaning, type of cleaning, and other general observations during cleaning (type of debris, quantities, etc.).	Annually
	Document all Sanitary Sewer Overflow (SSOs) using the State form or other similar form. All spills, reportable or not, must be documented. Spills that are reported to the State should be on the required form.	As Needed
	Incorporate information from new construction and rehabilitation projects, including line diameter, material, and scoring for other Key Performance Indicators (KPIs), into the collection system GIS within one (1) year of construction completion.	As Needed
	All high priority lines (including aerials, sub-waterway crossings, lines contacting surface waters, lines positioned parallel to stream banks and subject to eroding in such a manner that may threaten the line, and any other segment of the system that is designated as high priority) must be inspected every six (6) months. A log must document the area inspected, the date, method of inspection, and any corrective actions performed or initiated.	Semi-Annual
Lift Station System Maintenance		
Lift Station Maintenance	Inspecting, cleaning, and removing debris from the lift station structure, outside perimeter, and wet well.	Annually
	Inspecting and exercising all valves.	Annually
	Inspecting and lubricating pumps and other mechanical equipment.	Annually
	Verifying the proper operation of the alarms, telemetry system, and auxiliary equipment.	Annually
	Other testing procedures as recommended by the manufacturer.	Annually
	Annual flow meter calibration (at a minimum).	Annually

NOTE: Lift stations not connected to telemetry systems must be inspected at least daily. Lift stations with telemetry must be inspected at least once per week.	Daily/Weekly
Record hours of running time from elapsed time meters.	Weekly
Check for equal run times on each pump.	Weekly
Inspect control panel switches for proper positioning.	Annually
Test alarms.	Annually
Check valves for proper positioning (valves functioning, normally open valves are open, normally closed valves are closed).	Annually
Confirm valve lever arms and weights are okay.	Annually
Check for unusual pump noise or vibration.	Annually
Check amp readings. Note discrepancies.	Annually
Confirm pumps appear to be seated properly.	Annually
Confirm that no leakage is observed.	Annually
Confirm guide rails and brackets are aligned and fastened.	Annually
Note any rust or loose parts.	Annually
Confirm that piping and valves are not leaking, and that bolts and nuts are properly torqued.	Annually
Confirm that any corroded or worn parts have been replaced, cleaned, painted, or restored.	Annually
Record flow rate observed during site visit.	Annually
Check and record pressure gauge readings during observed flow rate. Note any changes from normal readings.	Annually
Manually pump down the wet well to check for and remove debris.	Annually
Inspect floats, transducer, and cables, and remove all debris to ensure proper operation.	Annually
Ensure all automatic cycle operation cables and appurtenances are free and clear of debris or obstructions and functioning as designed.	Annually
Check control settings.	Annually
If a pump is removed, place the lead pump selector switch on the number of the pump remaining in operation.	Annually
Inspect the pump hand/off/automatic selector switch. Turn to off. Fill up wet well with water until high water is activated. Turn to auto and check if both pumps operate automatically with slight delay between each. Pump until pump shuts off. Fill water until the lead pump starts. When the lead pump starts, shut off water. Allow pump to lower the wet well until the pump shuts off.	Annually
Check pumps for blockage and any abnormalities in operation.	Annually

	<p>Confirm generator is automatically exercising on schedule at start-up. Periodically manually throw main disconnect to check the Automatic Transfer Switch (ATS) and generator operation.</p>	<p>Annually</p>
	<p>Cut grass, pick up trash, remove debris, walk around perimeter, inspect fencing and landscaping, look for vandalism or evidence of trespassing or other security concerns.</p>	<p>Annually</p>

# 7 Capital Improvement Plan

## 7.1 Capital Costs

The capital improvement cost includes the material cost and labor cost for the rehabilitation, replacement, or installation of a new or existing sewer system asset. This cost can be determined for an asset with direct price quotes provided by a supplier or general cost estimates based on an evaluation of recent construction bids across North Carolina and the RSMeans Catalog. For the purposes of this project, a combination of direct price quotes and general cost estimates were used to determine unit costs for gravity mains, force mains, manholes, and lift stations replacements or rehabilitations.

## 7.2 Capital Improvement Projects

Based on input from the Town Staff and results of risk analysis, the projects listed in Table 18 below are recommended for inclusion in the CIP budget for the sewer system over the next ten (10) years.

1. Gravity Sewer System – Annual Rehabilitation (Wastewater Project #8)  
This project is intended to replace all the gravity mains and associated appurtenances within the High Risk and Tier 3 categories, as identified in the analysis sections above.
2. Longleaf Dam Sewer Relocation (Wastewater Project #7)  
An existing aerial sewer line along the longleaf dam will be relocated downstream away from the dam. This project is scheduled for completion in FY 28 – 29 with a project cost of \$1,900,000.
3. Sewer Lift Station Emergency Backups (Wastewater Project #5)  
The town plans to purchase lift station backup generators for emergency situations and preparedness. The project is scheduled to take place in FY 26-27 with a projected cost of \$205,000.
4. Warrior Woods Pump Station Upgrade Phases IB, II, III (Wastewater Projects #1-3)  
Significant upgrades to both the Warrior Woods Pump Station and associated Force Main will occur through a series of projects that are ultimately scheduled for completion in 2027. The estimated cost of all projects is \$9,239,300. The Town intends to appropriate approximately \$4,880,812.50 of System Development Fee revenues to the CRF for this purpose with the balance derived from Retained Earnings, Sewer Capital Funds, loans, and remaining Impact Fees collected prior to October 1, 2018. The first phase of this project was initiated in FY 2018-2019 with completion in 2020 with \$791,250 appropriated in the 2018-2019 Budget from the previous Impact Fee account and \$263,750 appropriated from Sewer Capital Funds. Previously, \$957,860 in SDF funds have been appropriated to the CRF-Wastewater SDF toward this multi-phased project. The upgrades will address additional capacity needed to support further

development within all wastewater infrastructure in addition to replacing the maintenance heavy current facilities.

Additional data could assist in refining the scope and estimates associated with these projects. Up to date Lift Station condition assessments should be considered as an instrumental next step for the Town to evaluate this critical infrastructure and any additional future CIP projects.

Table 22 - List of Proposed Capital Improvement Projects

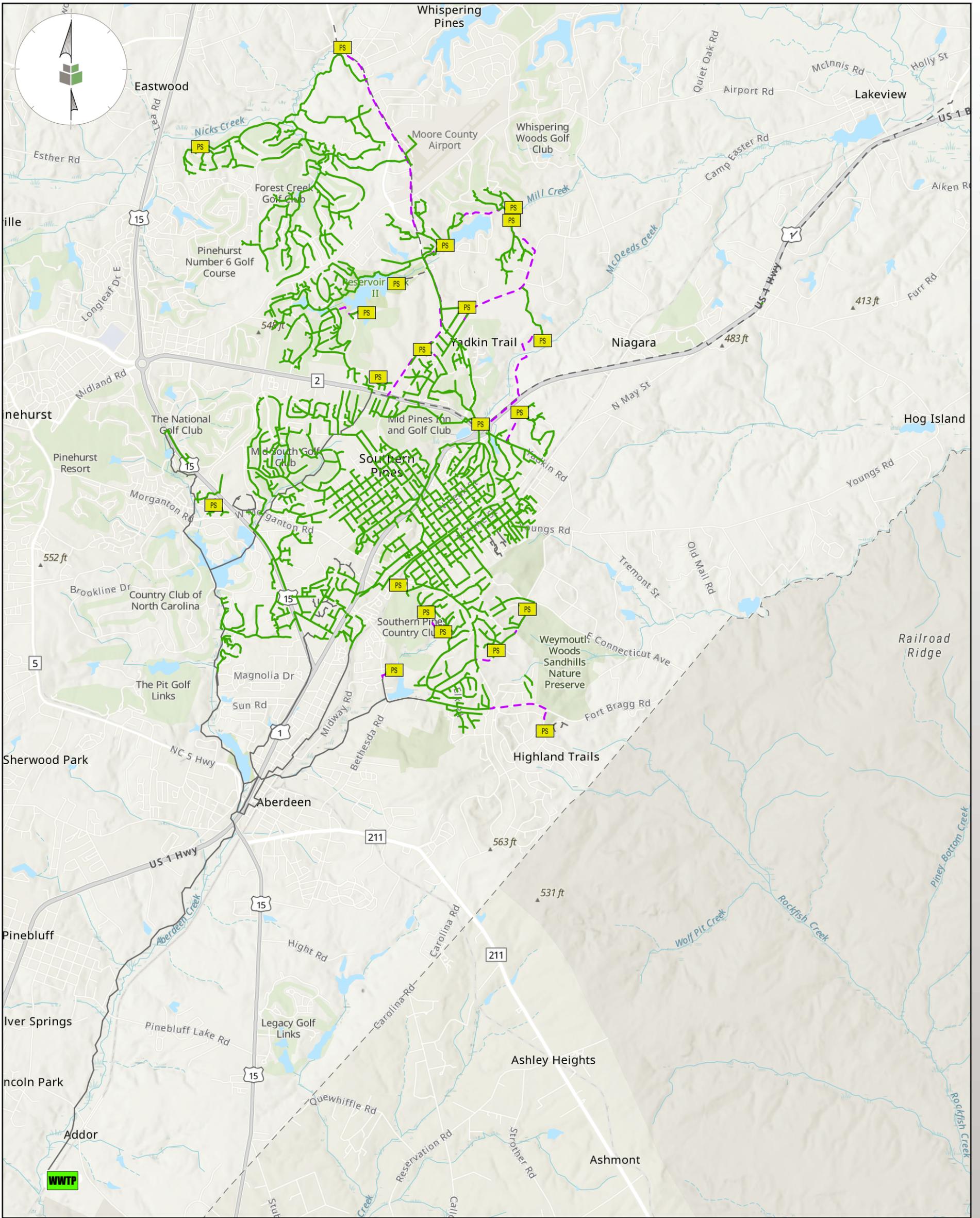
Project Location	Year 1 FY 26 - 27	Year 2 FY 27 - 28	Year 3 FY 28 - 29	Year 4 FY 29 - 30	Year 5 FY 30 - 31	Future Years FY 31 - 36
Gravity Sewer System - Annual Rehabilitation (Wastewater Project #8)	360,500	\$371,315	\$382,454	\$393,928	\$405,746	\$2,154,161
Longleaf Dam Sewer Relocation (Wastewater Project #7)	\$1,900,000					
Sewer Lift Station Emergency Backups (Wastewater Project #5)	205,000					
Warrior Woods Pump Station Upgrade Phases IB, II, III (Wastewater Projects #1-3)			\$135,000	\$1,070,000		\$5,036,300
<b>TOTAL</b>	<b>\$2,465,500</b>	<b>\$371,315</b>	<b>\$517,454</b>	<b>\$1,463,928</b>	<b>\$405,746</b>	<b>\$7,190,461</b>

## 8 Utility Easement Assessment

As part of the Southern Pines Sewer AIA, WR completed a comprehensive, GIS-driven easement, vegetation and tree-removal assessment to support long-term maintenance planning. Using high-resolution imagery and Esri's deep-learning Image Analyst tools, WR created a detailed tree canopy polygon dataset and intersected it with the Town's sewer easement network to quantify canopy coverage systemwide. To calibrate cost estimates, WR digitized the Reservoir Park II easement-clearing zone, where the Town reported an actual project cost of approximately \$240,000. Canopy area within this zone was measured, and a cost-per-acre unit rate was derived and then applied to the remainder of the system's easements. Subzone-level cost estimates were generated by calculating canopy-on-easement coverage for each sewer basin and applying the calibrated cost factor, with all outputs stored in the GIS deliverables.

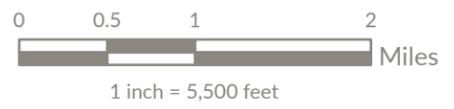
Additional work included WR's field-based tree-survey effort, supported by a custom Survey123 form and field-mapping workflow. This provides the Town with a repeatable method for documenting above-ground vegetation and incorporating those observations into the cost matrix to generate more refined, defensible, planning-level tree-removal and easement-clearing cost estimates by zone.

# APPENDIX I – GIS Maps



# Overall Sewer System

## Town of Southern Pines, NC

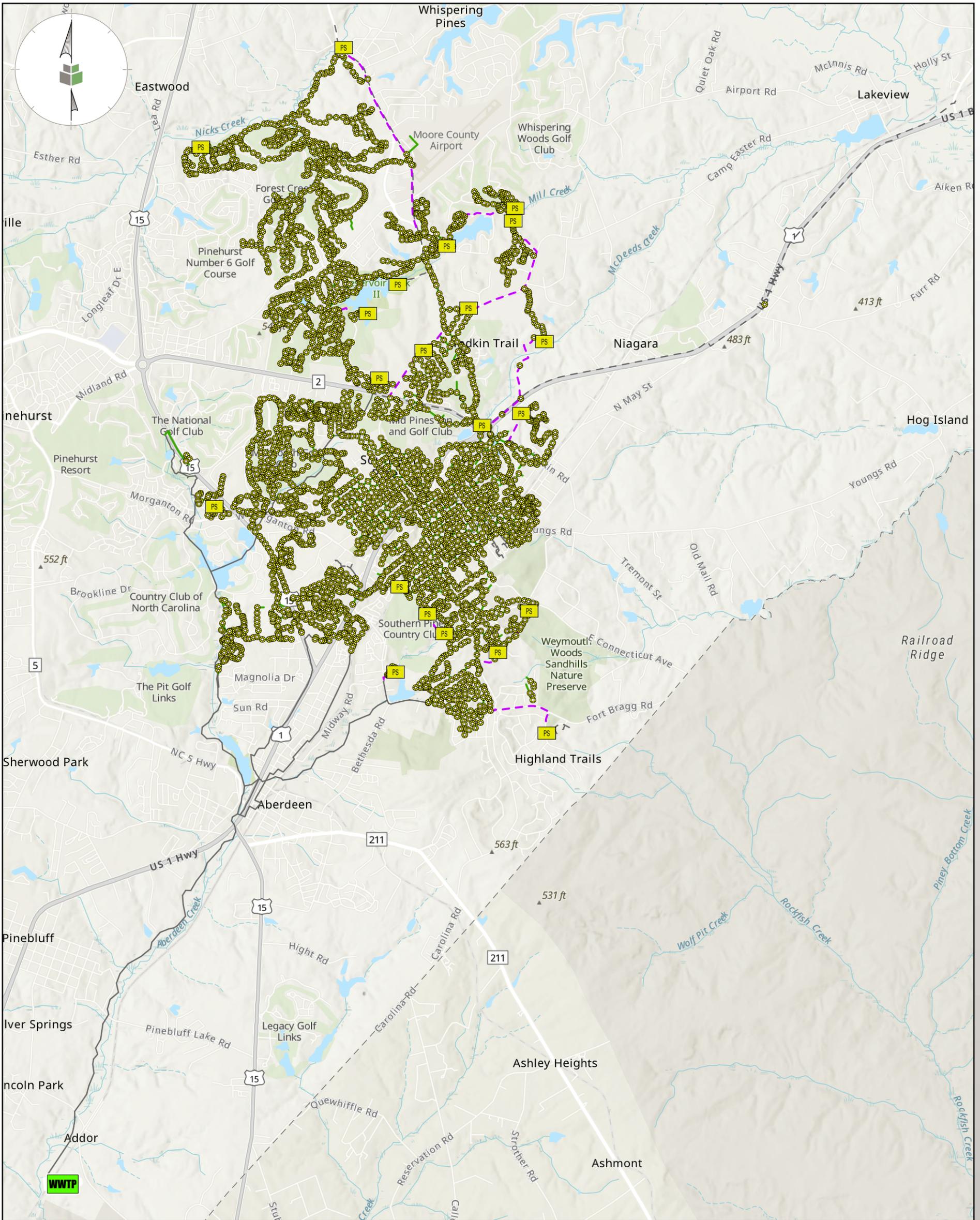


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- WWTP Treatment Plant
- PS Lift Station
- Gravity Main
- - - Force Main
- - - Non-Town Owned Force Mains
- Non-Town Owned Gravity Mains

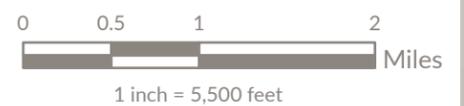
This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.



## Overall Sewer System

### Town of Southern Pines, NC

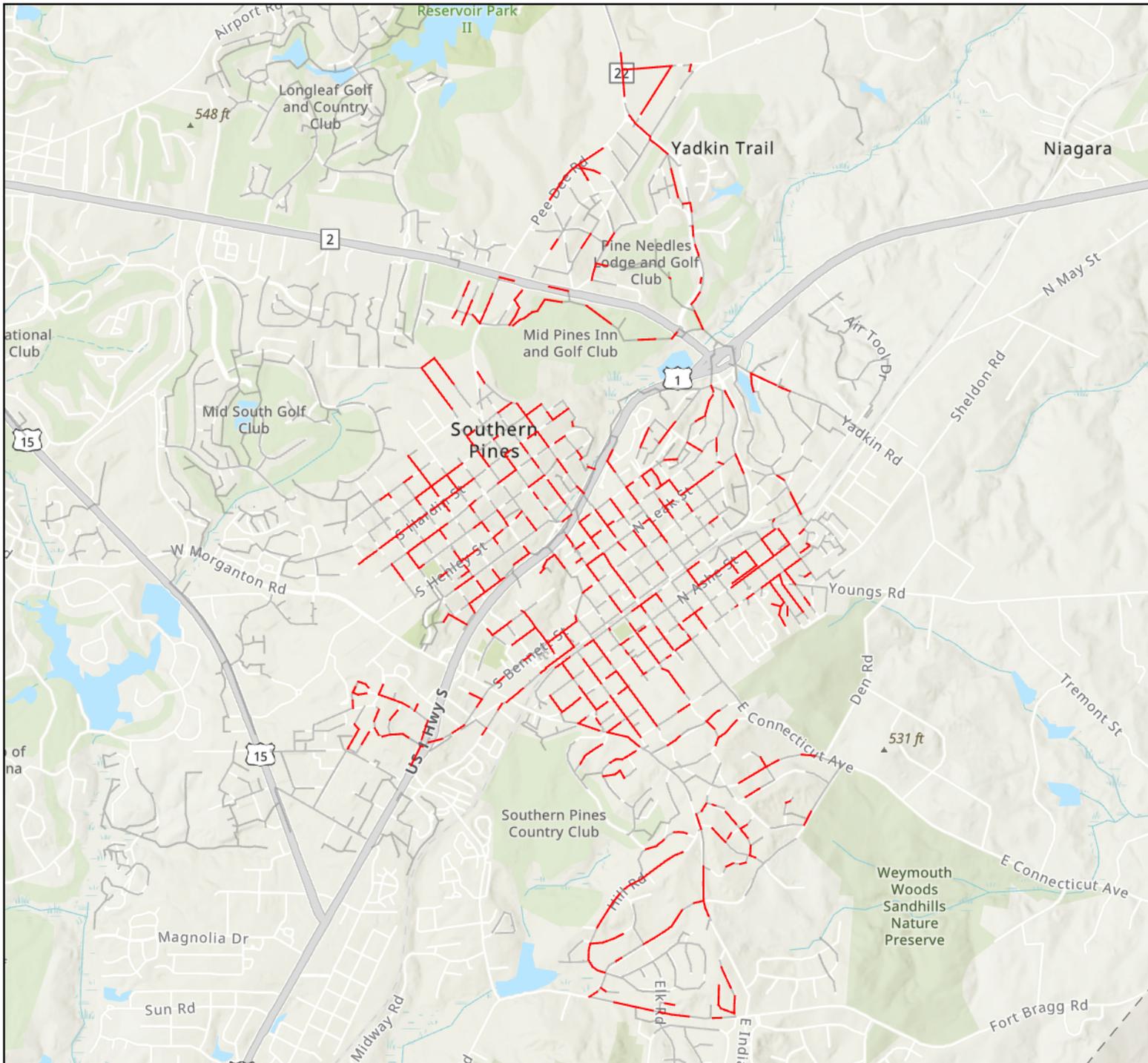


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- Manhole
- WWTP Treatment Plant
- PS Lift Station
- Gravity Main
- - - Force Main
- - - Non-Town Owned Force Mains
- Non-Town Owned Gravity Mains

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.



# CCTV Abandoned Map

Town of Southern Pines, NC



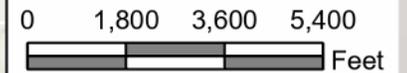
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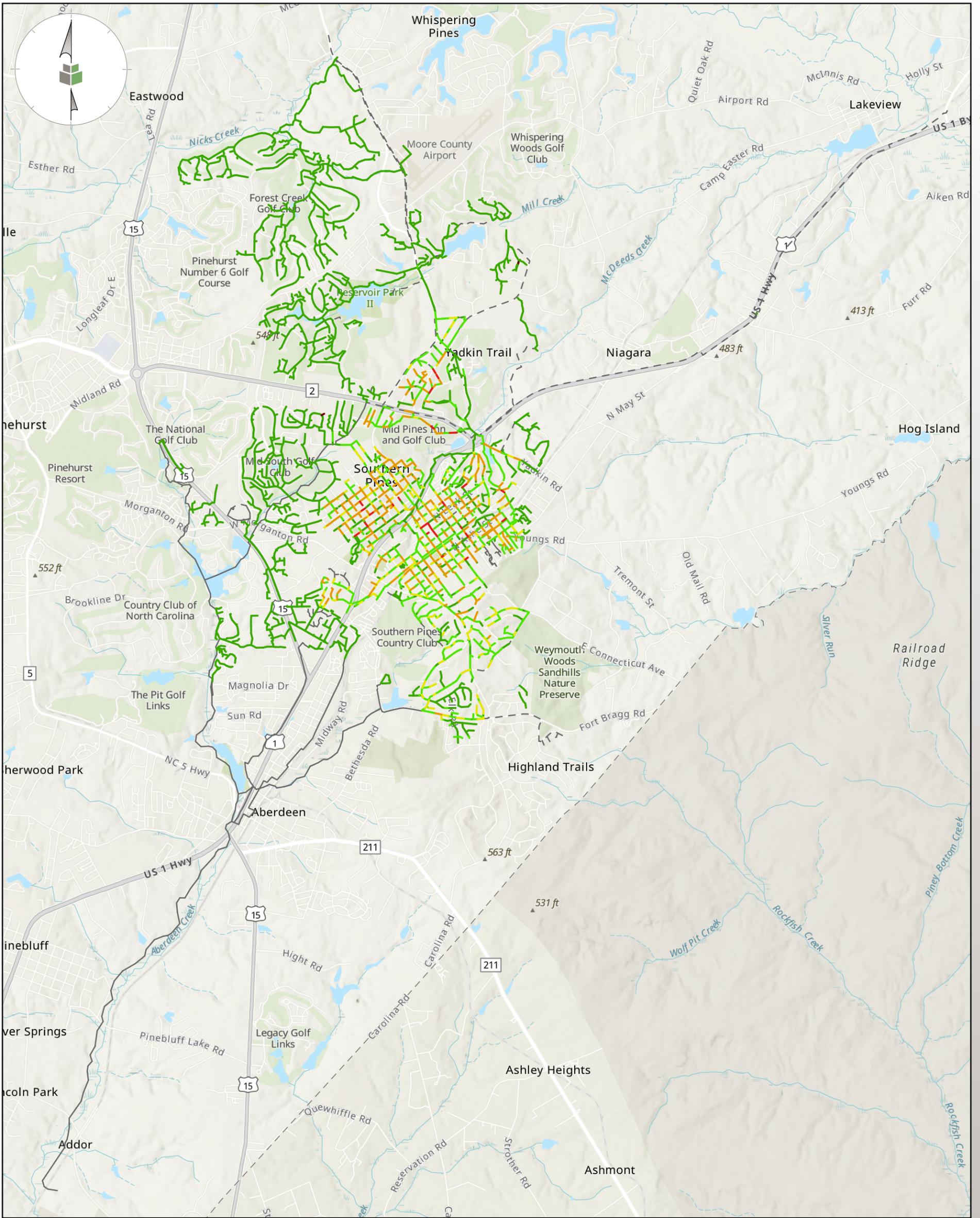
Data features are not based on professional field survey unless stated otherwise.

### Legend

- Gravity Mains With Survey Abandoned Record
- Gravity Mains

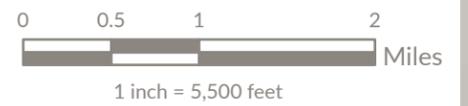


1 inch = 3,488 feet



## Gravity Mains by LoF

### Town of Southern Pines, NC



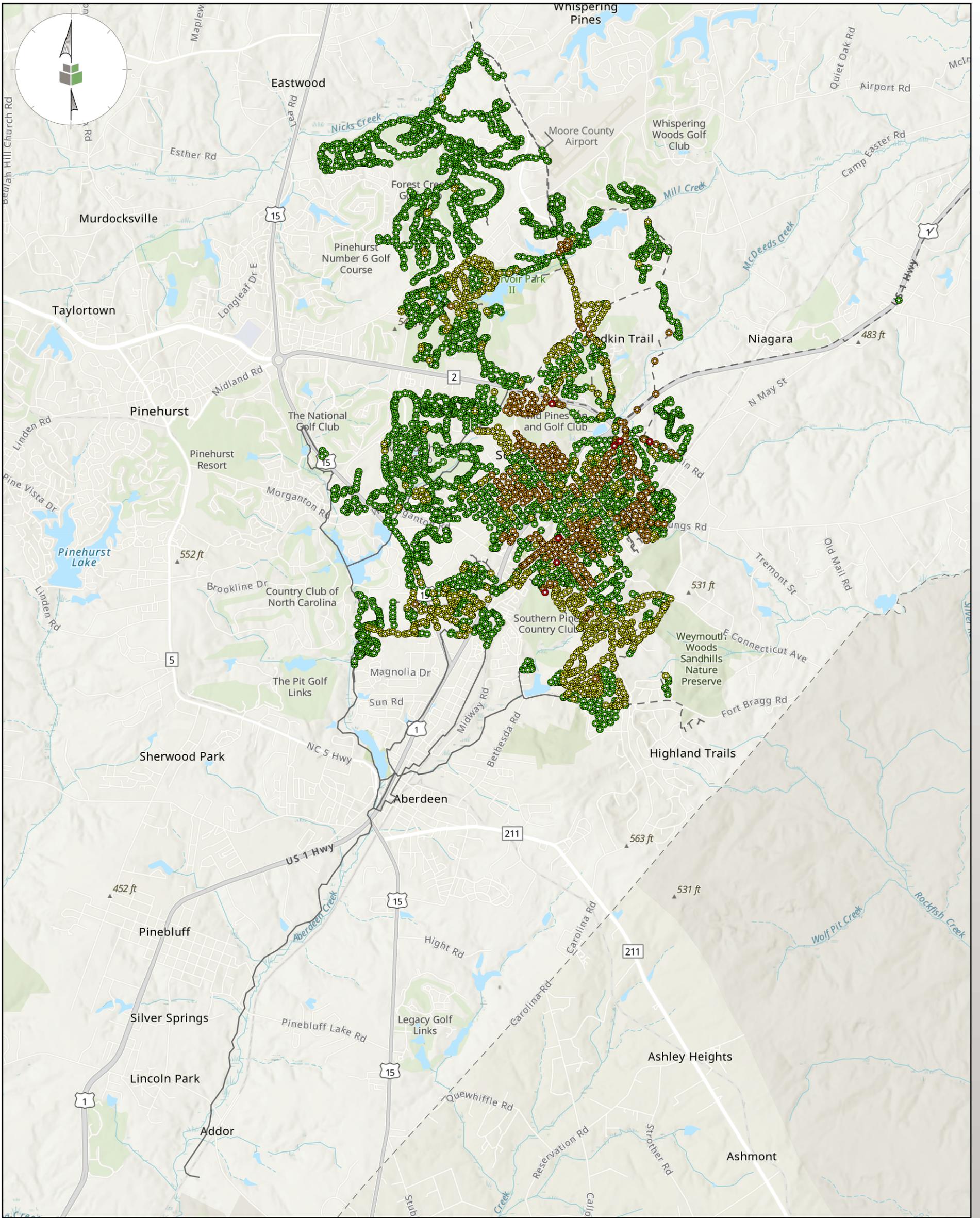
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#### Gravity Mains by LoF

- Excellent (513,754 LF)
- Good (153,790 LF)
- Fair (44,018 LF)
- Poor (78,750 LF)
- Very Poor (6,325 LF)
- Unknown (261 LF)
- - - Force Main
- Non-Town Owned Gravity Mains

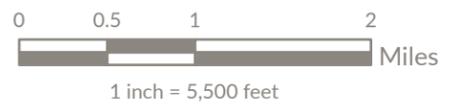
This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.



# Manholes by LoF

## Town of Southern Pines, NC

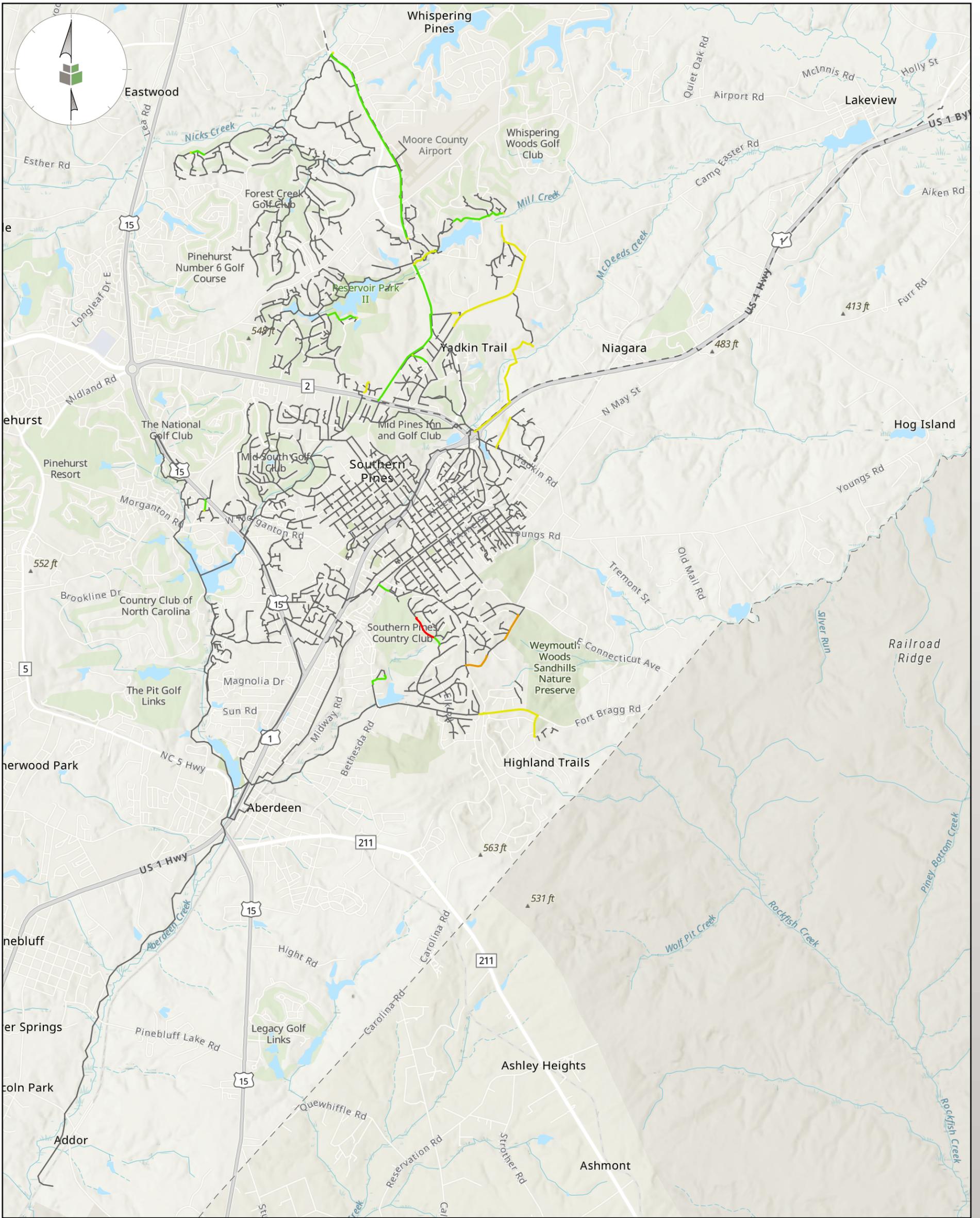


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- LoF
- Excellent (0)
  - Good (2,766)
  - Fair (618)
  - Poor (351)
  - Very Poor (8)
  - Gravity Main
  - - - Force Main

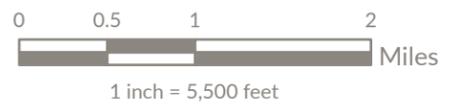
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# Force Mains by LoF

## Town of Southern Pines, NC

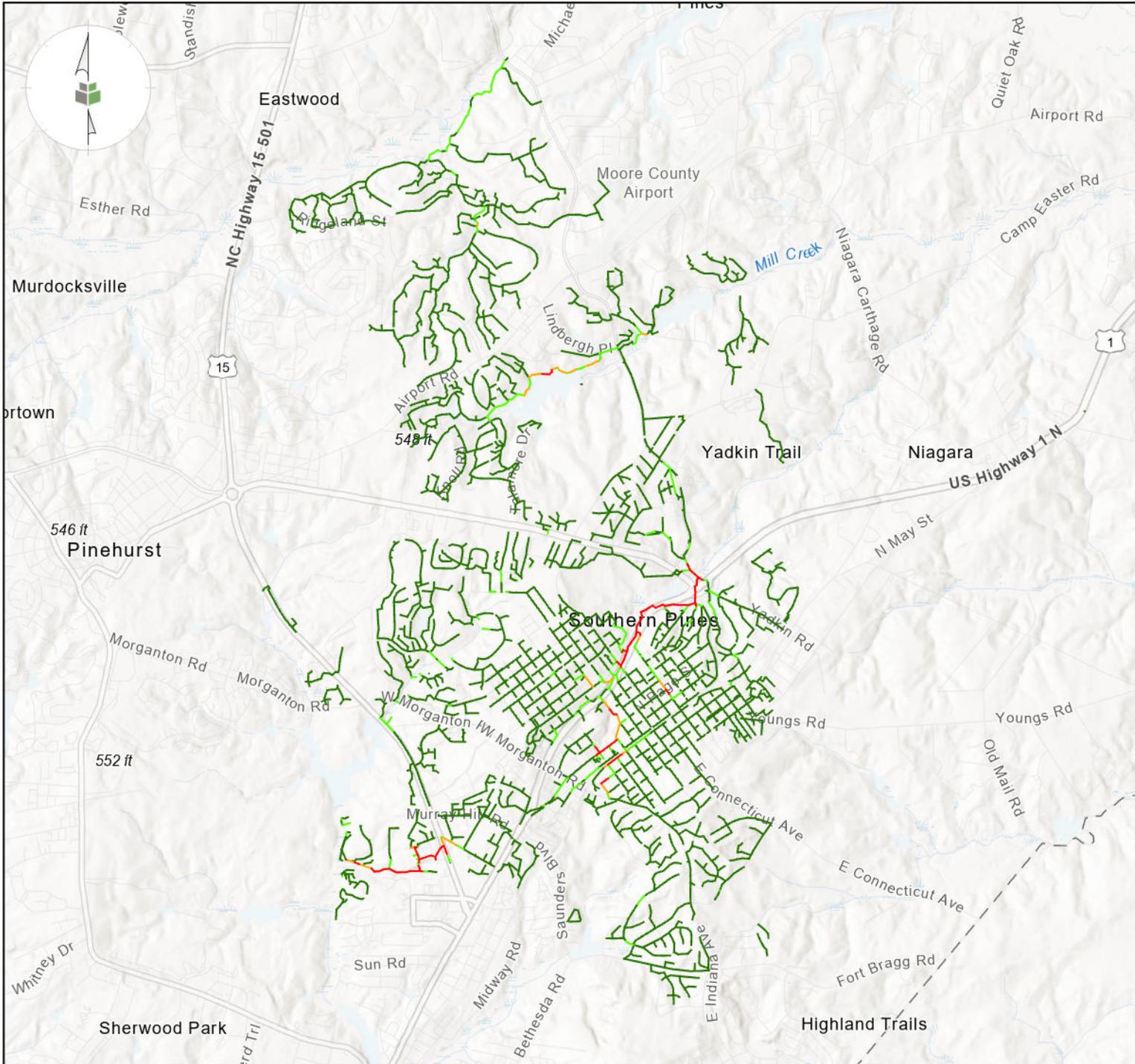



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- Force Main by LoF**
- Excellent (952 LF)
  - Good (33,669 LF)
  - Fair (26,368 LF)
  - Poor (3,273 LF)
  - Very Poor (1,588 LF)
  - Unknown
  - Non-Town Owned Force Mains
  - Gravity Main

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## Sewer System Capacity Ratings

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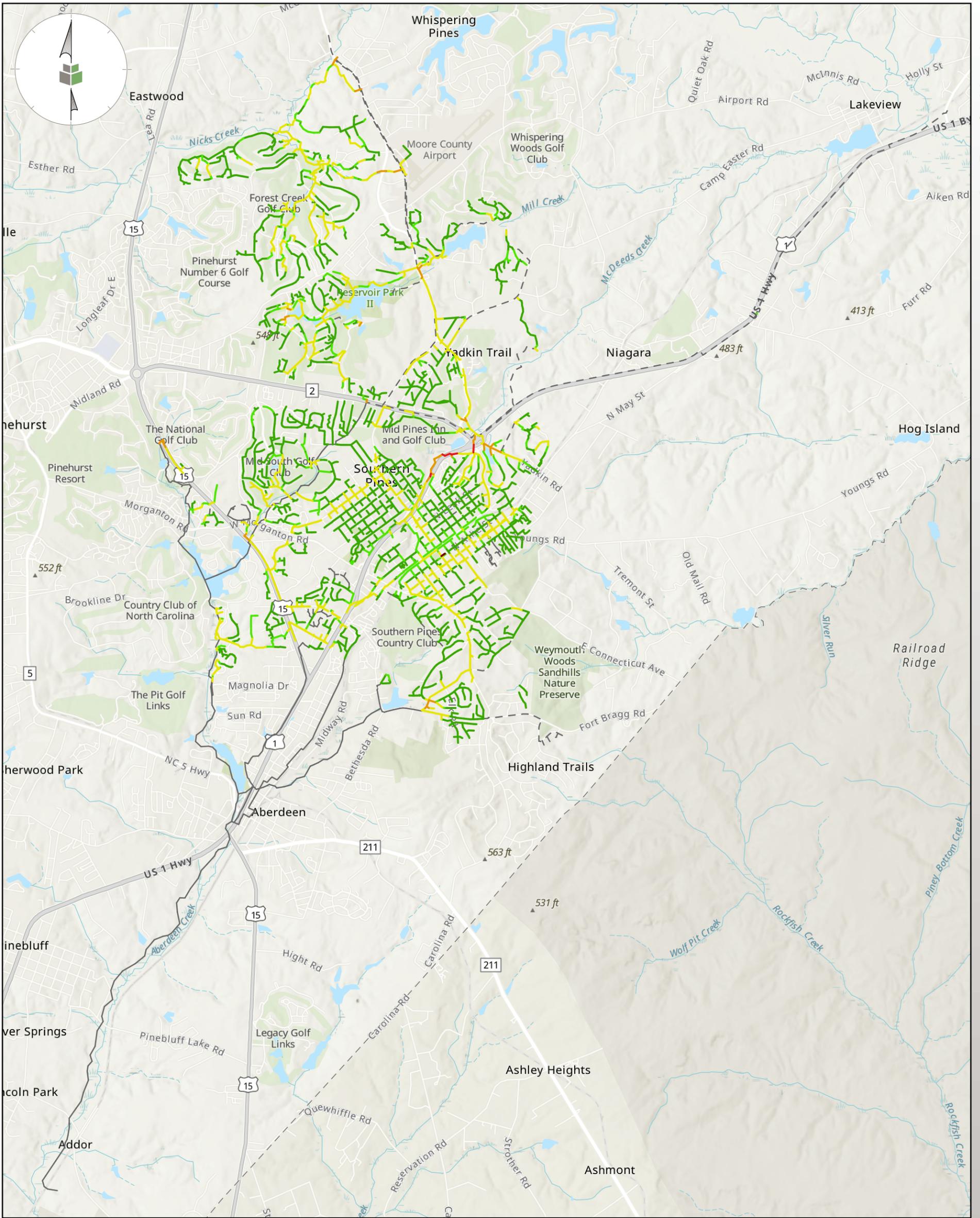
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### Capacity Rating

- Excellent (728,960 LF)
- Good (40,945 LF)
- Fair (0 LF)
- Poor (9,247 LF)
- Very Poor (17,236 LF)

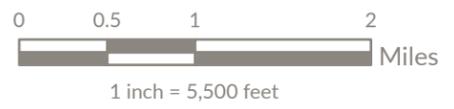


1 inch = 6,007 feet



# Gravity Mains by CoF

## Town of Southern Pines, NC

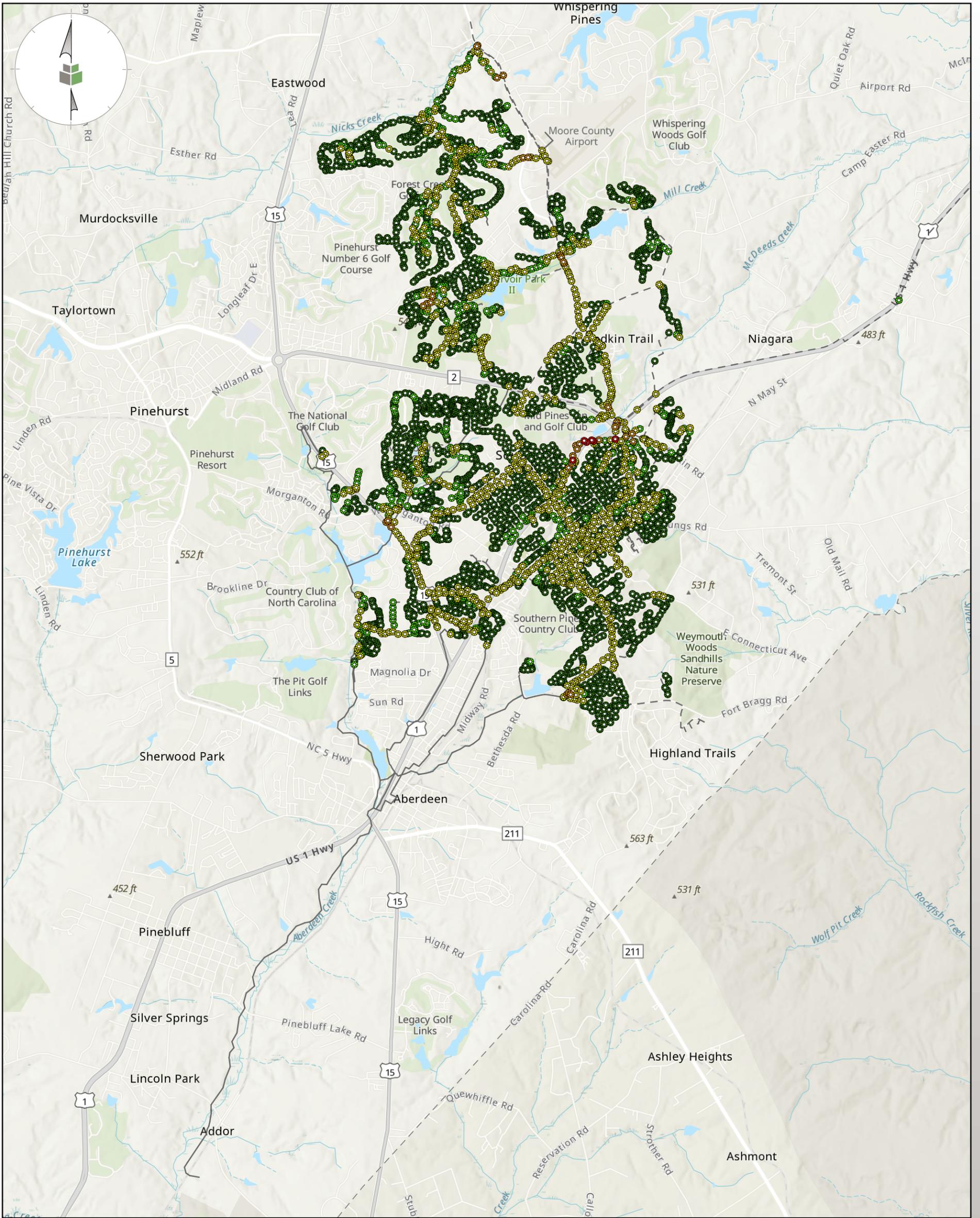



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- Gravity Main by CoF
- Very Low (480,309 LF)
  - Low (96,210 LF)
  - Fair (206,829 LF)
  - High (11,741 LF)
  - Very High (1,561 LF)
  - Unknown (249 LF)
  - - - Force Main
  - Non-Town Owned Gravity Mains

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# Manholes by CoF

## Town of Southern Pines, NC

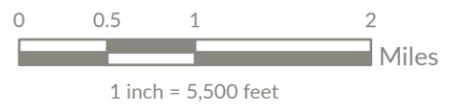


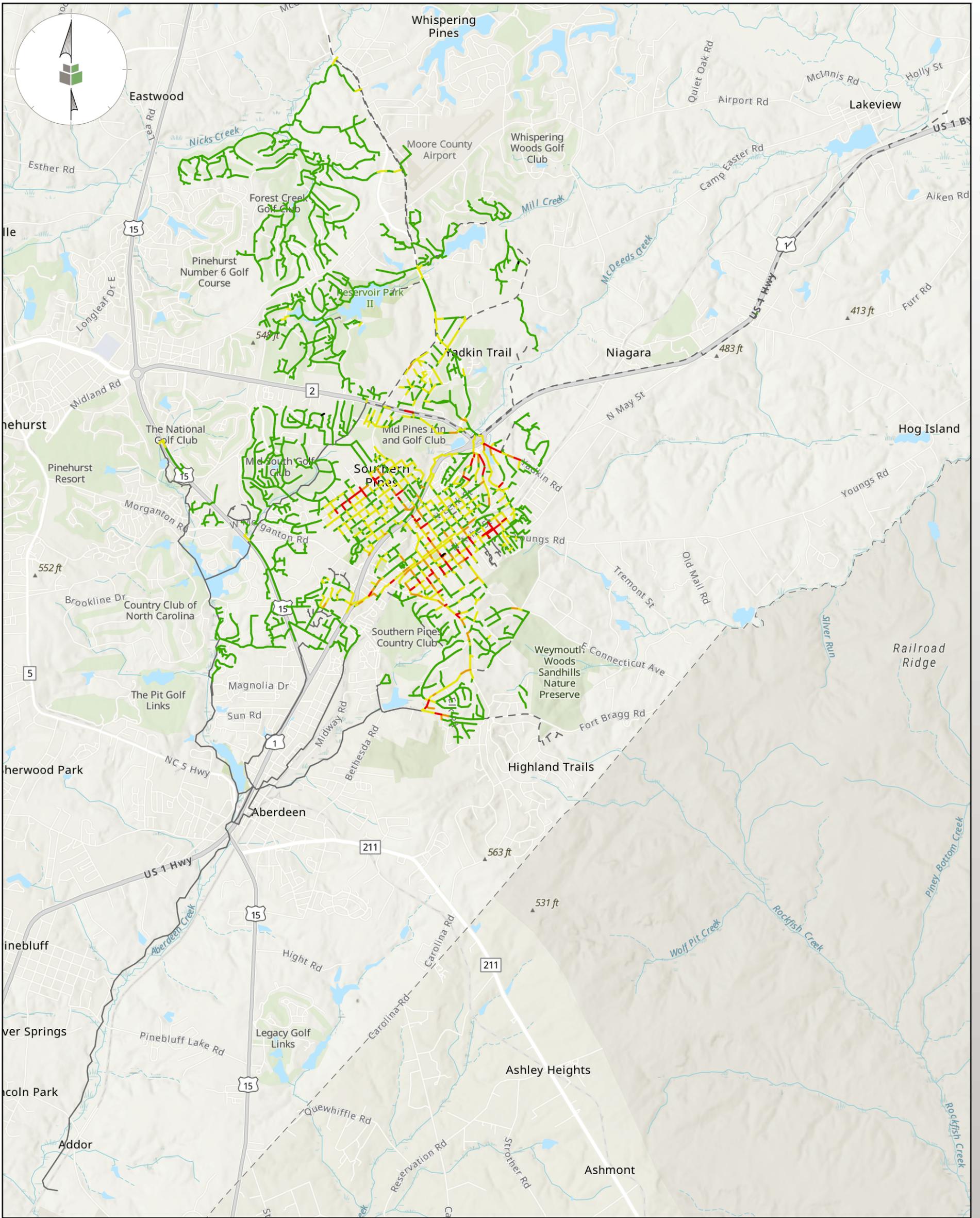
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- CoF**
- Very Low (2,425)
  - Low (391)
  - Fair (886)
  - High (35)
  - Very High (6)
  - Gravity Main
  - - - Force Main

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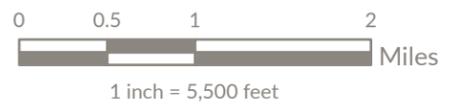
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# Gravity Mains by Risk

## Town of Southern Pines, NC

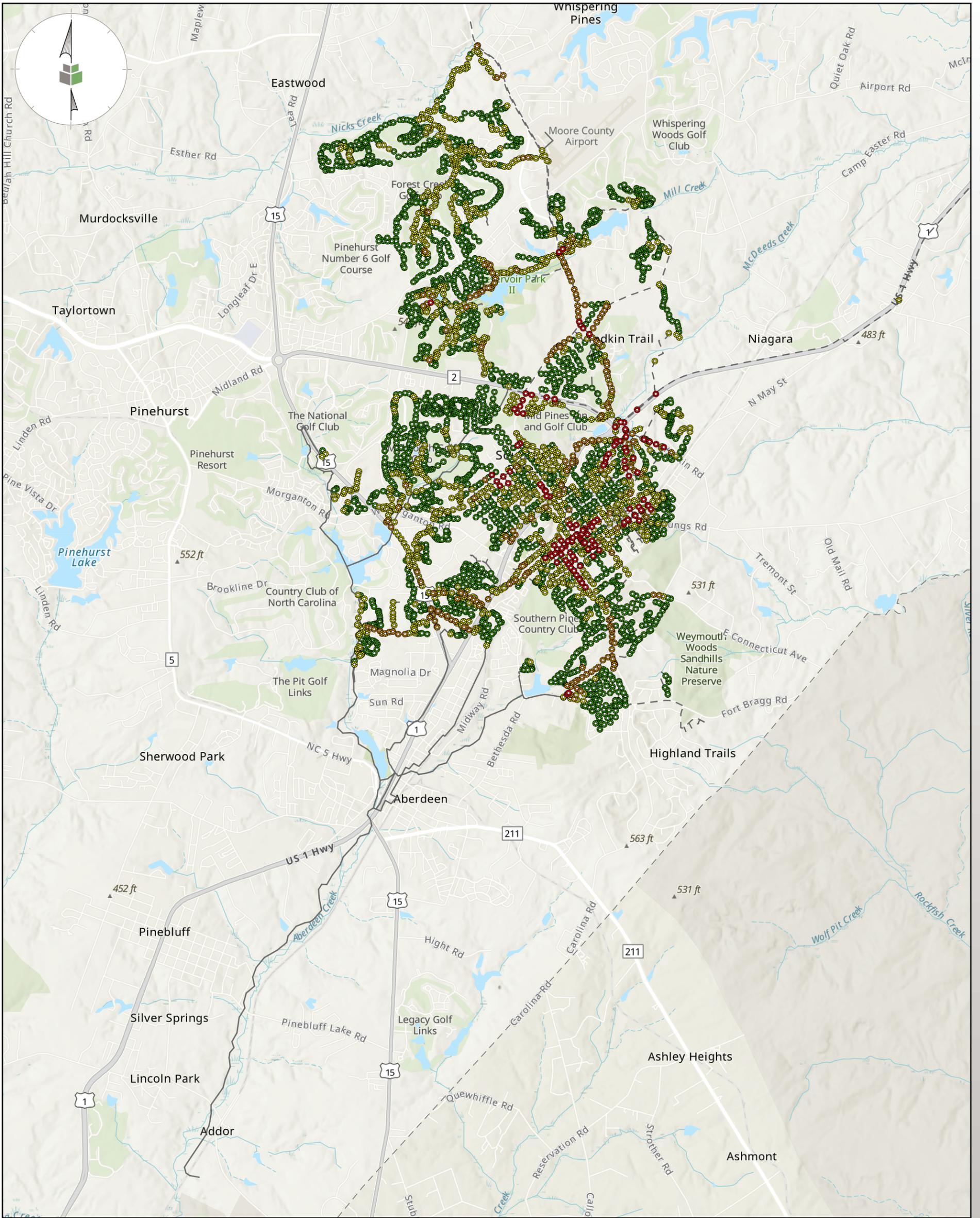



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- Gravity Main Risk**
- Very Low (623,054 LF)
  - Low (132,669 LF)
  - Significant (21,741 LF)
  - High (18,924 LF)
  - Extreme (0 LF)
  - Unknown (511 LF)
  - - - Force Main
  - Non-Town Owned Gravity Mains

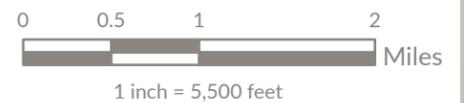
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# Manholes by Risk

## Town of Southern Pines, NC

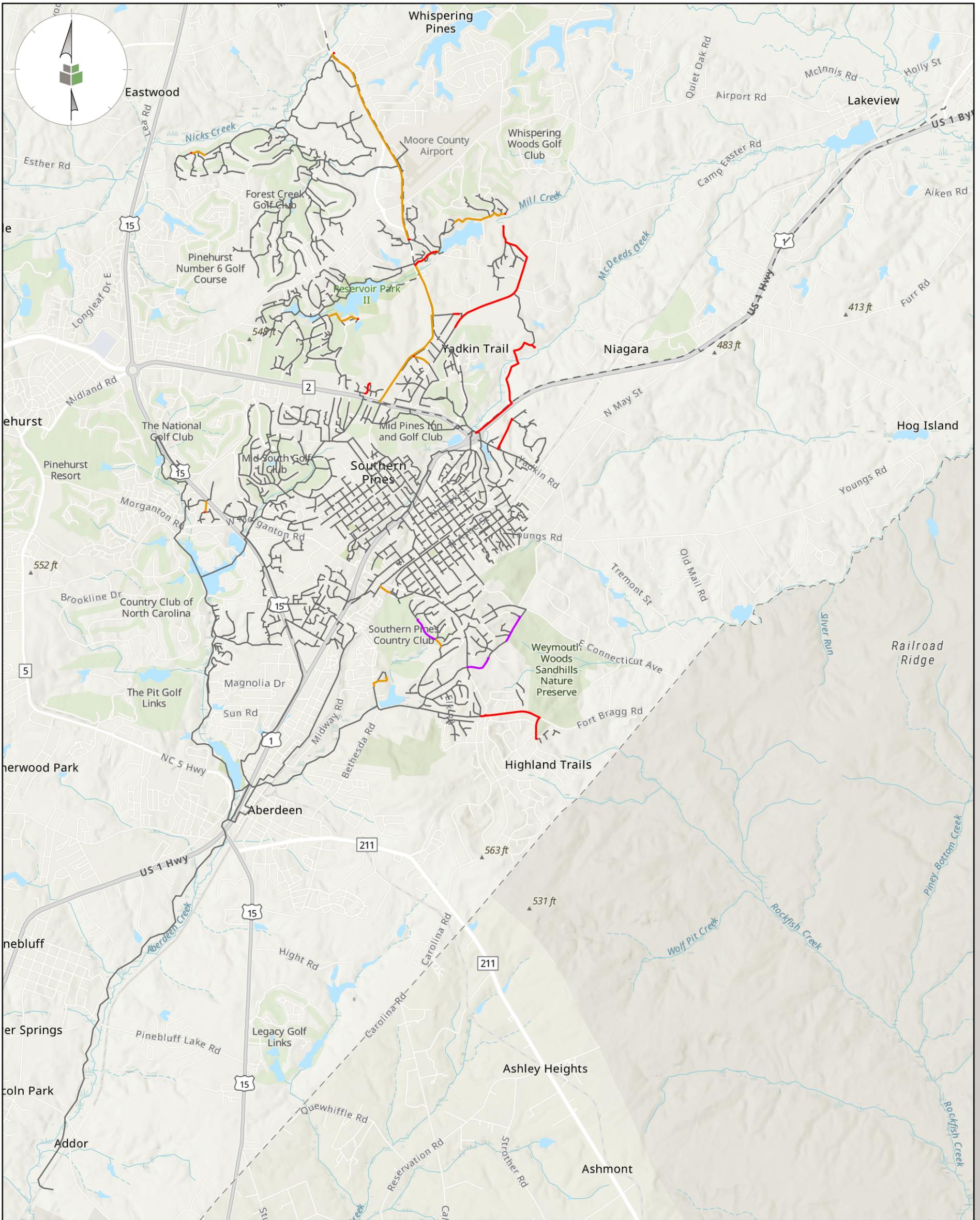


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- Risk**
- Very Low (2,226)
  - Low (1,123)
  - Significant (256)
  - High (138)
  - Extreme (0)
- Gravity Main  
 - - - Force Main

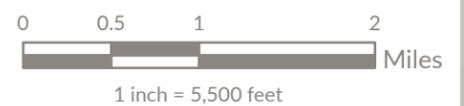
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# Force Mains by Risk

## Town of Southern Pines, NC

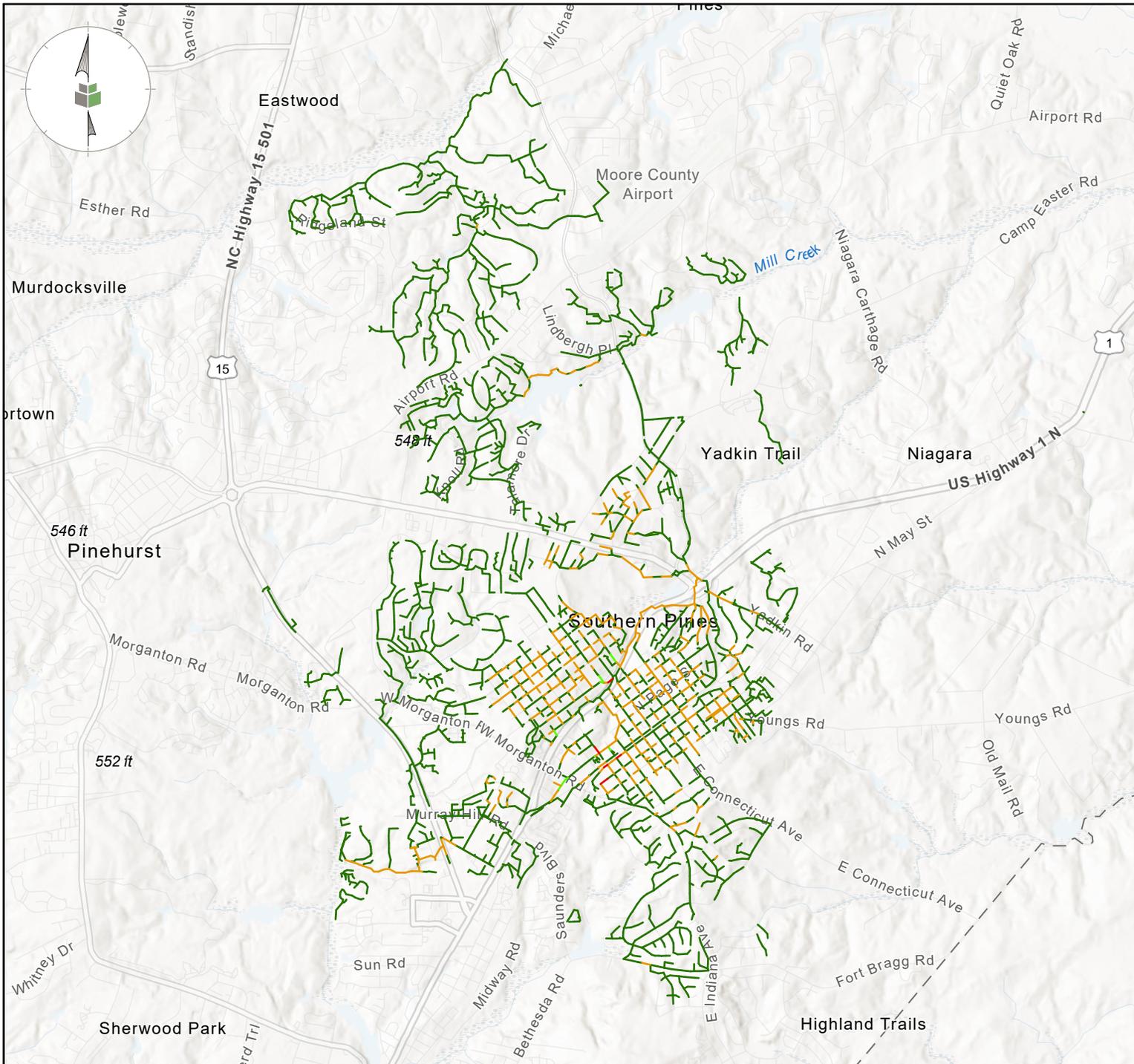


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- Force Main**
- Risk**
- Very Low (0 LF)
  - Low (952 LF)
  - Significant (33,669 LF)
  - High (26,368 LF)
  - Extreme (4,861 LF)
  - Non-Town Owned Force Mains
  - Gravity Main

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## Overall System Cost Estimate

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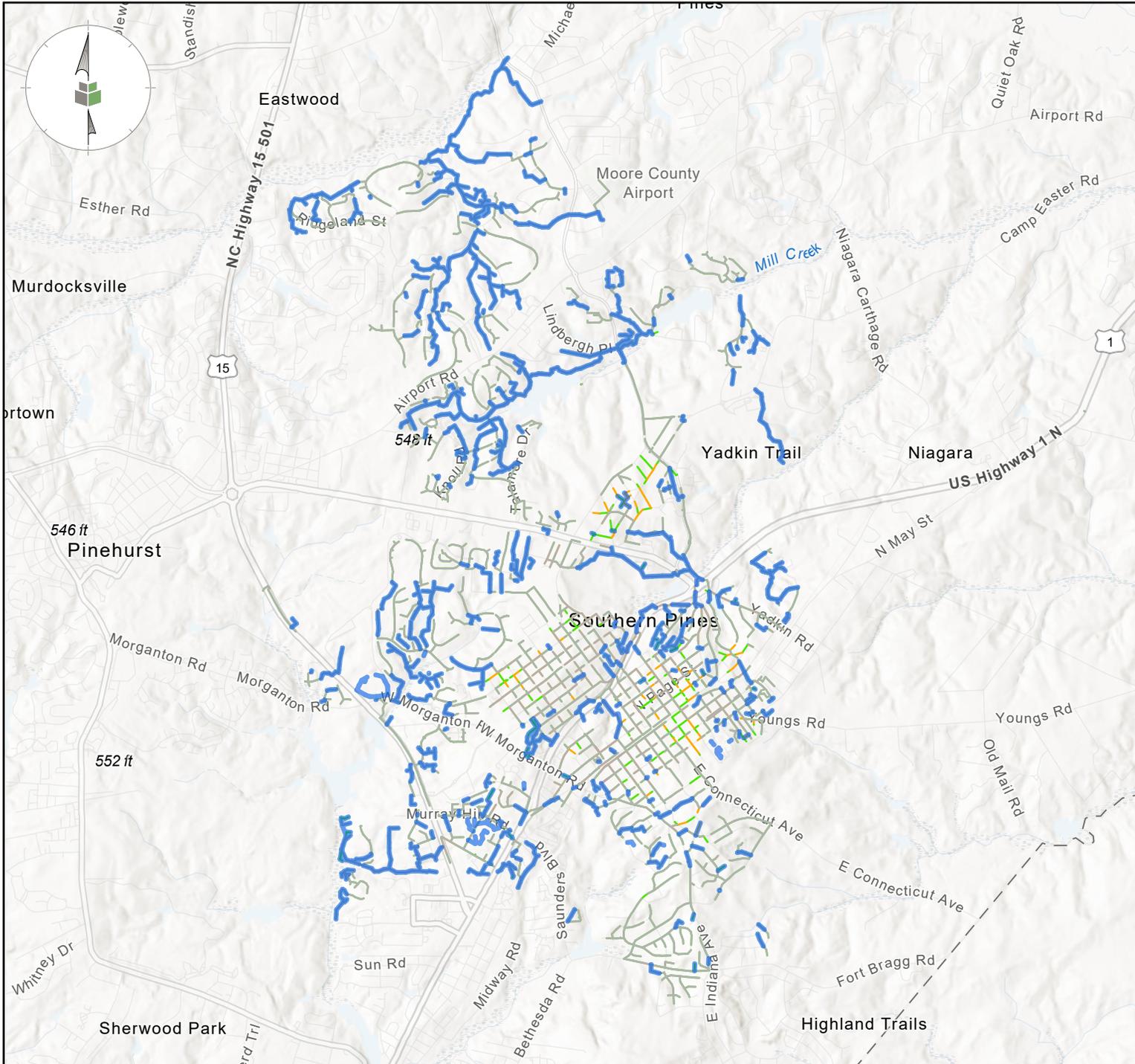
## Gravity Mains

### CIP Tier & Cost Estimate

- 1 - \$173,677,255
- 2 - \$513,773
- 3 - \$30,708,797
- 4 - \$364,343



1 inch = 6,007 feet



## Overall Cost Estimate

### Town of Southern Pines, NC



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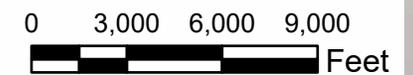
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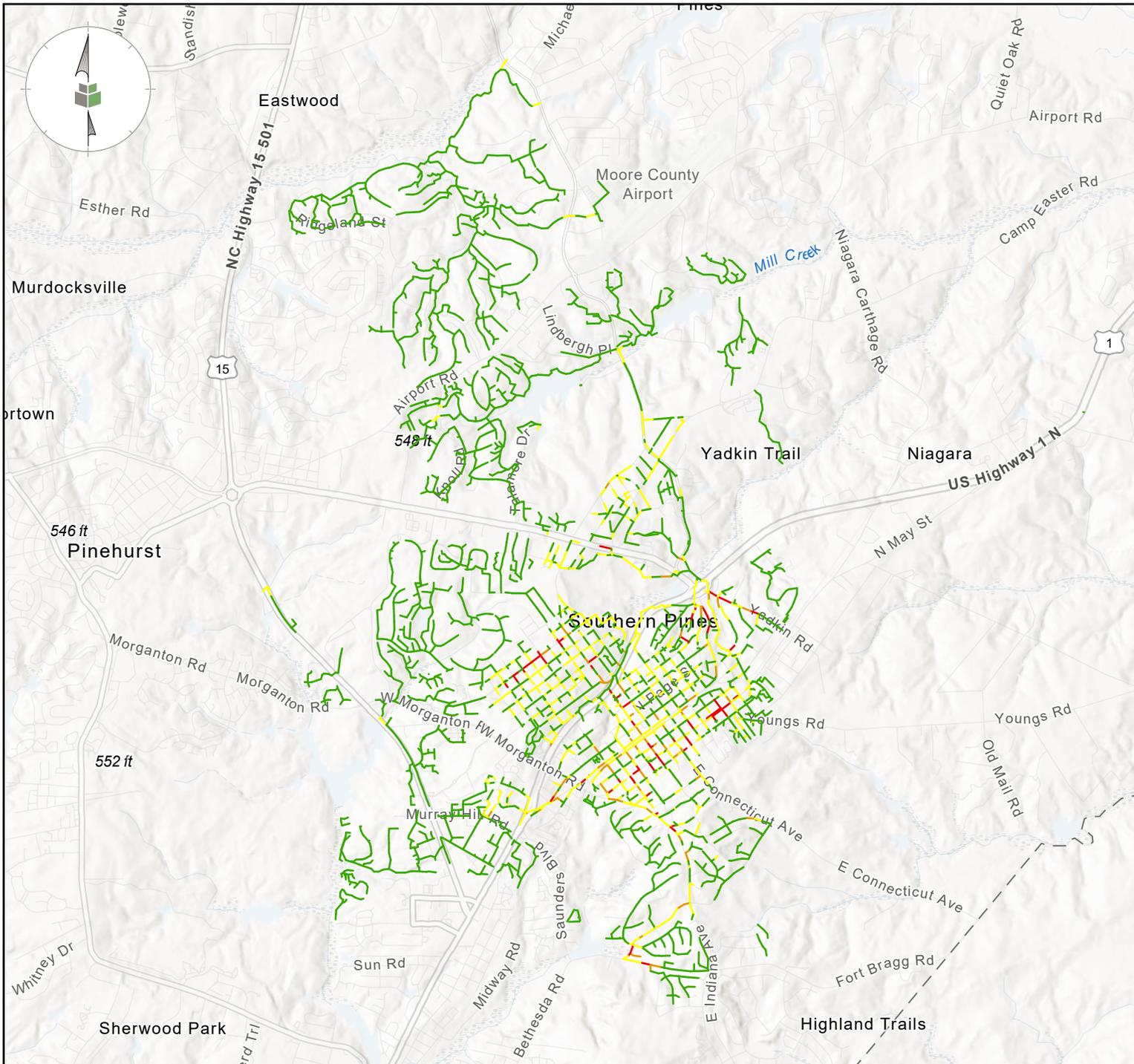
## Gravity Mains

### CIP Tiers & Cost Estimate

- 1 - \$173,677,255
- 2 - \$513,773
- 3 - \$30,708,797
- 4 - \$364,343
- Non 6 Inch Lines
- █ Easements



1 inch = 6,007 feet



## Overall System Cost Estimate

Town of Southern Pines, NC



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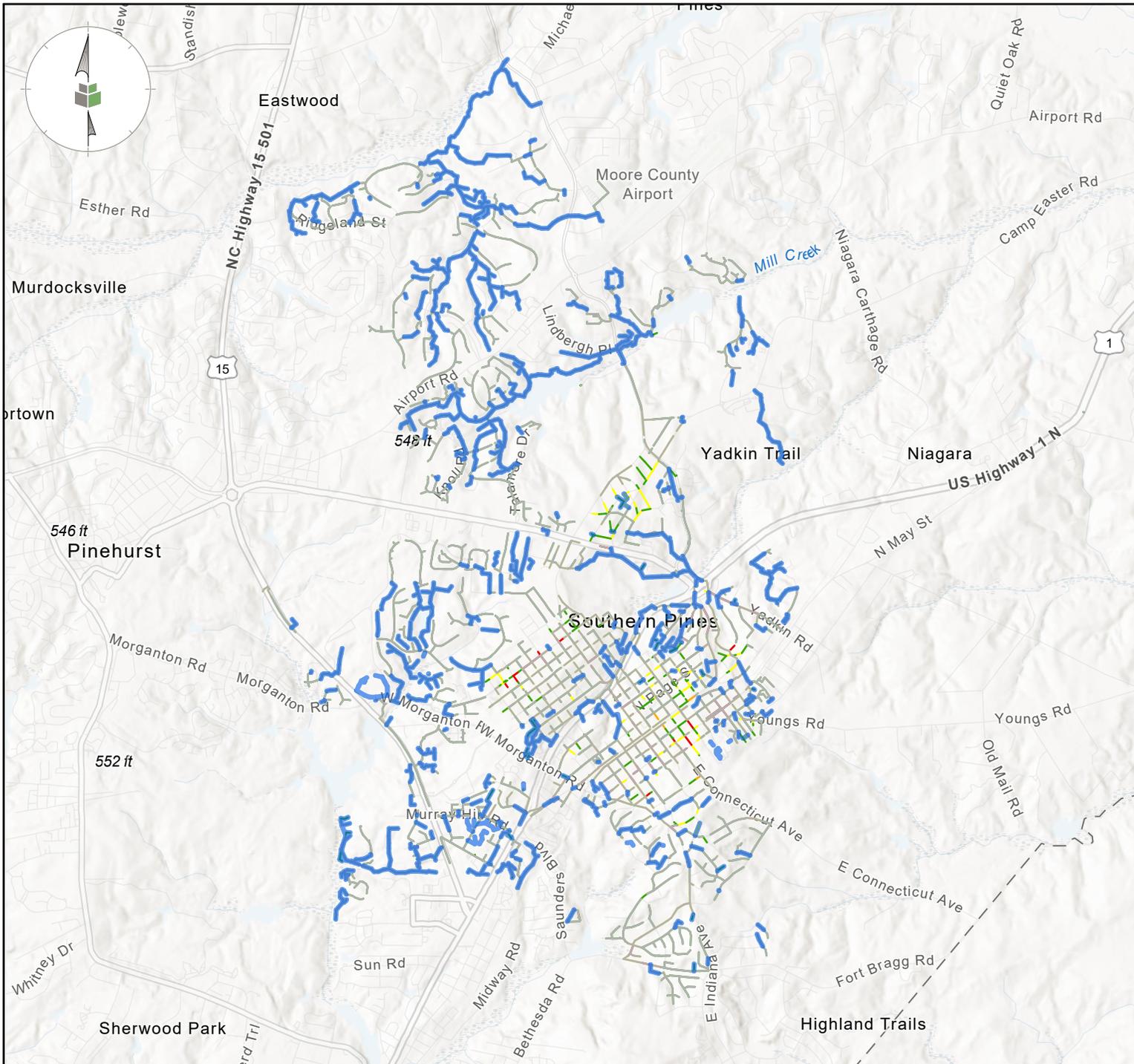
## Gravity Mains

### Risk / Cost Estimate

- 1 - 3 / \$158,247,442
- 4 - 7 / \$36,441,425
- 8 - 11 / \$5,578,633
- 12 - 19 / \$4,996,668
- 20 - 25 / \$0



1 inch = 6,007 feet



## Overall Cost Estimate

### Town of Southern Pines, NC



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## Gravity Mains

### Risk / Cost Estimate

- 1 - 3 / \$158,247,442
- 4 - 7 / \$36,441,425
- 8 - 11 / \$5,578,633
- 12 - 19 / \$4,996,668
- 20 - 25 / \$0
- Non 6 Inch Lines
- Easements



1 inch = 6,007 feet

# **APPENDIX II – Hydraulic Modeling Report**



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# Hydraulic Modeling Report

## Southern Pines Sewer AIA Engineering Services



Prepared For:  
Town of Southern Pines  
125 SE Broad Street  
Southern Pines, NC 28387

Prepared By:  
WithersRavenel  
115 MacKenan Drive  
Cary, NC 27511  
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WithersRavenel Project No. 02220447.01

October 2025

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# List of Abbreviations

AIA	Asset Inventory and Assessment
AMP	Asset Management Plan
BSF	Base Sanitary Flow
CHI	Computational Hydraulics International
d/D	Depth-to-Diameter
DEM	Digital Elevation Model
DWF	Dry Weather Flow
GIS	Geographic Information System
GW	Groundwater
GWI	Groundwater Infiltration
HGL	Hydraulic Grade Line
IDF	Intensity-Duration-Frequency
ISE	Integral Square Error
I&I	Inflow and Infiltration
LiDAR	Light Detection and Ranging
MDC	Minimum Design Criteria
MG	Million Gallons
NAVD88	North American Vertical Datum Of 1988
NCDEQ	North Carolina Department of Environmental Quality
NOAA	National Oceanic and Atmospheric Administration
PCSWMM	Personal Computer Stormwater Management Model
RDII	Rainfall-Derived Inflow and Infiltration
SCS	Soil Conservation Service
SCADA	Supervisory Control and Data Acquisition
SRTC	Sensitivity-Based Radio Tuning Calibration
SSO	Sanitary Sewer Overflow
SWMM	Storm Water Management Model
WO	Work Order
WR	WithersRavenel
WWTP	Wastewater Treatment Plant

# Appendices

Appendix I – Work Orders and Rehabilitation Context

Appendix II – Design Storms Results: Maps

## 1 Executive Summary

This report has been prepared by WithersRavenel (WR) as part of the Town of Southern Pines' (Town) Asset Inventory and Assessment (AIA) project. It outlines the development of a representative hydraulic model for the Town's sanitary sewer system. The model was built using PCSWMM software and calibrated according to industry standards based on available data. It simulates the hydraulic behavior of the system and provides valuable insights into its performance under various rainfall events. The results from this effort will inform the Town's future Asset Management Plan (AMP) and help prioritize capital improvements.

The Town's sewer system includes approximately 151 miles of gravity sewers, 12 miles of force mains, nineteen (19) active public pump stations, and 3,902 active manholes. The model development and calibration relied on data from a four-month monitoring period between March 11 and July 9, 2024, and while the model effectively reflects 2024 conditions, further data collection, including longer duration of flow monitoring, will increase its predictive capabilities.

System performance was evaluated under three design rainfall events (2-, 5-, and 10-year, 24-hour storms). For the 2-year storm, the system generally performed within capacity, though localized surcharging and minor sanitary sewer overflows (SSOs) were predicted near the Moore County Pump Station, the SPFM-05 subbasin, and downstream of Walmart (north of the intersection of Daytona Avenue and Johnson Street). A significant overflow (>0.1 MG) was predicted at manhole SSMH1211 (in basin SPFM-04), while several others were predicted to surcharge. Under the 5-year storm, these conditions worsened, with the same major overflow persisting and additional minor SSOs predicted. By the 10-year storm, the model indicated further increases in severity, with additional pipe segments approaching or exceeding capacity and multiple manholes predicted to surcharge.

This report does not serve as a comprehensive wet weather mitigation plan; rather, it provides an overview of the current system's performance under design storm conditions. Based on the current model results, several key priorities have been identified to improve system performance, particularly at the Moore County Pump Station, which serves as a critical bottleneck under all design storm scenarios. Also, targeted rehabilitation should be prioritized in areas with high Inflow and Infiltration (I&I), such as SPFM-04 and SPFM-05, along with monitoring critical manholes identified in this study. However, rehabilitation activities and work orders completed after the flow monitoring period, especially in basins SPFM-04 and SPFM-05, may already have reduced I&I and improved system performance beyond what is reflected in the model. By decreasing peak flows conveyed to the pump station, these improvements could help mitigate the capacity issues identified in the model.

Therefore, additional flow monitoring and model recalibration are recommended to benchmark the impacts of rehabilitation and work orders completed in the Town. This will also allow the Town to re-assess system performance following the recent discovery and repair of a significant I&I source from the Moore County airport. Specifically, if upgrades are implemented to increase capacity at the Moore County Pump Station, it is important to note that the bottleneck may shift downstream. Since the airport area discharges to the Warrior Wood Pump Station and its force main ties into the system downstream of the Moore County PS, the repaired I&I source may help

reduce peak flows to the downstream system and, in turn, decrease the risk of bottlenecks if the Moore County Pump Station is upsized.

## 2 Introduction

This document details the development of a planning-level hydraulic model for the Town of Southern Pines' sanitary sewer system, providing a detailed assessment of the system's current performance under various hydrological conditions. The model was calibrated to industry standards using available data and constructed to reflect the sewer system's hydraulic characteristics. This effort is part of a broader Asset Inventory and Assessment (AIA) project, designed to inform the Town's future Asset Management Plan (AMP).

As shown in Figure 1, the Town's sanitary sewer system infrastructure included in the model consists of:

- Nineteen (19) public pump stations
- Approximately 151 miles of gravity sewer
- Approximately 12 miles of force main
- 3,902 active sewer manholes

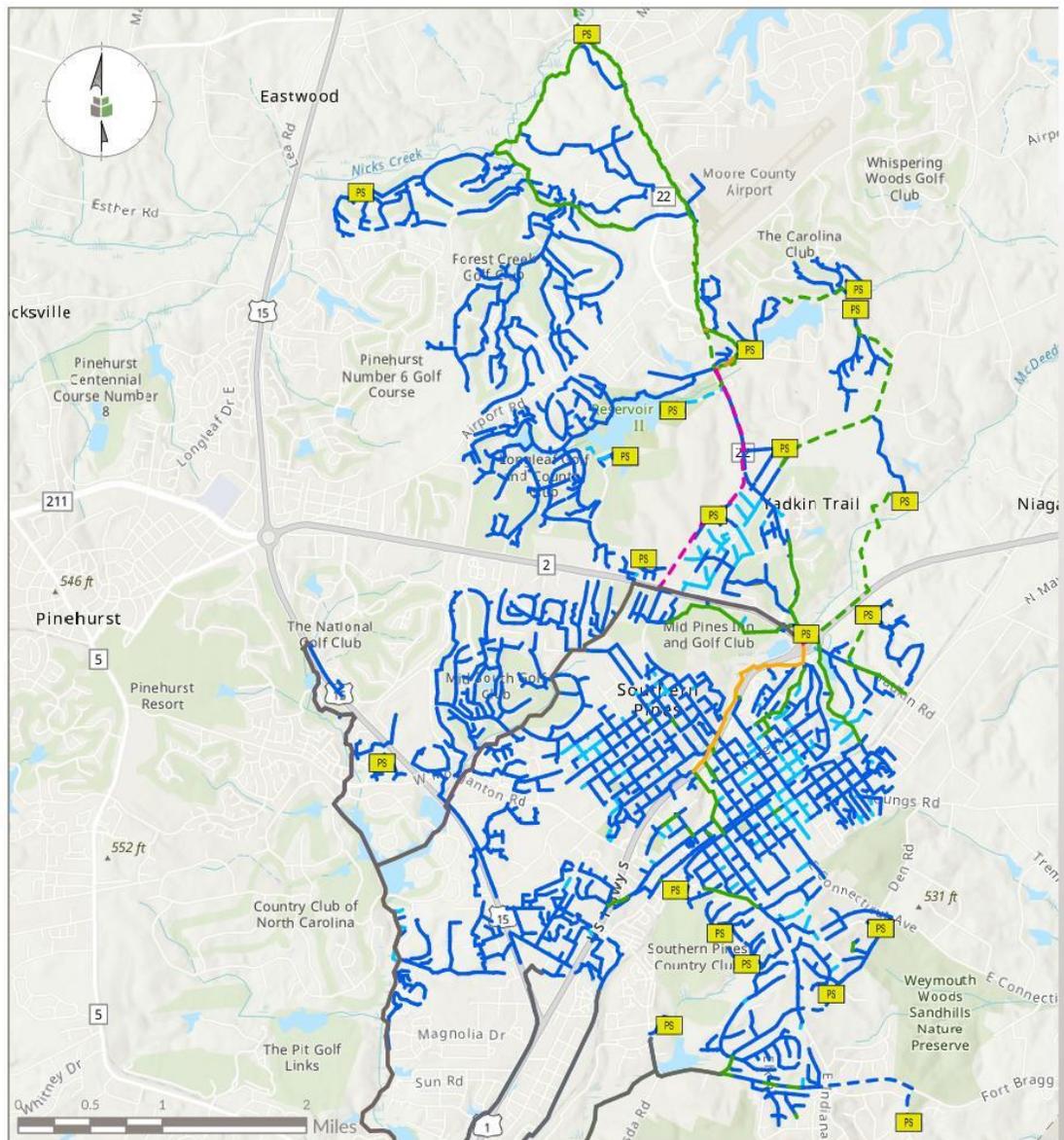
To model the Town's sewer system, it was necessary to connect the model to applicable sections of downstream systems owned by Moore County and the Town of Aberdeen, which required the addition of approximately 21 miles of gravity sewer, 243 sewer manholes, 1.3 miles of force main, one (1) Moore County pump station, and one (1) wastewater treatment plant (Moore County WWTP).

Data provided by the Town and from a four-month (March 11 to July 9, 2024) flow monitoring effort was used to build a hydraulic model of the system with Personal Computer Stormwater Management Model (PCSWMM) software by Computational Hydraulics International (CHI).

The following summarizes the composition of this report:

- ▶ **Section 3 Model Development:** describes data sources, data gaps, processing, and methodology of building different compartments of the model.
- ▶ **Section 4 Model Calibration:** expresses the adjustment of model parameters to achieve agreement between observed conditions and model-predicted values under dry and wet weather conditions.
- ▶ **Section 5 Model Scenarios:** summarizes system deficiencies identified in a 2-year, 5-year, and 10-year, 24-hour design storm event under rainfall events during the monitoring period.
- ▶ **Section 6 Conclusions and Recommendations:** discusses model results and recommendations to improve model reliability for prioritizing capital improvements.

Model results are also presented on figures and tables in the report appendices. In addition, the output results have been exported to a Geographic Information System (GIS) format and provided alongside this report in the form of shapefiles containing the above information.



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Sewer System Pipe Diameters



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**PS** Pump Station  
— Lines Not Owned by SP

Gravity Main Diameter	Force Main Diameter
4 - 6	1.25 - 2.5
8	3 - 4
10 - 12	6 - 8
16 - 18	10 - 12
24 - 27	14 - 18
30 - 36	
42 - 48	
Unknown	

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Path: K:\22\22-0440\220447.01-Southern Pines Sewer AIA Engineering\Geomatics\GIS\Data\Model Builder Maps\Southern Pines Model Builder Maps.aprx | 7/25/2025 | eareth | Data Source:

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EST. 1983

## 3 Model Development

The development process began by utilizing the Town's existing electronic GIS database for its sanitary sewer collections system. The model represents a near one-to-one relationship to relevant assets such as gravity sewer mains, manholes, lift stations, and force mains.

### 3.1 Software

PCSWMM was selected as the modeling software to characterize the Town's collections system. PCSWMM utilizes the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM) computational engine. This software allows for fully dynamic rainfall-runoff simulations over a range of single-event or long-term conditions.

### 3.2 Model Network

The first step of the PCSWMM model development process is attribution, which is adapting the physical characteristics of the system into representative links and nodes. GIS datasets provided by the Town, and refined as part of the larger AIA, included the horizontal location of system sewer mains, force mains, manholes, and pump stations. GIS of Moore County and the Town of Aberdeen were used as-is for model connectivity. Portions of the GIS data included additional information needed to characterize the hydraulic model network, such as rim and invert elevation data and pipe diameter.

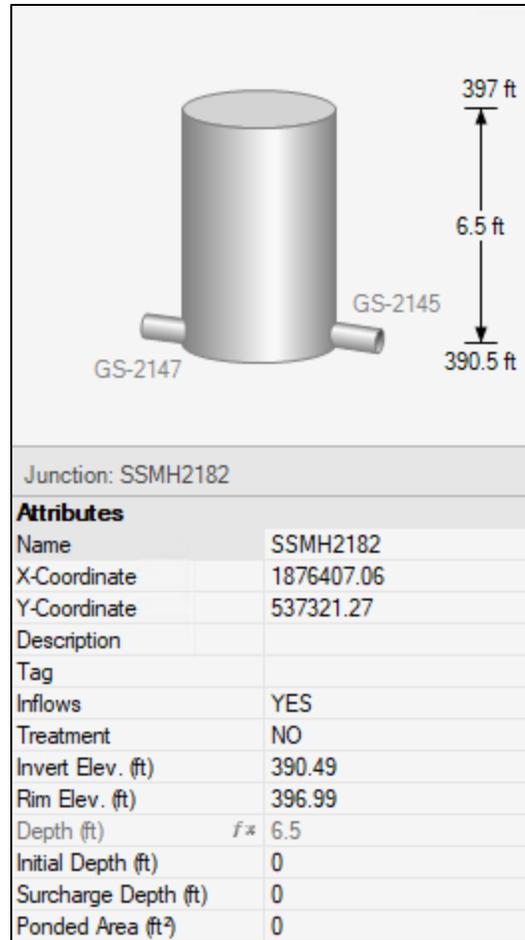
Once network connectivity was achieved using GIS tools, the features were imported into PCSWMM to create the model network. Elevation datasets from GIS were all reviewed and missing data were estimated based on the North American Vertical Datum of 1988 (NAVD88). The following sections describe the model network components of nodes and links which represent the physical sanitary sewer system.

#### 3.2.1 Node

Model nodes form the connection points between links such that flows can be conveyed throughout a system. This subsection details the three types of nodes for a sanitary sewer model.

##### 3.2.1.1 Junctions

Connecting junctions represent manholes and are where external inflows are loaded to enter the system for conveyance. Excess water at junctions will cause partially pressurized conditions when connecting links are surcharged, and model settings can either allow the water to be lost from the system or be allowed to pond on top and drain back into the junction. Figure 2 demonstrates an example of a manhole junction, where required fields are name, coordinates, and rim and invert elevations. Supplemental attributes, when available, can account for structure shape and size (otherwise standard manhole size is assumed) or indicate if the cover is bolted, which prevents the model junction from experiencing an SSO when surcharged beyond the manhole depth.



**Figure 2. Example of a manhole represented as a model junction**

The Town's sewer system includes 3,902 active manholes.

Where manhole elevation data needed updating from the GIS dataset, rims were assigned elevations based on the following methodology:

- ▶ Interpolation between known upstream and downstream elevations
- ▶ Available 2-foot Light Detection and Ranging (LiDAR) contour data

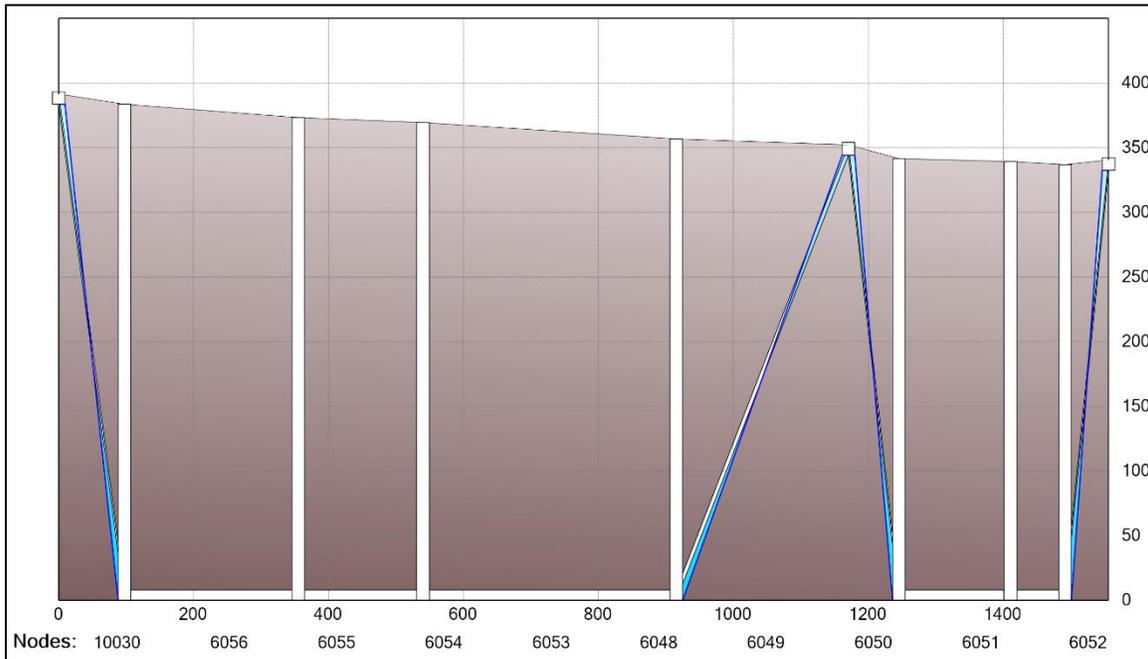
All manholes from Aberdeen and Moore County systems included both rim and invert elevations and did not require estimation or interpolation.

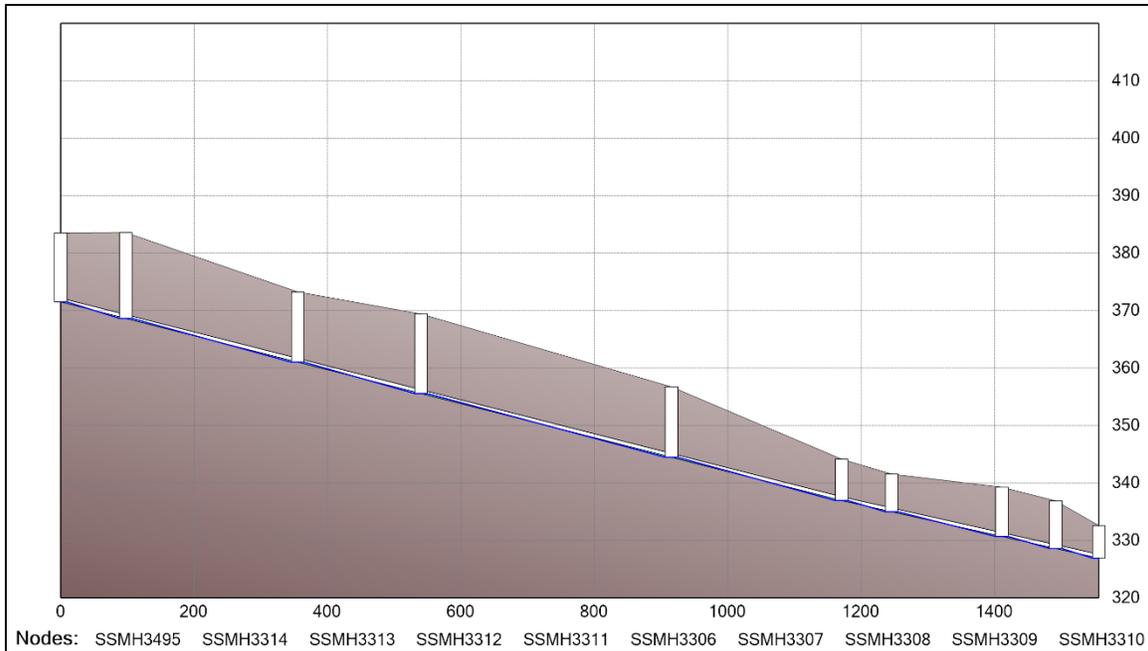
As data was added to the system, manhole features were flagged according to the system shown in Table 1. In some cases, to resolve inconsistencies or improve model accuracy, the original data source was modified and labeled with the suffix "Adj" (Adjusted). These adjustments were made based on engineering judgment. For example, GS-Adj indicates that GIS-provided elevations were adjusted to better reflect surrounding terrain or pipe slopes, while SV\_WR\_Adj refers to minor corrections applied to survey data collected by WithersRavenel.

**Table 1. Data flag naming convention and percentages of data flags used among all model junctions within the Town sewer system**

Data Flag	Description / Source	Invert Elevation Data Source	Rim Elevation Data Source
GIS	Data from Existing GIS Attributes	71.8%	70.0%
RD	Record or As-Built Drawings	3.4%	1.7%
GS-Adj	Data adjusted from Existing GIS Attributes	1.0%	0.0%
ES	Inferred or Estimated Values	10.9%	0.0%
SV_WR	Surveyed by WithersRavenel (WR)	11.3%	11.5%
SV_WR_Adj	Data adjusted from Surveyed by WithersRavenel (WR)	0.3%	0.2%
LD	LiDAR data	0.0%	14.2%
LD_Adj	Data adjusted from LiDAR Attributes	0.0%	0.9%
CCTV	Closed-Circuit Television	1.3%	1.5%

Figure 3 provides an example of a sewer profile with missing manhole rim and invert elevations and a polished version with estimated values. Sewer models require specific slope conditions to enable gravity flow. Therefore, any missing or inaccurate elevation data must be filled in with expected values. The model can be refined in the future as updated input data becomes available.





**Figure 3. Example of a profile missing manhole invert and rim elevations (top) and corrections (bottom) for hydraulic continuity**

### 3.2.1.2 Storages

Storage elements are nodes which account for volume, which are either defined by a function or table of surface area versus height. In a sanitary system, these nodes represent wet wells.

To determine wet well dimensions, rim elevations, and invert elevations for the twenty (20) active public pump stations, WR used the available drawings provided by the Town and Moore County. Where rim or invert information was missing or unrealistic, estimations were made using the same method as junction elevation estimations. The wet well dimensions were entered as a constant area under a “Tabular” function from the Storage Curve for each storage node. Figure 4 shows the required elements of a storage node, including name, coordinates, rim and invert elevations, and storage volume characteristics.

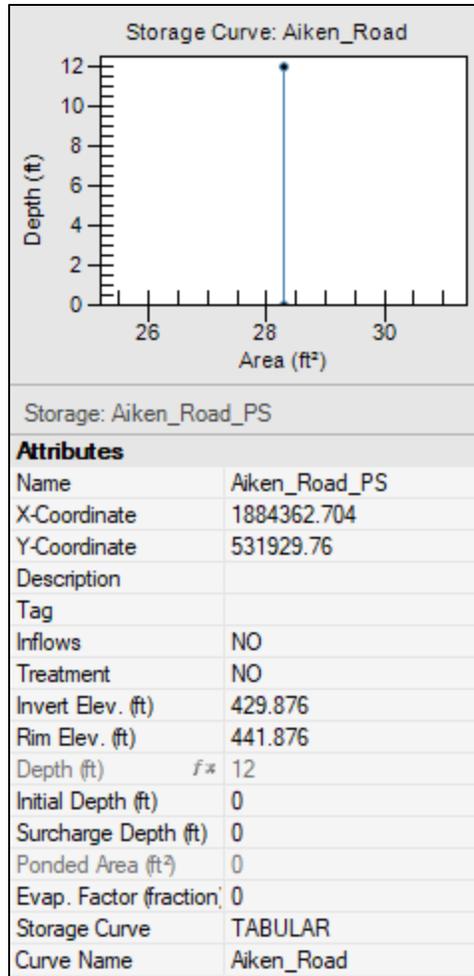


Figure 4. Example of a wet well represented as a storage element

### 3.2.1.3 Outfalls

Outfalls represent the final discharge points of a sewer system. Although the Town's system does not have its own outfall, its flow is conveyed to the Moore County WWTP. Therefore, in this model, the outfall is defined as the Moore County WWTP. The model is calibrated to discharge into a "free" discharge condition at the WWTP. Model results downstream of the Town's system before this outfall do not reflect inclusion of other municipal flows tributary to this WWTP.

## 3.2.2 Links

Model links connect the nodes discussed above and fall into three main categories: conduits, pumps, and flow regulators (e.g., orifices, weirs, or outlets). The following subsections will detail the model links.

### 3.2.2.1 Conduits

Conduits convey water between nodes in the sewer system, either as gravity flow or via pressure from pumps for force mains. Required fields are IDs for the pipe itself, upstream and downstream

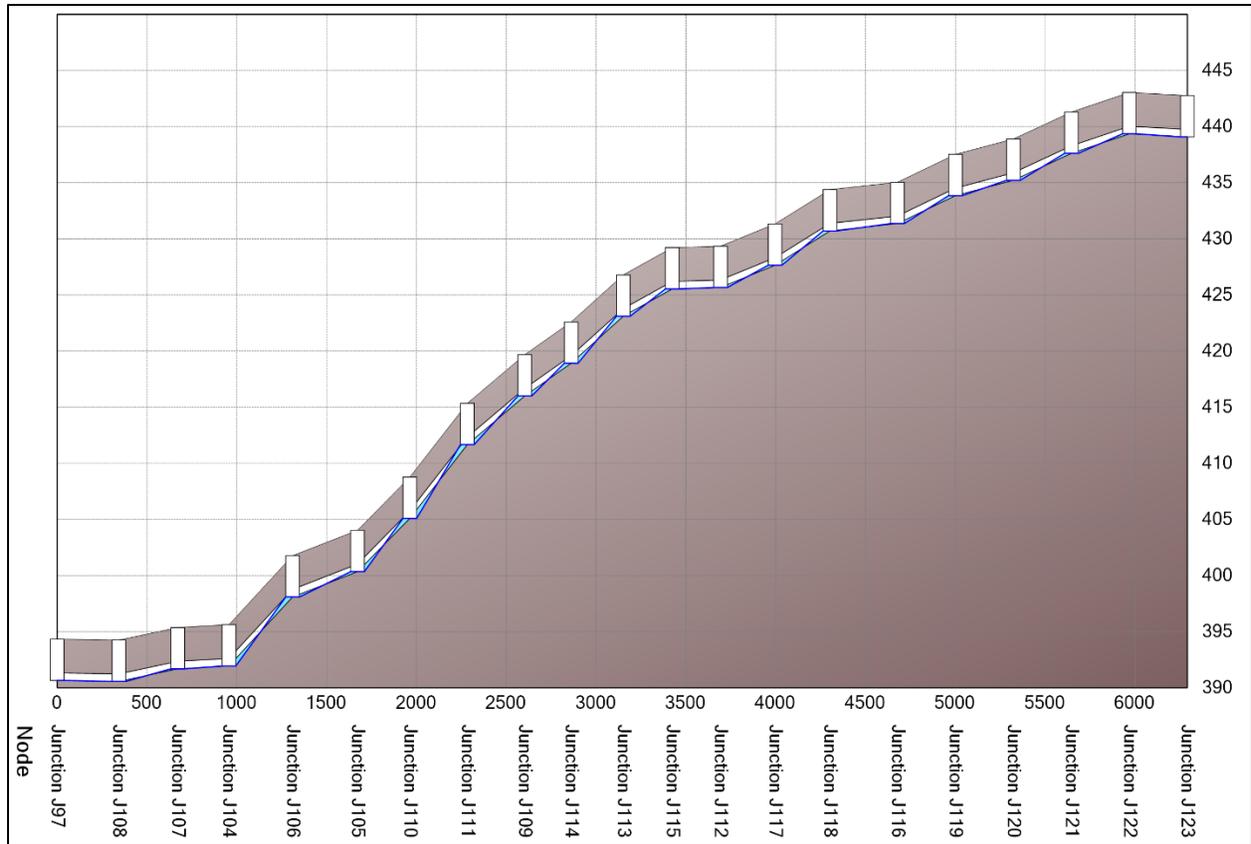
nodes, as well as diameter, length, material, and upstream and downstream inverts. Where GIS dataset invert elevations were not available or were unrealistic, they were extracted from connecting manhole inverts which were based on GIS data or estimated using the method described in Section 2.1.1.1 Junctions. Pipe inlet and outlet offsets improve model accuracy by enabling more realistic slope calculations and energy losses at junctions, so where invert data was estimated the model results may not reflect actual flow conditions.

The Town's sewer system that was included in the model comprises of 3,907 gravity pipes and 210 force main pipes. The total length of the gravity pipes is 151 miles, while the total length of the force main pipes is approximately 12 miles. Detailed information on the gravity pipes, including diameter, length, and slope, in the context of North Carolina Minimum Design Criteria (MDC) is presented in Table 2. The table indicates approximately 7.53% of the pipes in the model have slopes below the minimum standard requirement. However, it should be noted that these calculations depend on accurate invert elevations of upstream and downstream manholes.

**Table 2. Summary of modeled gravity pipes by diameter and slope for diameters with current design criteria**

Diameter (inch)	Number of Pipe	Length (ft)	Length (%)	Minimum Slope (ft/100ft)	Pipes below Minimum Slope		
					Pipes	Length (ft)	Length (%)
4	3	708	0.1	0.8	1	248	0.03
6	233	50,504	6.3	0.6	24	6,548	0.8
8	3,403	688,595	86.5	0.4	216	46,931	5.9
10	100	22,742	2.9	0.28	9	1,987	0.25
12	130	26,180	3.3	0.22	15	3,285	0.4
16	2	483	0.06	0.14	0	0	0.0
18	28	6,843	0.9	0.12	3	785	0.01
24	3	438	0.06	0.08	1	192	0.02
<b>Total</b>	<b>3,902</b>	<b>796,493</b>	<b>100</b>		<b>269</b>	<b>59,975</b>	<b>7.53</b>

Because the vertical profile of force mains was not available digitally, the force main profile was estimated using a digital elevation model (DEM) derived from LiDAR data, in accordance with the NCDEQ Minimum Design Criteria for the Permitting of Lift Stations and the Recommended Standards for Wastewater Facilities (10 States Standards). First, dummy junctions were added at major elevations or depressions, before and after streams, at angles, or after 200-300 ft of pipe. Then, the junctions invert elevation was set to have the crown of force mains three (3) ft below the ground surface. The modified vertical profile of a force main is shown in Figure 5 as an example.



**Figure 5. Force main vertical profile for Belle Meade PS**

**3.2.2.2 Pumps**

Pumps are represented as links with head-discharge curves, which in combination with the model elements discussed above, form a model lift station. Influent sewer links connect to the storage wet well, which is then drained by the pump element, and then finally pumped through the force main link as seen in Figure 6.

The existing pump design curves were compiled from a combination of data sources, including as-built drawings, pump information provided by the Town, and records from pump suppliers. For the Moore County pump station, the model parameters were provided by Moore County. Twenty-three (23) pump curves were created from this data, while three (3) pump curves were modified to match the drawdown test results. This data includes the pumping rate for each pump as well as the station pumping rate while both pumps are in operation. An example of a pump curve is presented in Figure 7.

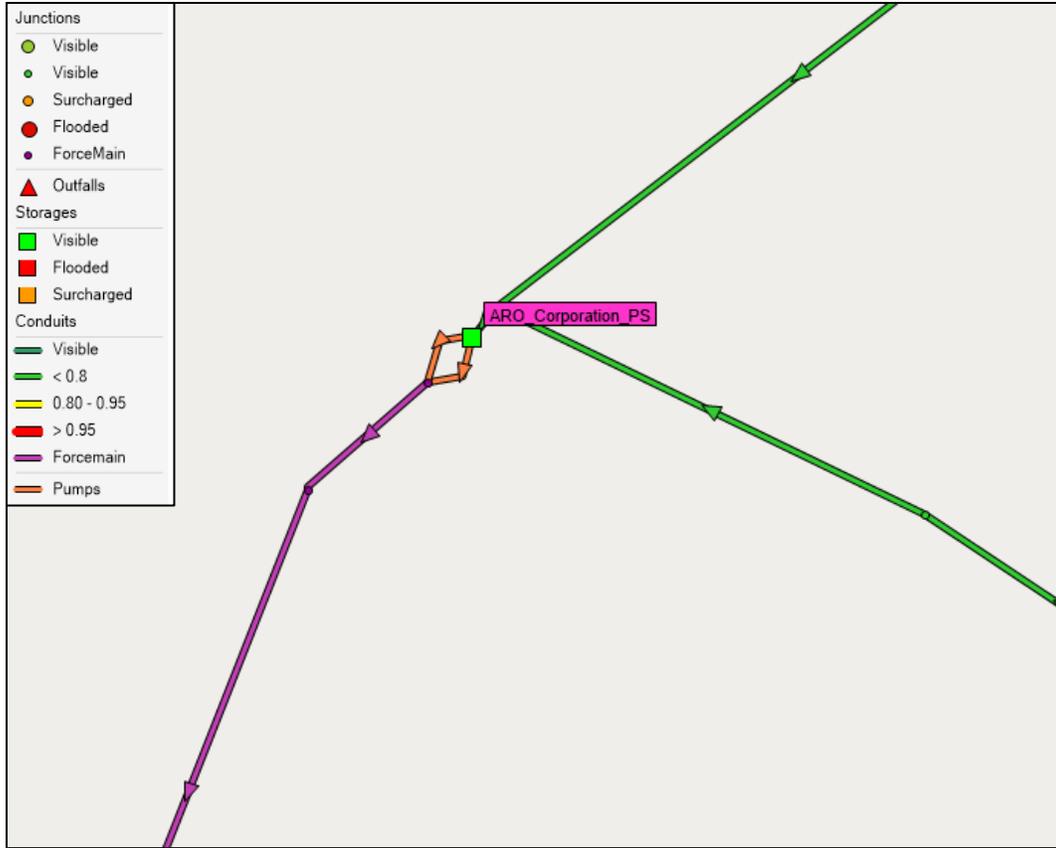


Figure 6. Example pump station show by influent sewer (green), wet well (light green), pump links (orange), and outgoing force main (pink)

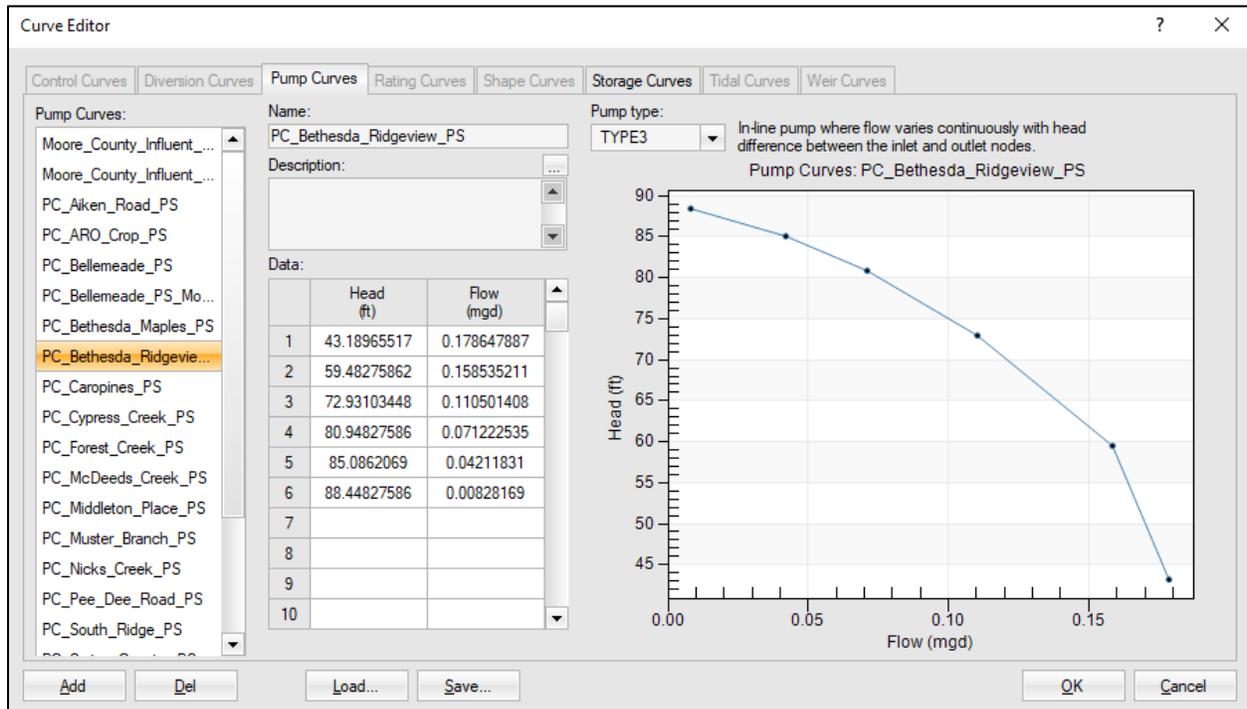


Figure 7. Example pump curve for Bethesda Ridgeview PS

## 4 Model Calibration

A critical aspect of model development is calibration, which is the adjustment of model parameters to achieve agreement between observed conditions and model-predicted values for the same study period as the observed data. A calibrated model serves as a predictive tool for characterizing the collection system under various scenarios and conditions.

### 4.1 Flow and Rain Monitoring

For a sewer system, wastewater flow and rain data can be used for several purposes including but not limited to (i) quantifying dry weather flow pattern and groundwater (GW) infiltration rate, (ii) estimating rainfall-derived inflow and infiltration (RDII) volumes, and (iii) obtaining data necessary for hydrologic model calibration. Temporary flow and rainfall monitoring was conducted by ADS between March 11 and July 9, 2024, using five (5) flow meters, six (6) level sensors, and one (1) rain gauge. Table 3 shows the meter names, manhole IDs, and addresses at which they were installed.

**Table 3. Manhole IDs and locations for 2024 meters and rain gauges, where numbered gages represent flow meters and letters represent level sensors**

Meter/Gauge ID	FACILITYID	Site Address
SPFM-01	SSMH-2638	Behind 330 Warrior Woods Rd
SPFM-02	SSMH-2214	Southwest of pond on golf course at Central Dr and Midland Rd
SPFM-03	SSMH-3615	Intersection of Yadkin Rd and Short Rd
SPFM-04	SSMH-1001	715 Midland Rd; Moore County Pump Station #4
SPFM-05	SSMH-1058	225 SE Service; easement
SPLM-A	SSMH-4791	Greenway trail adjacent (35.251567, -79.411264)
SPLM-AA	SSMH-4801	7165 NC-Hwy 22; Nicks Creek Pump Station
SPLM-B	SSMH-2649	Across from 269 Warrior Woods Rd, easement
SPLM-C	SSMH-2692	134 Cherokee Dr
SPLM-F	SSMH-3396	125 Belfair Ct; easement behind house
SPLM-G	SSMH-2793	104 Plantation Dr
SPRG-01	-	South of 2953 Camp Easter Rd and end of gravel road at school entrance; McDeeds Creek Pump Station

This study also included overlapping flow data from six (6) permanent flow meters owned by Moore County. The relative locations of all flow meters, pump stations, and their connectivity are shown in Figure 8 and their spatial locations are shown in Figure 9.

Additionally, a data source known as Tempest<sup>1</sup> was used to collect historical and current rainfall data for available devices in the study area. Figure 10 displays the resulting Thiessen polygons generated from ADS and Tempest rain gauge locations. Accurate RDII analysis requires assigning rainfall data collected at individual sites to the entire basin drainage area. Several distribution methods are available, such as assigning each gauge to the nearest flow meter basin, inverse distance weighting, kriging, or spatial adjustment of radar rainfall data using ground gauge measurements. The choice of method depends on factors such as study area size, the number and spatial distribution of gauges, topographic influences on storm movement and intensity, and the level of effort required. For this study, the Thiessen polygon method was selected due to its ease of implementation in ESRI GIS tools and its ability to represent localized rainfall influence. Each Thiessen polygon defines a zone of influence around a rain gauge such that any point within the polygon is closer to that gauge than to any other.

<sup>1</sup> <https://shop.tempest.earth/products/tempest>

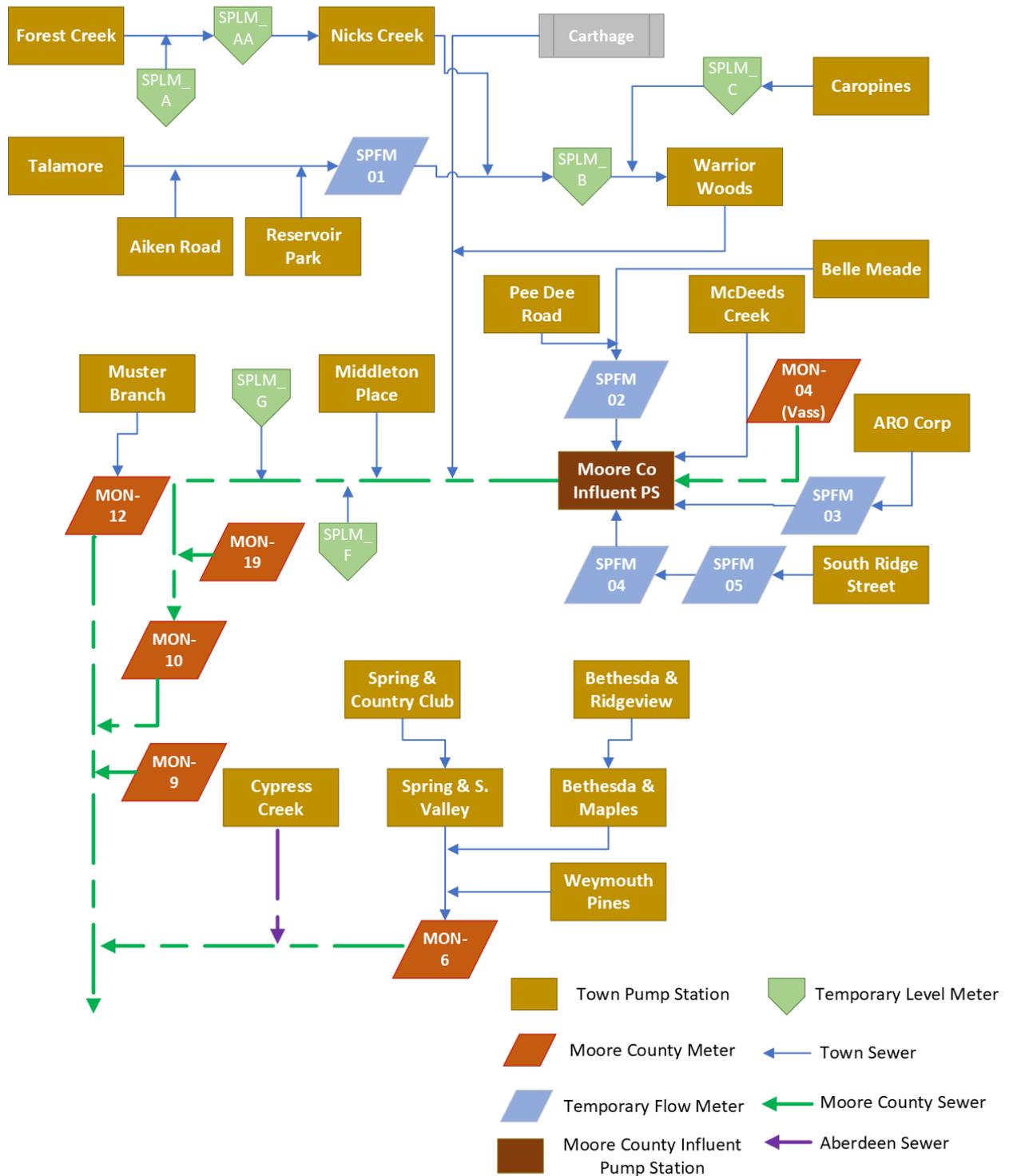
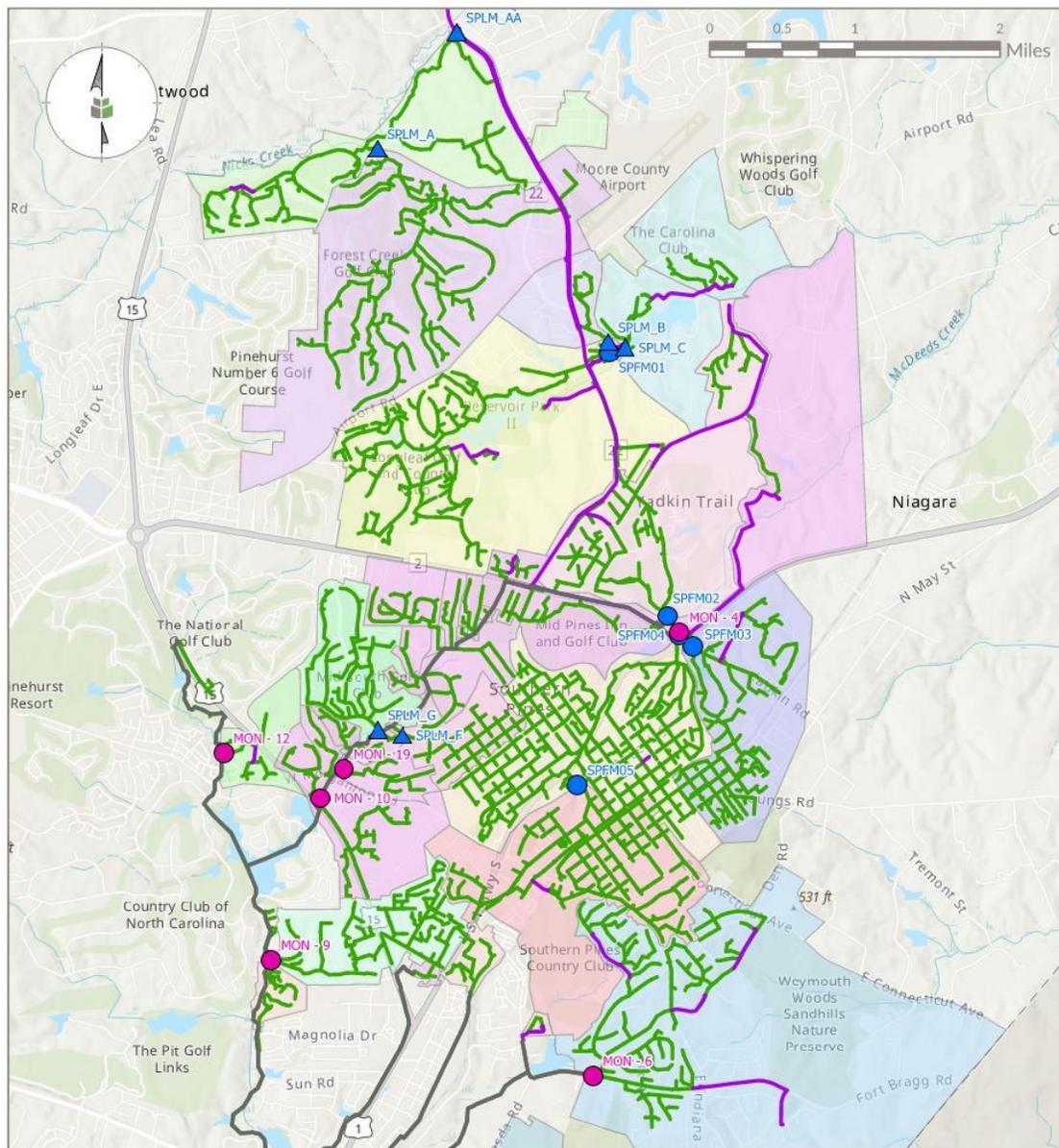


Figure 8. Flow meter, level sensor, and pump station connectivity, which demonstrates a mixture of temporary study meters and permanent Moore County meters.



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Sewer System Flow Meters

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**Legend**  
 — Gravity Main  
 — Force Main  
 — Lines Not Owned by SP

**Southern Pines Flow Meters**  
 ● Flow-Type Meter  
 ▲ Level-Type Meter

**Moore Flow Meters**  
 ● Flow-Type Meter

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

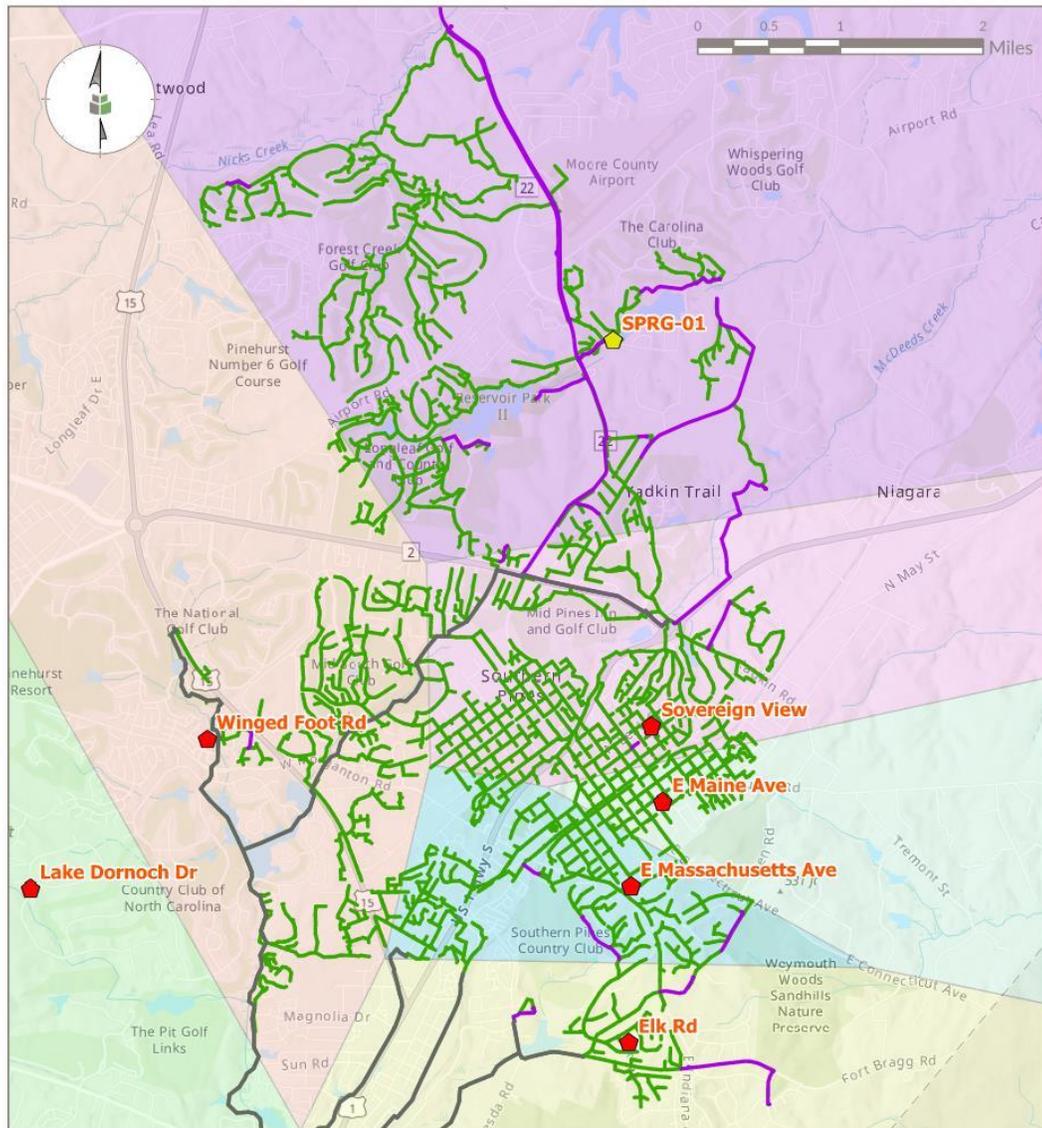
Data features are not based on professional field survey unless stated otherwise.

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**Figure 9. Flow meter locations and drainage areas for the 2024 monitoring period. Blue circles represent temporary flow meters, blue triangles indicate SP level sensors, and purple circles are Moore County flow meters**



### Town of Southern Pines, NC

ADS and Tempest Gauges with Thiessen Polygons

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

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#### Legend

Modeled Sewer Mains

- Gravity Main
- Force Main
- Lines Not Owned by SP

Rain Gauges

- Tempest Gauges
- ADS Gauges

Path: K:\22\22-0440\220447.01-Southern Pines Sewer AIA Engineering\Geomatics\GIS\Data\Model Builder Maps\Southern Pines Model Builder Maps.aprx | 7/15/2025 | areath | Data Source:

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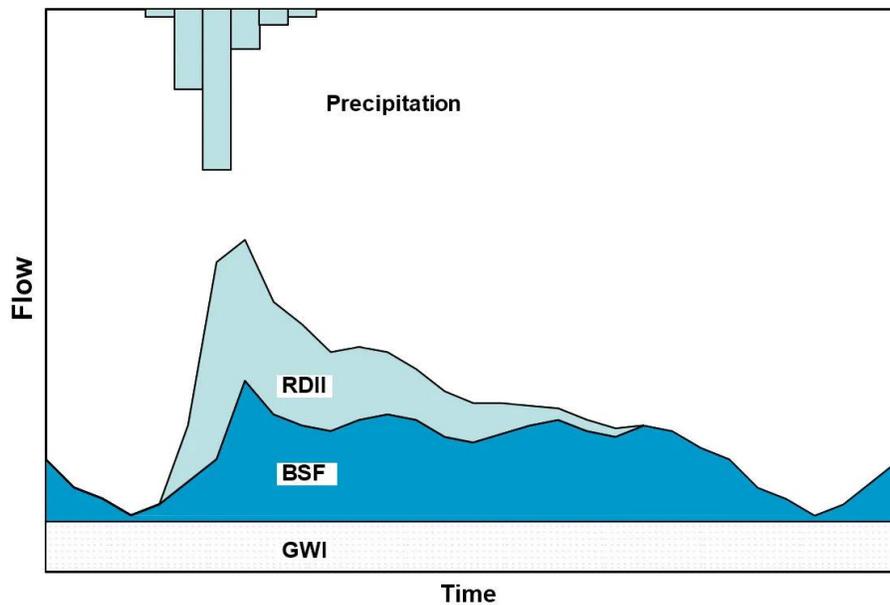
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**Figure 10. Rain gauge locations for 2024 monitoring period with Thiessen polygons to distribute rainfall over study area. Yellow shape represents the ADS rain gauge, while red shapes represent Tempest gauge**

When flow and rain data is available for calibration, the recommended methodology is a two-step process. First, using dry weather to define representative diurnal baseflow loadings and patterns, and second, defining RDII with RTK unit hydrographs. Dry and wet weather methodology is detailed in the following sub-sections.

## 4.2 Dry Weather Calibration

Dry weather flows (DWFs) are defined from time periods with no wet weather and no remaining hydrograph recession after a wet weather event. DWFs have two components: groundwater infiltration (GWI) and dry weather base sanitary flow (BSF) loadings. GWI is typically estimated at 80-90% of nightly minimum flows. This is associated with GW entering the sanitary sewer system through defects in pipes and manholes. The remaining dry weather sanitary sewer flows are due to BSF loadings (i.e., wastewater flushed into the sewer). Figure 11 shows a graphical representation of GWI, BSF, and RDII before, during, and after a rainfall event.



**Figure 11. Components of wastewater flow (EPA SWMM5, 2016)**

Using the rain gauges data, the intervals of time with no more than trace amounts of precipitation or no observable RDII response were selected. Typically, intervals were chosen such that they reflect several continuous days of dry weather flow, with clear repeating minimum flows and no significant trends and/or deviations in day-to-day averages. From meter data and for the selected dry periods, the model calculated daily, hourly, and weekend patterns to represent upstream average DWF loading and diurnal patterns of domestic, commercial, and industrial users. An example of derived hourly patterns for weekdays is shown in Figure 12.

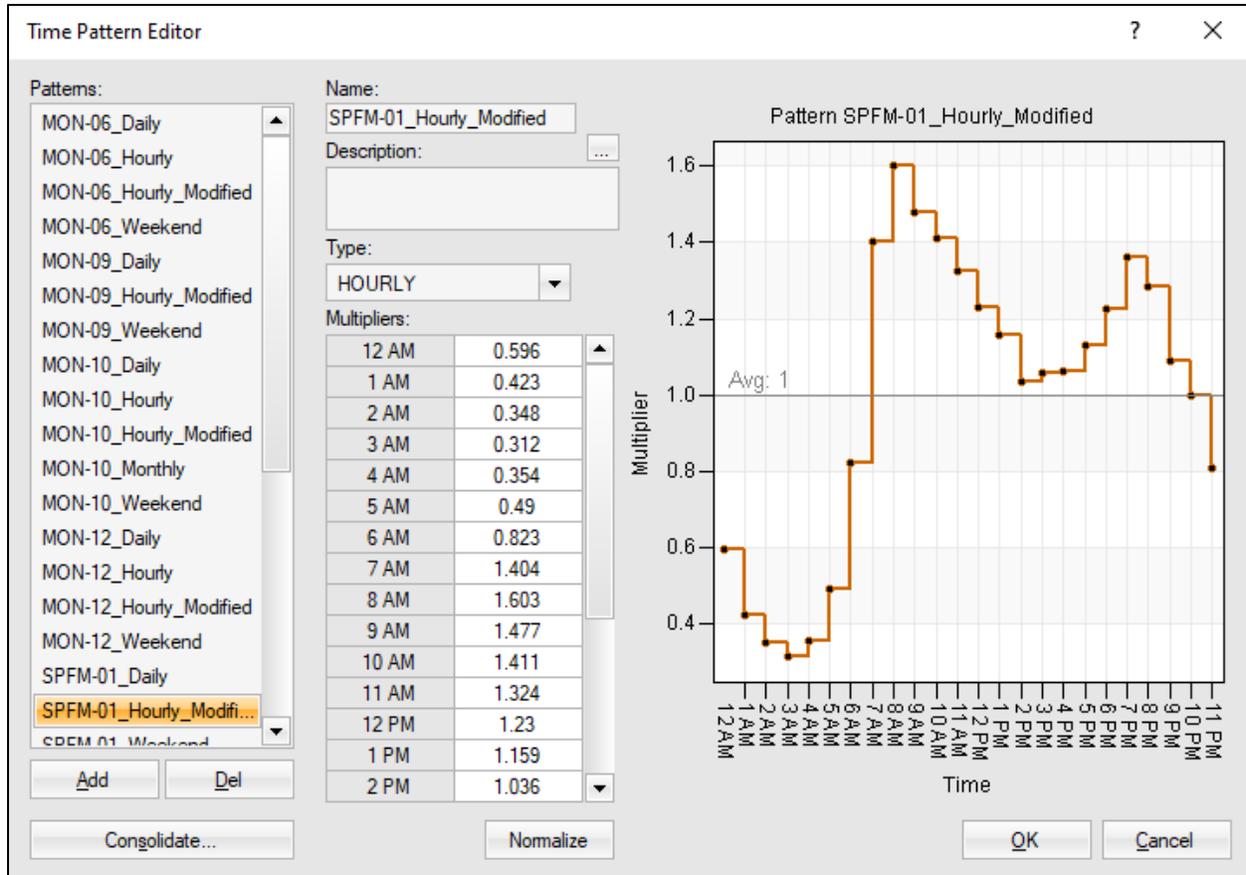


Figure 12. PCSWMM time pattern editor and example hourly pattern

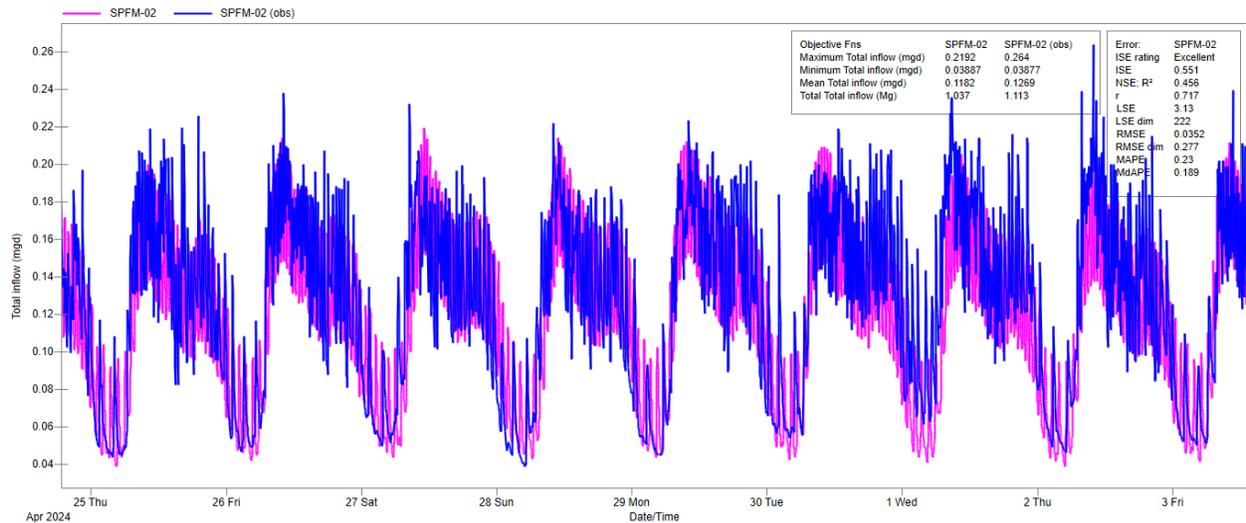
One limitation of dry weather patterns is that they reflect typical conditions derived from averaged data and may not capture irregular peaks caused by industrial discharges or upstream pump operations. To account for this, diurnal patterns were adjusted as needed to introduce artificial peaks, enabling the model to better match observed maximum flows during dry periods. After refinement, hourly, daily, and weekend dry weather patterns were assigned to each meter's corresponding upstream junctions.

Following the time pattern adjustments, average DWFs obtained from flow meters were spatially distributed across the sewer system. Each manhole within a subbasin received a share of the total DWF, based on the number of upstream sewer manholes contributing to the flow, ensuring consistent and proportional loading across the network.

Once DWF rates and time patterns were assigned to all model manholes, the model was run over the monitoring period to evaluate its accuracy in simulating observed dry weather flow. Additional calibration was performed by reviewing pump station capacities using available Supervisory Control and Data Acquisition (SCADA) runtime data. For example, the capacity of Nick's Creek Pump Station was adjusted to reflect higher runtimes observed in SCADA compared to initial model outputs. Similarly, Belle Meade Pump Station's capacity was adjusted after model runtimes underestimated actual performance. These modifications enhanced alignment between modeled results and actual pump operations.

Further validation was conducted in subbasins equipped with continuous depth monitoring. Depth data were converted to flow using Manning’s equation and compared to the model-predicted flows at the same locations. The close agreement between observed and simulated values provided independent confirmation of the model’s hydraulic accuracy under dry weather conditions.

An example of observed versus measured (SSMH0218) dry weather flow for SPFM-02 is shown in Figure 13.



**Figure 13. Modeled versus measured dry weather flow for SPFM-02. Blue line represents observed flow from the flow meter; pink line represents the modeled result**

The example scatter plots for maximums, minimums, means, and totals of model simulated DWFs versus measured DWFs for the same meters are shown in Figure 14. PCSWMM evaluates model performance using the Integral Square Error (ISE), which rates the agreement between observed and simulated flows on a scale from “poor” to “excellent.” For all basins, the ISE ratings were maintained within the “good,” “very good,” or “excellent” range across all evaluated metrics, including event total, mean, maximum, and minimum flows. For DWF, total and mean are the more important metrics to verify before proceeding to wet weather calibration.

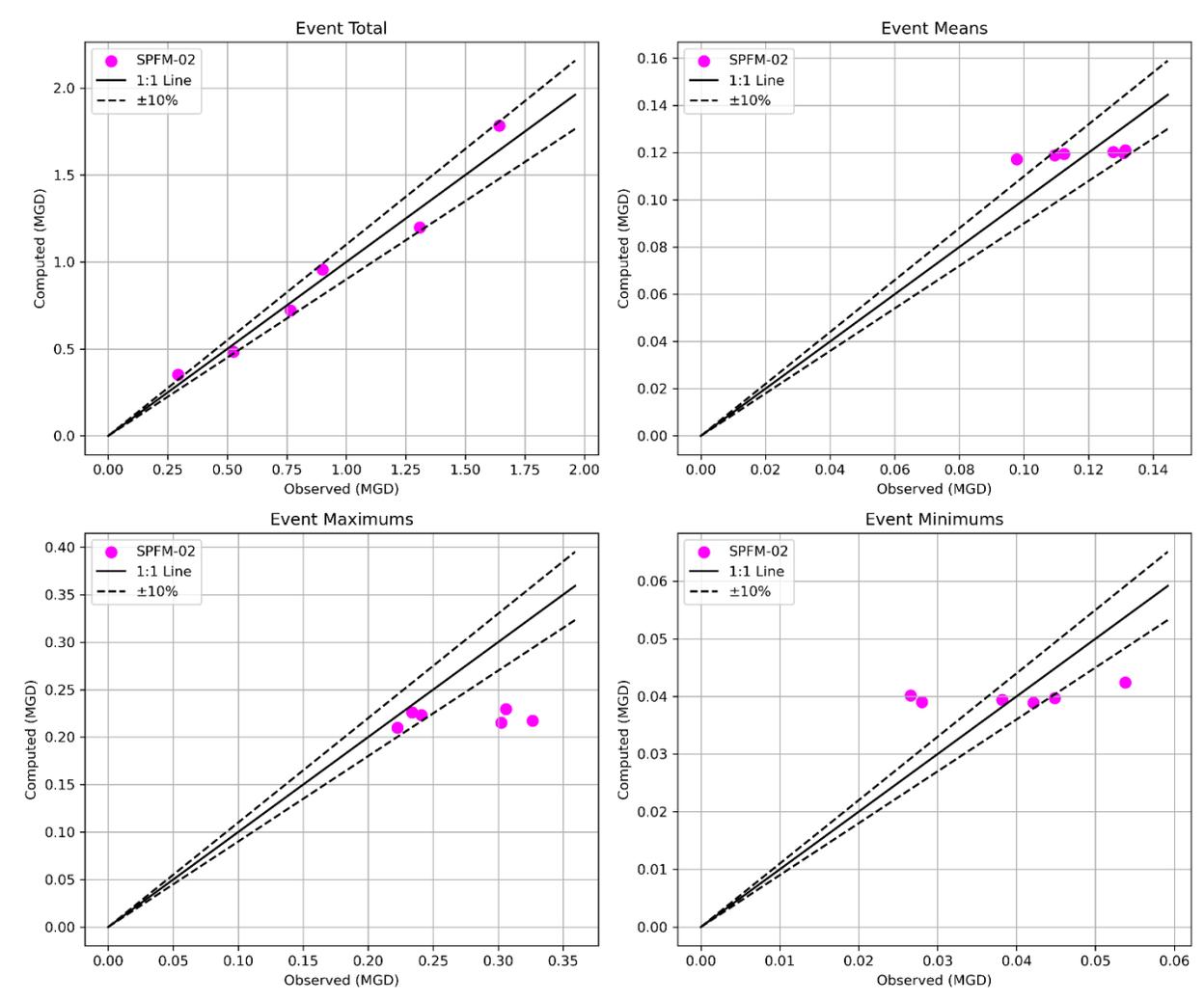


Figure 14. Dry weather calibration scatter plots for SPFM-02

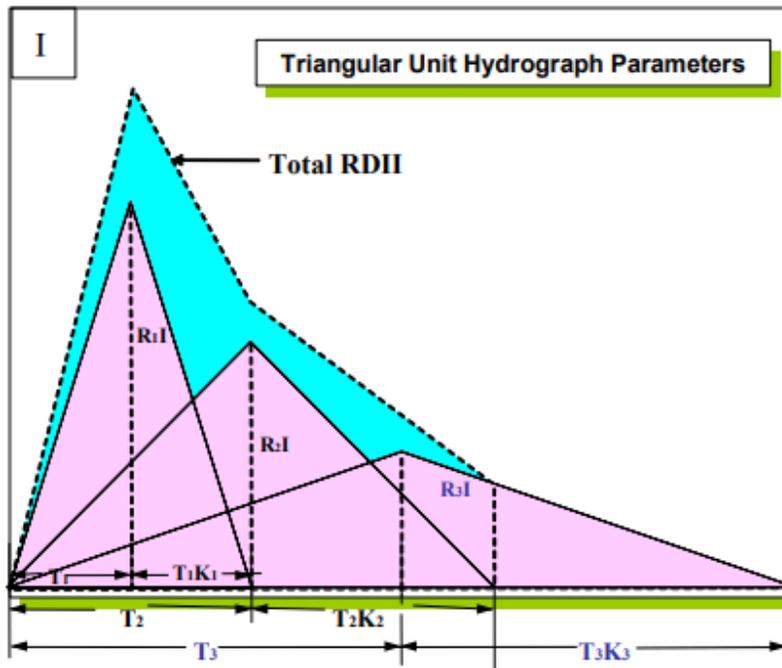
### 4.3 Wet Weather Calibration

The RTK method combines three triangular unit hydrographs which respectively represent short-term inflows, intermediate infiltration, and long-term infiltration. The RTK parameters include:

- ▶ R – fraction of precipitation that enters the collection system for that component
- ▶ T – the time from the precipitation pulse
- ▶ K – the ratio of the time to peak to time to end of hydrograph for that component

For every parameter there are three inputs representing the short-term (R1, T1, K1), medium-term (R2, T2, K2), and long-term (R3, T3, K3) rainfall responses. The sum of the three inputs for R-values (R1, R2, R3) equals the total fraction of rainfall over the sewershed that entered the sewer system. A high R1 value indicates that the RDII is primarily inflow-driven, commonly driven by direct influences such as stormwater cross-connections or roof leaders connected to the sanitary system. If more of the total R value is allocated to R2 and R3, this will indicate that the RDII is primarily infiltration driven. Intermediate and longer-term infiltration sources possibly could derive from

leaky house laterals, leaking mains, and manholes. These component hydrographs are shown in Figure 15.



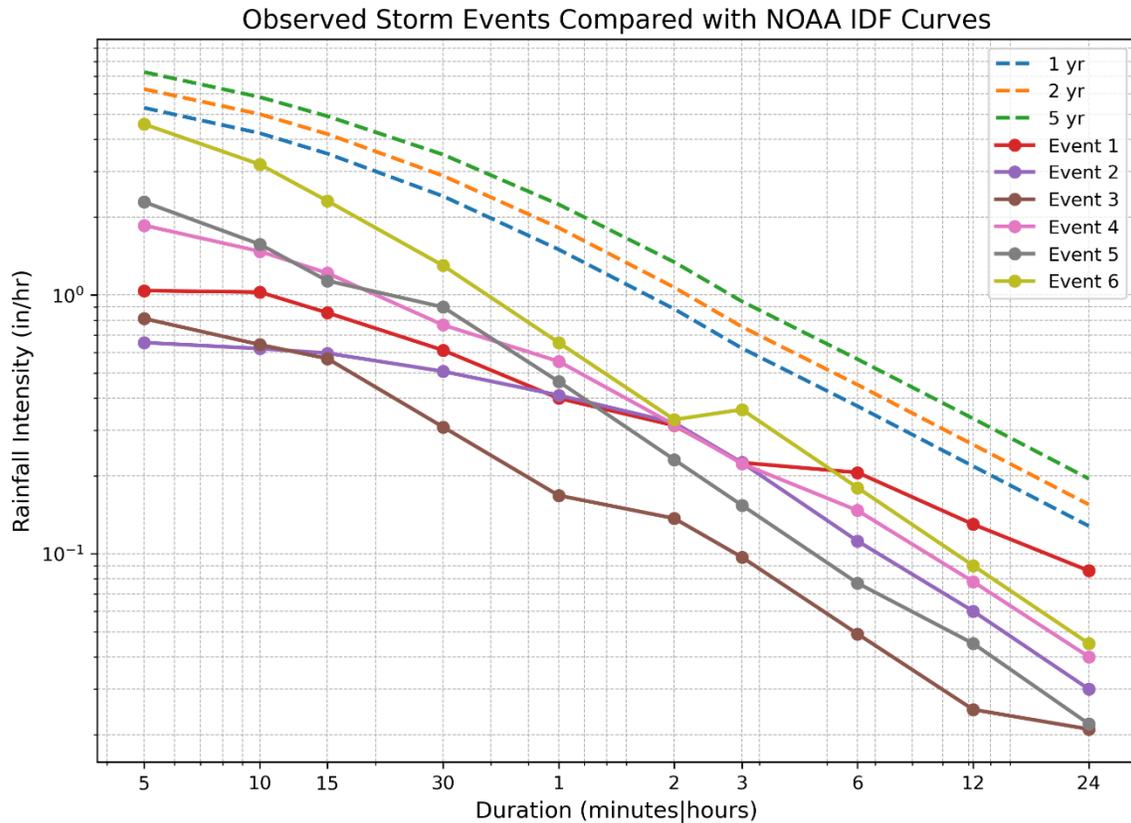
**Figure 15. RTK parameters and component hydrographs**

Wet weather events were selected using the rain gauges data and the remaining recession in flow data after the rain events. Rain gauges were used to collect data and distinguish between wet and dry events. The rain data after March 10, 2024 was used for calibration. Six (6) wet weather events were used for calibration, ranging from 0.58 inches to 2.88 inches rainfall, to capture a variety of rainfall depths, intensities, durations, and corresponding recurrence intervals (Table 4).

Although based on the National Oceanic and Atmospheric Administration (NOAA) Intensity-Duration-Frequency (IDF) curves all six events used to calibrate the model fell below even the 1-year return period storm (Figure 16). This indicates that the calibration represents relatively minor rainfall events compared to NOAA-defined design storms.

**Table 4. Summary of wet weather events used for calibration**

Event Date	Duration (h)	Rain Intensity (in)
3/27/2024	72	2.88
4/3/2024	72	0.70
4/19/2024	72	1.03
5/14/2024	144	2.14
5/26/2024	72	0.58
6/30/2024	48	1.10



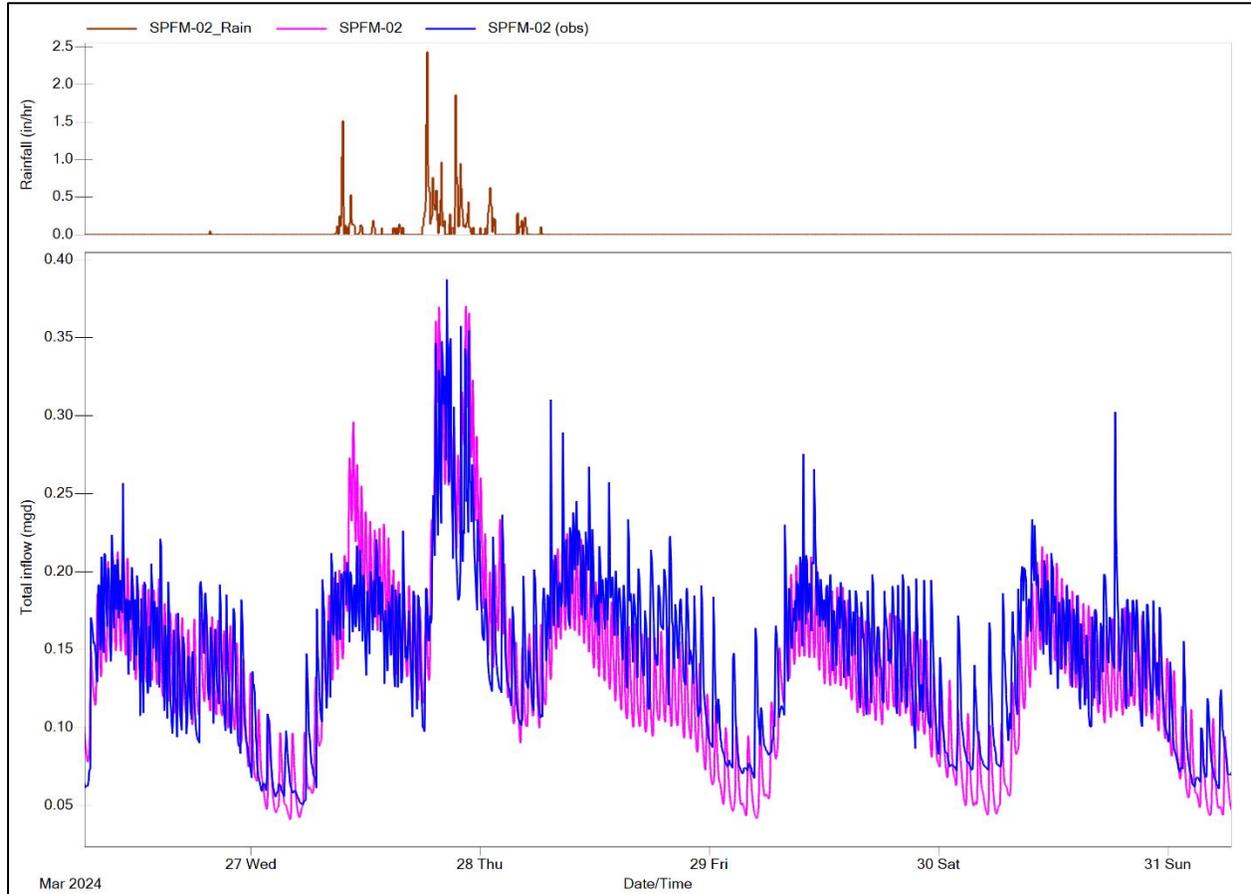
**Figure 16. Comparison of observed wet weather calibration events with NOAA Intensity-Duration-Frequency (IDF) curves**

Defining RDII volume (i.e., the value that represents only the wet weather response) from rainfall depths first requires calculating sewershed area, which for this system was assumed as a 50-ft buffer around each length of gravity sewer pipe. This buffer distance represents the median distance of buildings from the collection system, and therefore length of sewer laterals. Subsequently, the sewershed area for each manhole within a subbasin was calculated by dividing the total area of the subbasin by the total number of upstream manholes. This method assumes that all manholes within a subbasin have an equal sewershed area. For the small unmetered regions, the RTK values and area of nearby sewersheds were used.

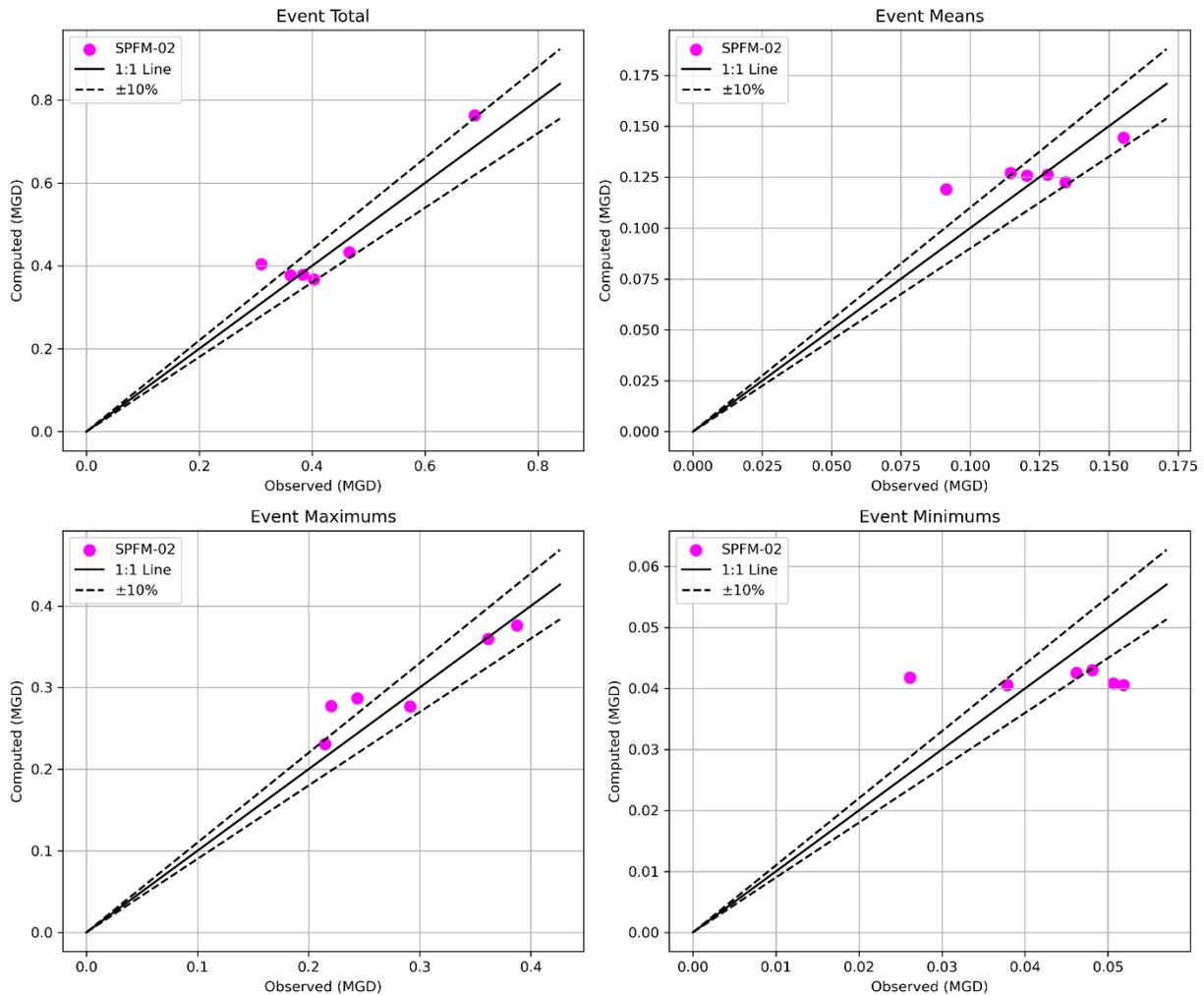
The total RDII volume is calculated by subtracting out the dry weather volume for each event period. The percentage of event rainfall which enters the sanitary system, known as the R-value, is then determined by dividing the calculated RDII volume by the total volume of rainfall. These R-values are calculated for every distinct sewershed. The calculated R-values alongside the typical values for T and K parameters were assigned to the manholes.

The Sensitivity-based Radio Tuning Calibration (SRTC) tool was used to calibrate the model for each sewershed against observed data by changing the assigned nine (9) RTK parameters. This iterative effort was performed until the model suitably predicted magnitude and timing of peak flows, along with overall hydrograph shape. Unlike dry weather calibration, event maximums were

given higher priority to predict peak flows from RDII. A representative hydrograph comparing observed and simulated wet weather flows at SPFM-02 is shown in Figure 17. Figure 18 provides example scatter plots showing the relationship between model-simulated and observed wet weather flow statistics, including maximums, minimums, means, and totals.



**Figure 17. Example of observed versus modeled flow after rainfall for SPFM-02. The blue line represents observed flow from the flow meter, the pink line shows the modeled result, and the brown line indicates rainfall data**



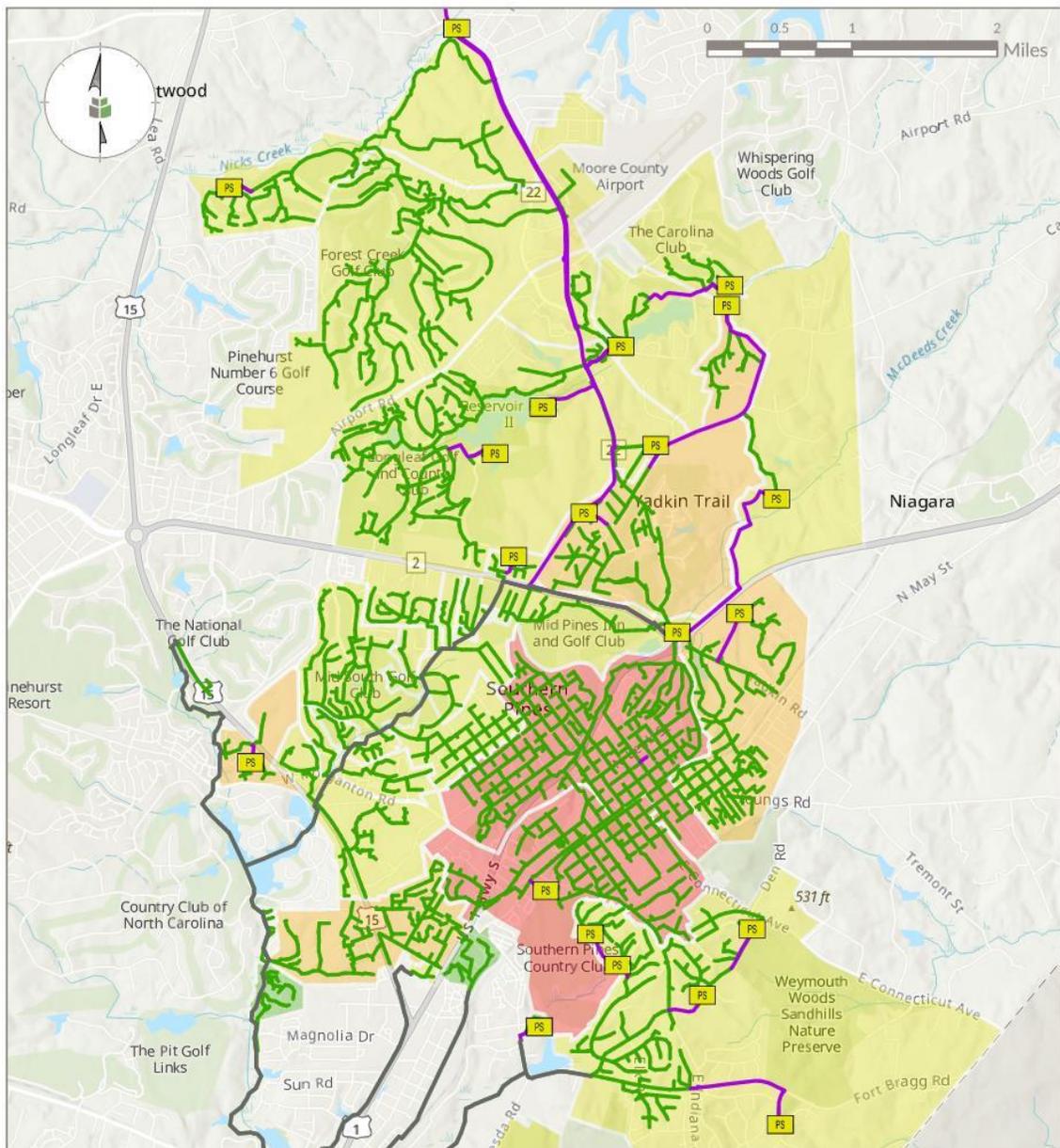
**Figure 18. Wet weather calibration scatter plots for SPFM-02**

All calibrated RTK parameters for each basin, except for MON-19, along with corresponding sewershed areas and dry weather flows are summarized in Table 5. Figure 19 also displays the calibrated total R-value for each flow meter basin.

Basin MON-19 was not included in the calibration due to inaccurately calculated flow data during the data collection period, per correspondence with the County. As a result, it was not evaluated separately and was instead considered part of MON-10, since it discharges into that basin. It should also be noted that meter MON-04 represents the Town of Vass flow. This flow was added directly to the Moore County Pump Station wet well, as it directly discharges to the pump station.

**Table 5. Sewershed area, net average dry-weather flow, net number of manholes, and calibrated RTK parameters for flow meters**

Meter ID	Sewershed Area (ac)	Net Avg DWF (MGD)	Total R Value (%)	Short-Term			Medium-Term			Long-Term		
				R (%)	T (h)	K	R (%)	T (h)	K	R (%)	T (h)	K
SPFM-01	173.19	0.0903	0.55	0.0030	1	1.5	0.0015	3	3	0.0010	5.5	5
SPFM-02	97.21	0.1190	1.10	0.004	0.5	1	0.004	2	2	0.003	5	3
SPFM-03	125.91	0.0712	1.30	0.006	0.7	1.7	0.004	2.2	2.8	0.003	5.5	5
SPFM-04	290.26	0.4310	2.50	0.015	0.5	2	0.006	1.8	3.3	0.004	5	7
SPFM-05	171.61	0.1500	2.20	0.01	0.5	1.9	0.006	2	3	0.006	4.5	7.3
MON-04 (Vass)	-	0.0767	0.11	0.00001	2	2	0.0001	5	3	0.001	10	7
MON-06	153.50	0.1260	0.55	0.0015	0.5	1	0.002	2	2	0.002	5	3
MON-09	92.62	0.1820	1.90	0.009	0.6	1	0.006	1.5	2.6	0.004	4.7	3.5
MON-10	618.00	0.4675	0.80	0.0015	0.5	2	0.003	2	3	0.004	5	7
MON-12	35.60	0.0437	1.30	0.0055	0.5	1	0.005	2	2	0.003	5	3



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**Town of Southern Pines, NC**  
Sewer System Flow Meter Sub-Basin with sum of R-Values

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.

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- Legend**
- PS Modeled Pump Stations
  - Gravity Main
  - Force Main
  - Lines Not Owned by SP

- Flow Meter Sub-Basin by R Value**
- 0%
  - 0% - 1%
  - 1% - 2%
  - 2% - 3%

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**Figure 19. Calibrated total R-values per flow meter basin**

The hydraulic model has been rigorously calibrated and validated using data from ten (10) flow meters, six (6) level sensors, and other available input sources. The robust calibration and validation process makes the model well-prepared for subsequent analysis. The next section will detail design storm simulations and predict sewer system responses such as surcharging or flooding.

While the calibrated model demonstrates agreement with observed flows under both dry and wet weather conditions, it is crucial to acknowledge the limitations of the relatively short monitoring period of approximately four (4) months. This timeframe may not fully capture the diverse hydrological conditions typically experienced in the Town throughout the year.

Looking forward, continuous validation and potential updates are recommended to improve the model's accuracy and applicability as new data becomes available and as it is utilized for various operational and planning purposes.

## 5 Model Scenarios

### 5.1 Design Storm Events

Regulatory agencies and local governments recommend using the design storm methodology to provide a standardized and uniform assessment of system behavior and resulting recommended improvements. For North Carolina, the Soil Conservation Service (SCS) Type II rainfall distribution is recommended.

Three design scenarios were simulated for this project: two (2)-year, five (5)-year, and ten (10)-year, each with a twenty-four (24)-hour rainfall event. These scenarios represent rainfall events with a 24-hour duration and reoccurrence intervals of once every 2, 5, and 10 years, respectively. Rainfall depth data, per NOAA Precipitation Frequency Data Server, indicated depths of 3.73 inches for the 2-year event, 4.70 inches for the 5-year event, and 5.46 inches for the 10-year event. Using these values and considering the Rainfall Type II distribution for the project area, three design rainfall events were generated with PCSWMM. The 2-year and 24-hour rainfall event is depicted in Figure 20.

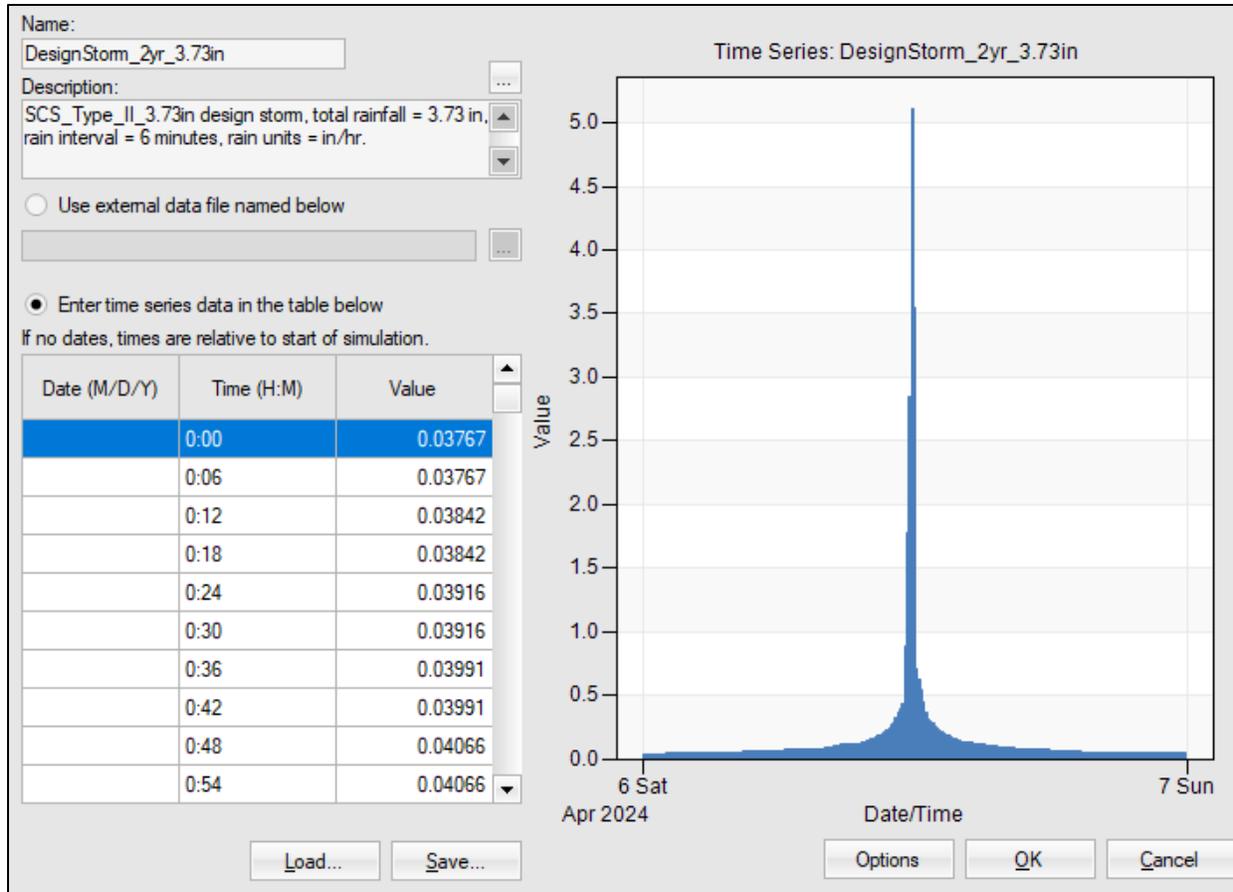
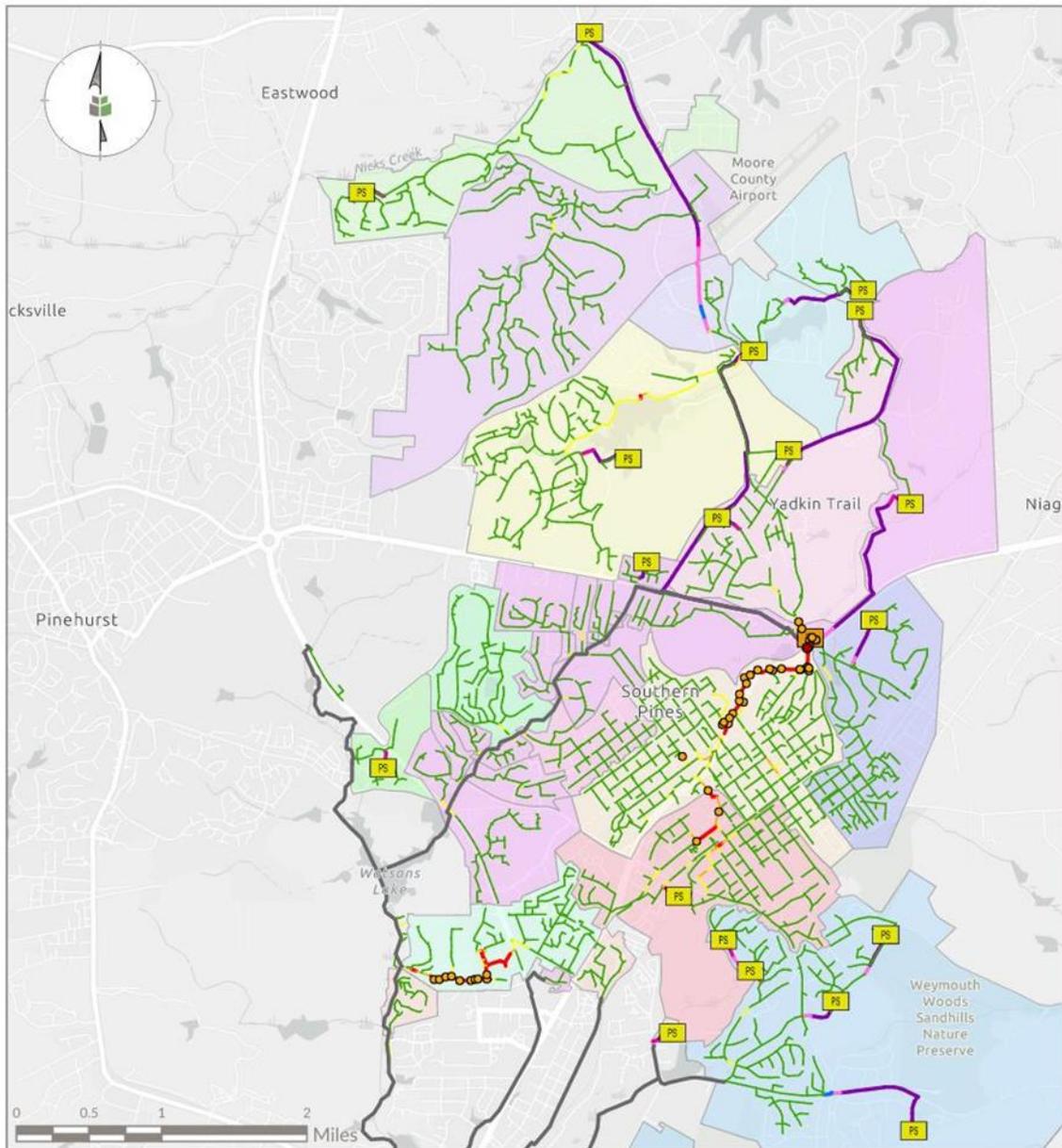


Figure 20. 2-year and 24-hour design rainfall event using SCS type II method

## 5.2 Analysis of Design Storm Event Results

The calibrated and validated PCSWMM model of the sewer system for the Town of Southern Pines was utilized to simulate three design rainfall scenarios: 2-year, 5-year, and 10-year, each with a 24-hour duration. These simulations aimed to evaluate the system’s performance under varying intensities of rainfall events and identify potential areas of concern within the sewer network. The simulation run time was three (3) days to capture the effects of the 24-hour rainfall events, including the two (2) days following the end of the rainfall. The maps of system hydraulic conditions after 2-year, 5-year, and 10-year design rainfall events are shown in Figure 21, Figure 22, and Figure 23. The following sections provide a detailed analysis of the results obtained from these simulations.



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**Town of Southern Pines, NC**  
2 Year Design Storm

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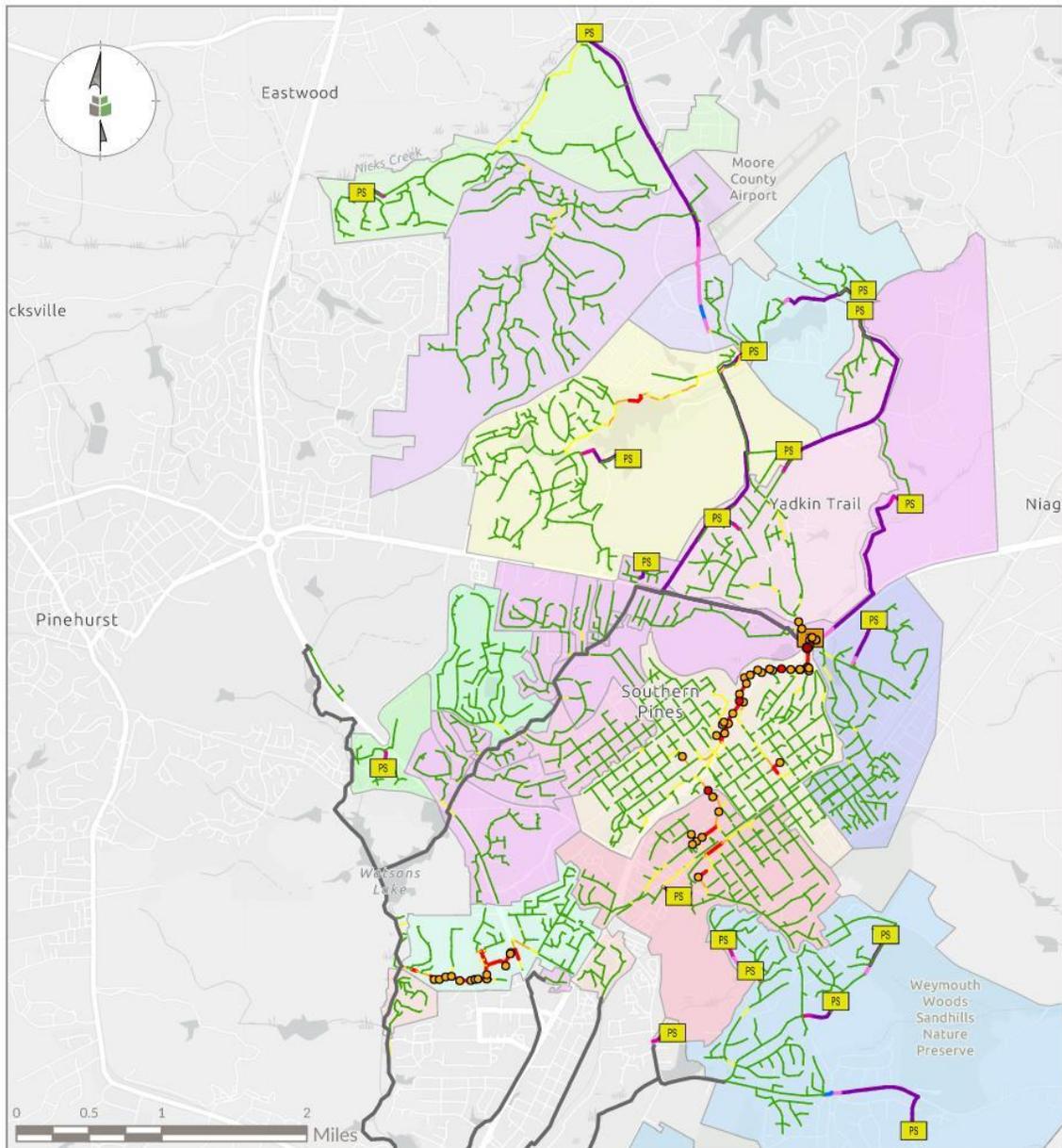
**Legend**

- |                               |                             |                                      |  |
|-------------------------------|-----------------------------|--------------------------------------|--|
| ● Critically Flooded Manholes | PS Surcharged Pump Stations | <b>Force Mains (Max/ Full Depth)</b> | <b>Gravity Mains (Max/ Full Depth)</b> |
| ● Flooded Manholes            | PS Modeled Pump Stations    | — < 0.5                              | — < 0.5                                |
| ● Surcharged Manholes         | — Lines Not Owned by SP     | — 0.5 - 0.75                         | — 0.5 - 0.75                           |
|                               |                             | — 0.75 - 0.99                        | — 0.75 - 0.99                          |
|                               |                             | — > 0.99                             | — > 0.99                               |

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EST. 1983

**Figure 21. Model-predicted SSOs, surcharging, and hydraulic restrictions for the 2-year design rainfall event**



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**Town of Southern Pines, NC**  
5 Year Design Storm

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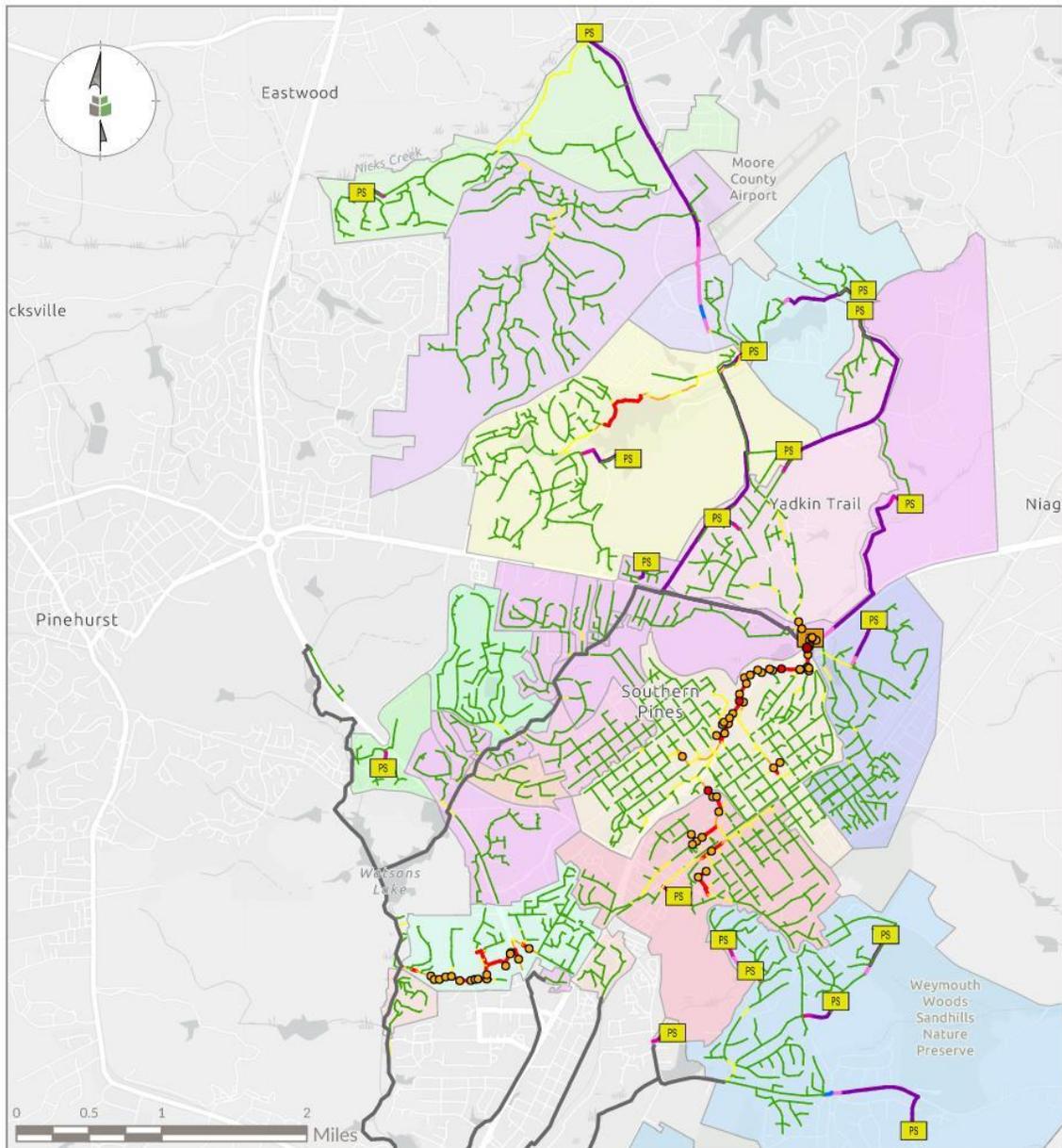
**Legend**

- Critically Flooded Manholes
  - Flooded Manholes
  - Surcharged Manholes
  - PS Surcharged Pump Stations
  - PS Modeled Pump Stations
  - Lines Not Owned by SP
- |  |                                      |
|--|--------------------------------------|
| <b>Gravity Mains (Max/ Full Depth)</b> | <b>Force Mains (Max/ Full Depth)</b> |
| — < 0.5                                | — < 0.5                              |
| — 0.5 - 0.75                           | — 0.5 - 0.75                         |
| — 0.75 - 0.99                          | — 0.75 - 0.99                        |
| — > 0.99                               | — > 0.99                             |

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EST. 1983

**Figure 22. Model-predicted SSOs, surcharging, and hydraulic restrictions for the 5-year design rainfall event**



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**Town of Southern Pines, NC**  
10 Year Design Storm

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**Legend**

- Critically Flooded Manholes
  - Flooded Manholes
  - Surcharged Manholes
  - PS Surcharged Pump Stations
  - PS Modeled Pump Stations
  - Lines Not Owned by SP
- |  |                                      |
|--|--------------------------------------|
| <b>Gravity Mains (Max/ Full Depth)</b> | <b>Force Mains (Max/ Full Depth)</b> |
| — < 0.5                                | — < 0.5                              |
| — 0.5 - 0.75                           | — 0.5 - 0.75                         |
| — 0.75 - 0.99                          | — 0.75 - 0.99                        |
| — > 0.99                               | — > 0.99                             |

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EST. 1983

**Figure 23. Model-predicted SSOs, surcharging, and hydraulic restrictions for the 10-year design rainfall event**

### 5.2.1 Flow and Capacity Analysis

The primary objective of the flow and capacity analysis is to assess the ability of the existing sewer infrastructure to convey the design of rainfall event flows without surcharging or causing SSOs. The key metrics analyzed include peak flow rates, flow depths, and hydraulic grade line (HGL) elevations at critical locations within the system.

#### 5.2.1.1 Peak Flow Rates

The model-predicted peak flow at each of the nine (9) flow meter locations during the 2-year, 5-year, and 10-year design rainfall events are summarized in Figure 23. These values indicate the maximum instantaneous flow rates that the system is required to handle during each event.

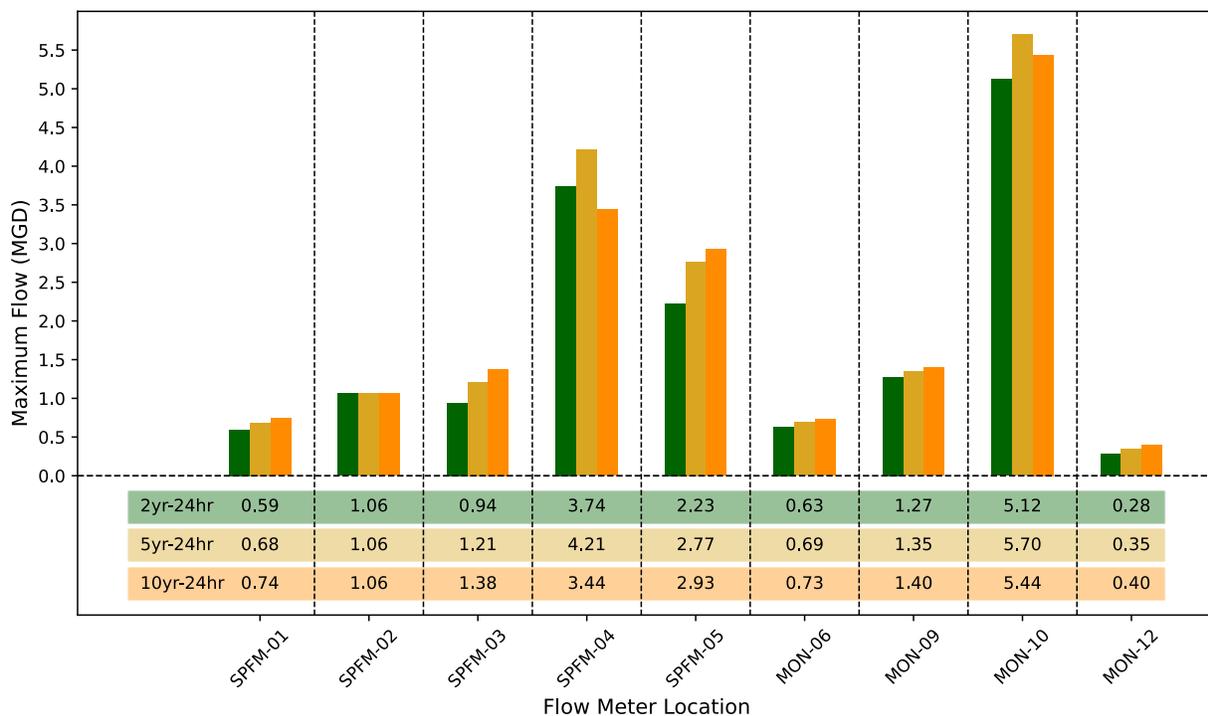


Figure 24. Peak flow rates (MGD) at flow meter locations for each design rainfall event

#### 5.2.1.2 Flow Depths

The flow depth at critical manholes and pipe segments are analyzed to determine the extent of surcharging and potential risk of SSOs. Depth-to-diameter (d/D) ratios are used to assess the level of surcharge, with values approaching or exceeding 1.0 indicating SSO conditions. The pipes capacity distribution is shown in Figure 25.

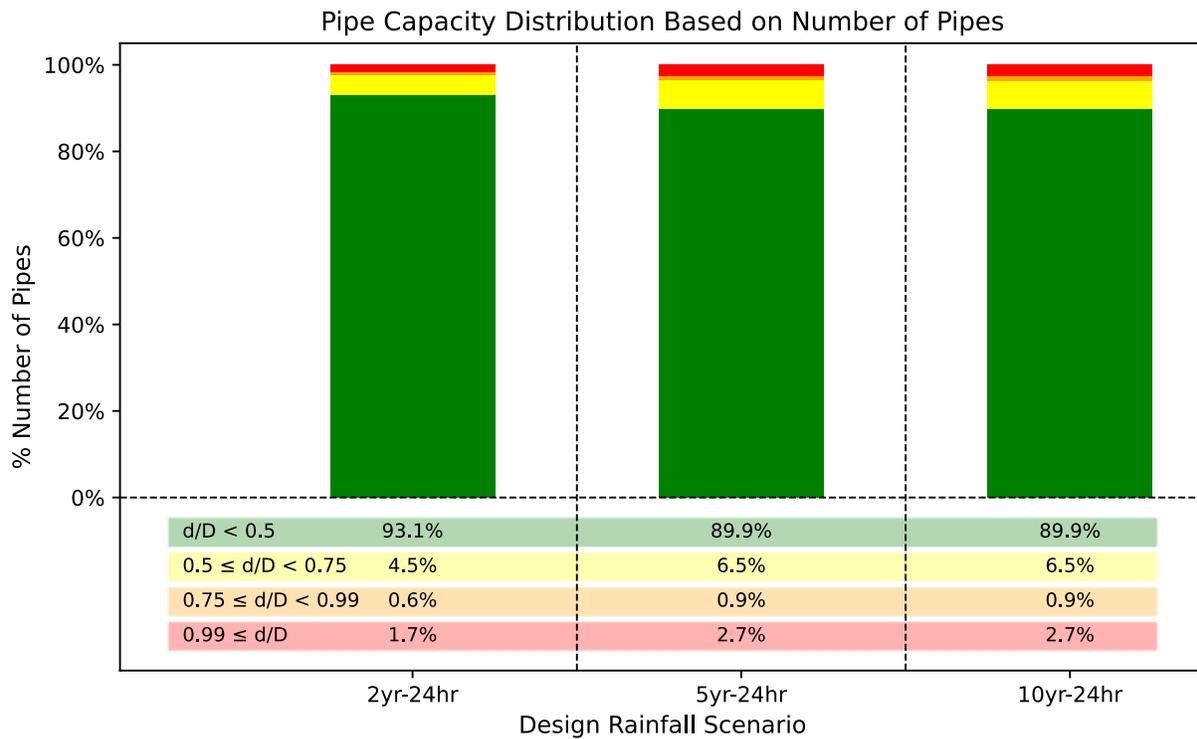


Figure 25. Pipe capacity distribution based on number of pipes

### 5.2.1.3 Hydraulic Grade Line (HGL) Elevations

This section examines the predicted HGL elevations at key junctions to assess they remain below the relative ground surface elevation, thereby avoiding SSOs. Locations where the HGL exceeds the ground elevation may indicate SSOs and are identified as potential points of failure. It is important to note that there is some uncertainty in tracking all elevated manholes, as these may create additional storage that could be missed. This uncertainty can affect the accuracy of predictions and the identification of potential failure points. Verifying data gaps will minimize uncertainty and improve the reliability of the analysis.

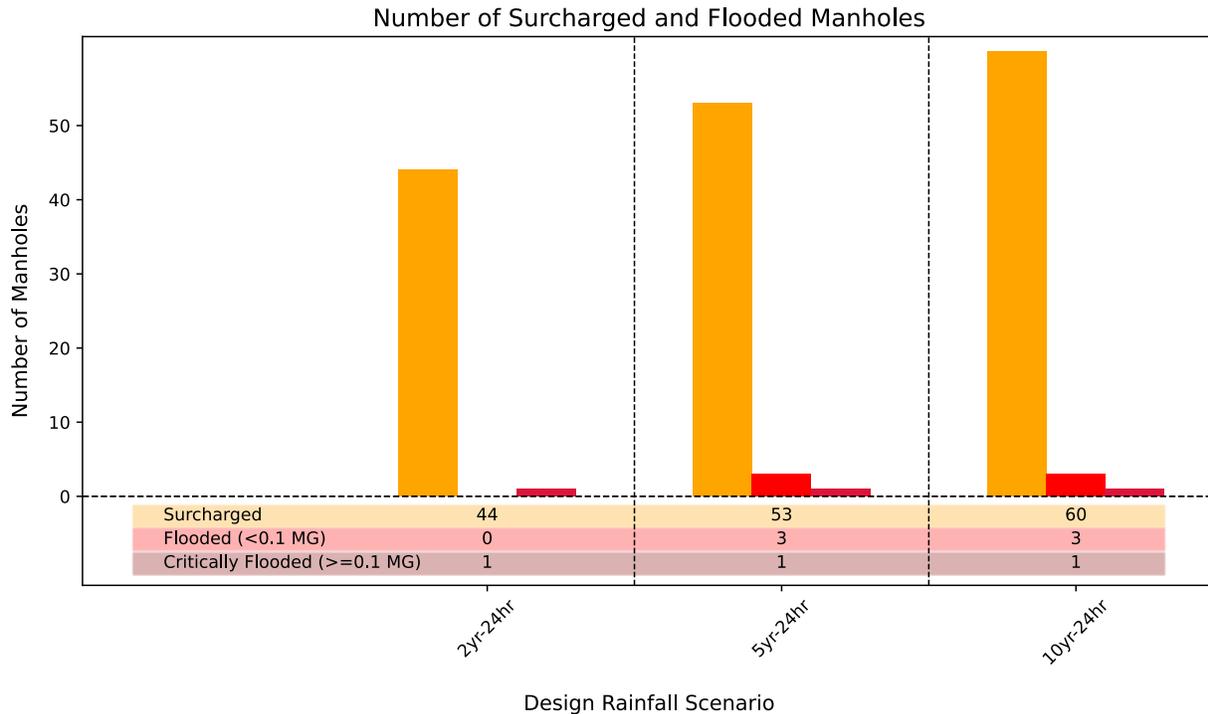
To identify potentially problematic manholes, two criteria and three categories were selected. The criteria are Minimum Freeboard (ft) and Total Flood Volume (MG). Minimum Freeboard represents the distance between the water surface, represented by the HGL, and the top of the manhole. The three categories selected are described below:

**Surcharged Manhole:** If the Minimum Freeboard for a manhole is less than two feet or if the Total Flood Volume is negligible (less than 0.01 million gallons), the manhole is classified as a surcharged manhole.

**Flooded Manhole (< 0.1 MG):** If the Total Flood Volume is between 0.01 and 0.1 million gallons, the manhole is classified as a flooded manhole.

**Flooded Manhole ( $\geq 0.1$  MG):** If the Total Flood Volume exceeds 0.1 million gallons, the manhole is classified as a critically flooded manhole.

By categorizing the flooded manholes into these categories, the map can effectively highlight which manholes are critical based on their flood volume. This classification aids in prioritizing maintenance and intervention efforts. Figure 26 shows the percentage of manholes that are surcharged and flooded.



**Figure 26. Number of surcharged and flooded manholes**

### 5.2.2 System Performance Score

The system performance for each design storm event is summarized in the following subsections, highlighting areas where the sewer network may require additional surveying or upgrades to handle the anticipated flows.

#### 5.2.2.1 2-year, 24-hour Design Rainfall Event

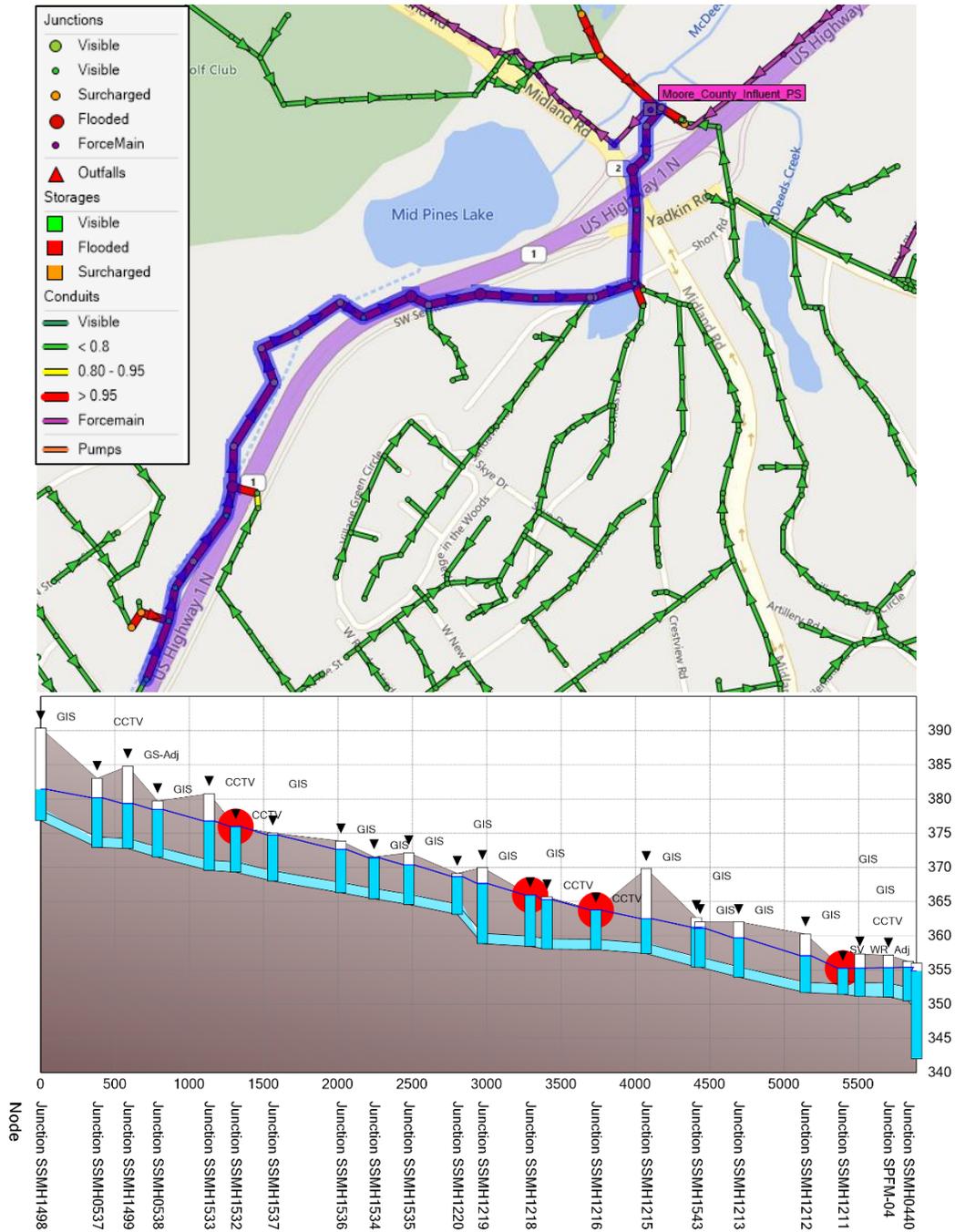
During the 2-year, 24-hour rainfall event, the sewer system generally performs well, with peak flow rates remaining within the capacity limits of the existing infrastructure. However, localized surcharging is predicted in a few segments, particularly near Moore Pump Station and downstream of the Walmart area (north of the intersection of Daytona Avenue and Johnson Street). Flooding greater than 0.1 MG has been identified at only one (1) manhole. The d/D ratios for 98.2% of pipes remain below critical thresholds, indicating adequate conveyance capacity; however, further investigation is recommended for the remaining 1.7% with d/D ratios equal to one.

Certain areas within the system experience model-predicted SSOs. The following provides additional insights into these locations:

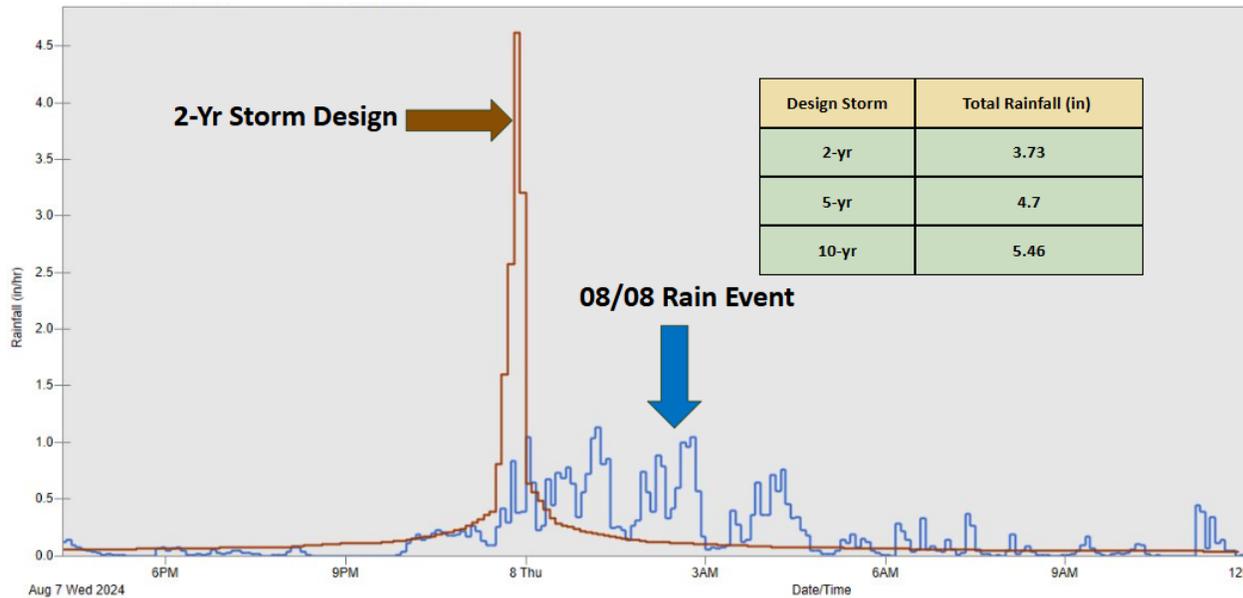
➤ **Moore County Pump Station**

As shown in Figure 27, the system's capacity upstream of this pump station is exceeded, resulting in SSOs in the area. This indicates that the pump station is undersized for managing peak flows during heavy rainfall events and requires infrastructure upgrades and/or RDII reduction to prevent future SSOs.

To verify this, WR reviewed the pump runtimes using SCADA data and analyzed a significant rain event from August 2024, which occurred after the flow meters had been removed. WR simulated this event in the model and adjusted the pump station's capacity and efficiency to reflect the observed runtimes. The results confirmed that the pump station lacked sufficient capacity during this event, indicating that an SSO likely occurred. For additional extreme weather context, it was also reported that during Tropical Storm Chantel (July 6, 2025), the Town reported an SSO in excess of 300,000 gallons at this location, which aligns with the model's findings. Figure 28 compares the storm intensity of the August 8, 2024 event with the 2-year design storm, clearly showing that the design storm has a significantly higher rainfall intensity, further emphasizing the system's vulnerability.



**Figure 27. SSOs upstream of Moore County pump station; Model overview displaying the critical pipes and associated manholes. (Bottom figure); Profile view showing sewer elevations in pipes and manholes at peak flow**



**Figure 28. Comparison of the 2-year design storm intensity (brown line) and the actual rainfall event on August 8, 2024 (blue line)**

➤ **Subbasin SPFM-05**

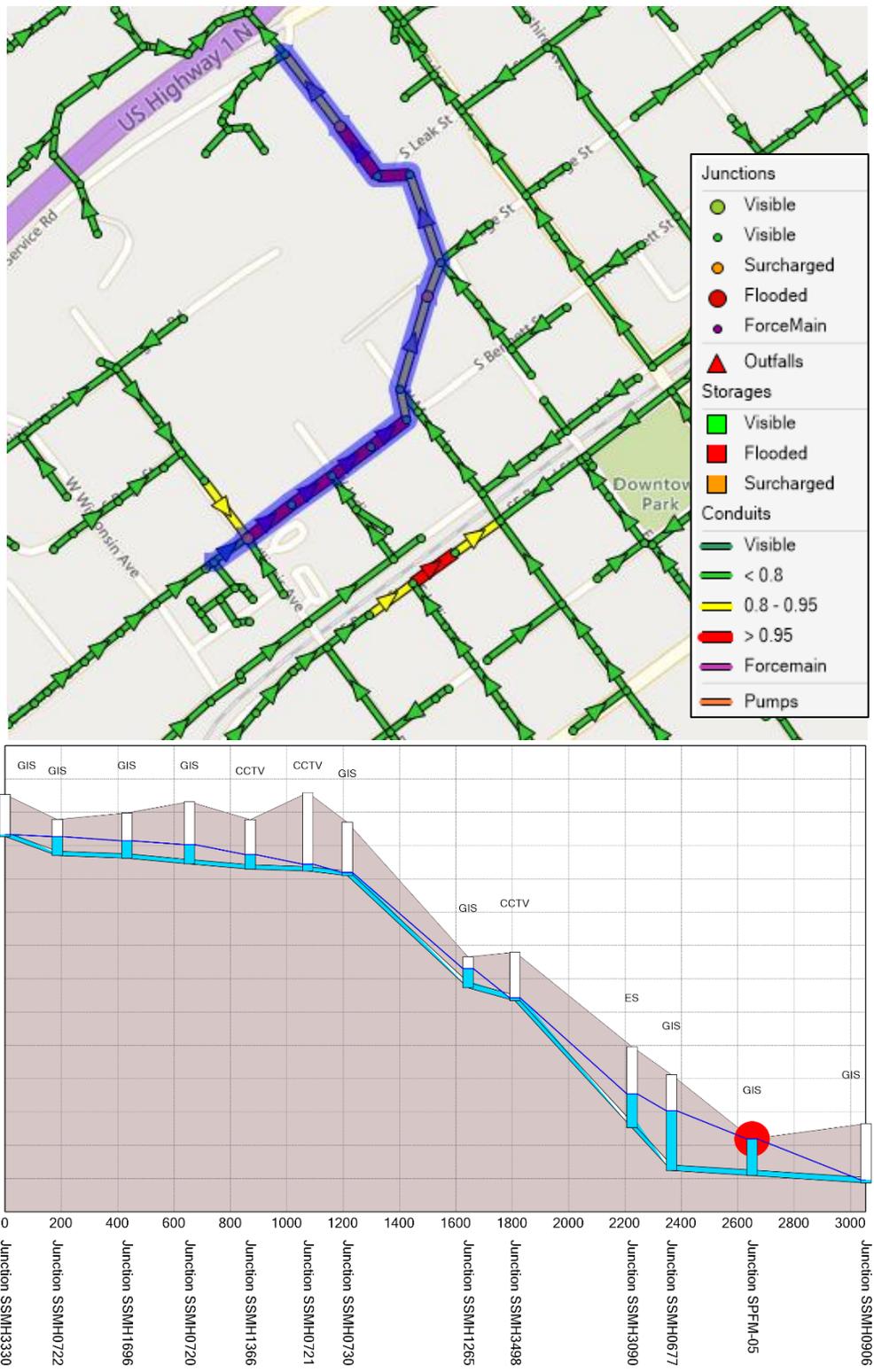
In subbasin SPFM-05, some full-capacity pipes and one surcharged manhole (SSMH0624, the location of flow meter SPFM-05) are predicted. Under the 5-year and 10-year design storms, this manhole shows a slight SSO (less than 0.1 MG), indicating that system capacity in this area is exceeded and unable to fully convey peak flows (Figure 29). The likely cause of the model-predicted SSO is the relatively shallow elevation of the manhole and the flat slope of the connecting pipes.

The Town, however, stated that no wet-weather SSOs have been observed at this location to date. It is important to note that this modeled result reflects design storm scenarios with relatively high rainfall intensities, whereas during the six wet-weather events—which were lower than even the 1-year NOAA IDF curve (see Figure 16)—used for calibration, no surcharging or SSOs were observed in this area. WR also reviewed the upstream asset condition context in this basin. Rehabilitation work had been performed after the flow monitoring period, with the greatest efforts concentrated in SPFM-04 (8.64% of pipe length) and SPFM-05 (3.16%) (see Table 6, Appendix I). In addition to these rehabilitation activities, Town work orders (WO) were also heavily concentrated in these two subbasins (Figure 31, Appendix I). These activities, including jetting, lining, localized repairs, pipe bursting, and full pipe replacements, likely improved hydraulic performance by reducing I&I, clearing blockages, removing grease buildup, addressing root intrusion, and restoring structural capacity.

Because the model was developed and calibrated using pre-rehabilitation data, these improvements are not reflected in the calibration. Additionally, non-ideal pipe conditions such as roots, grease, and obstructions can cause localized impediment to gravity flow in individual pipes. Meaning, the model is well-calibrated in terms of matching observed RDII volume at the meter location but may not represent changes to predicted velocities upstream due to pipe

condition. In a future model update effort, a basin-focused study with more measured velocity data can revisit the calibration process with respect to modifying Manning's  $n$  to reflect roots and accounting for decreases in pipe capacity from sediment and/or blockages.

Overall, while the model indicates limited capacity at the Moore County Pump Station and SSOs within SPFM-04 and SPFM-05, the post-monitoring rehabilitation efforts and Town WOs may already have reduced I&I and improved hydraulic performance. By decreasing peak flows, these improvements could in practice provide sufficient capacity at the pump station to prevent or reduce SSOs, and may also mitigate the frequency or severity of SSOs predicted in these basins. Continued monitoring and model recalibration will be important to verify the effectiveness of these improvements.

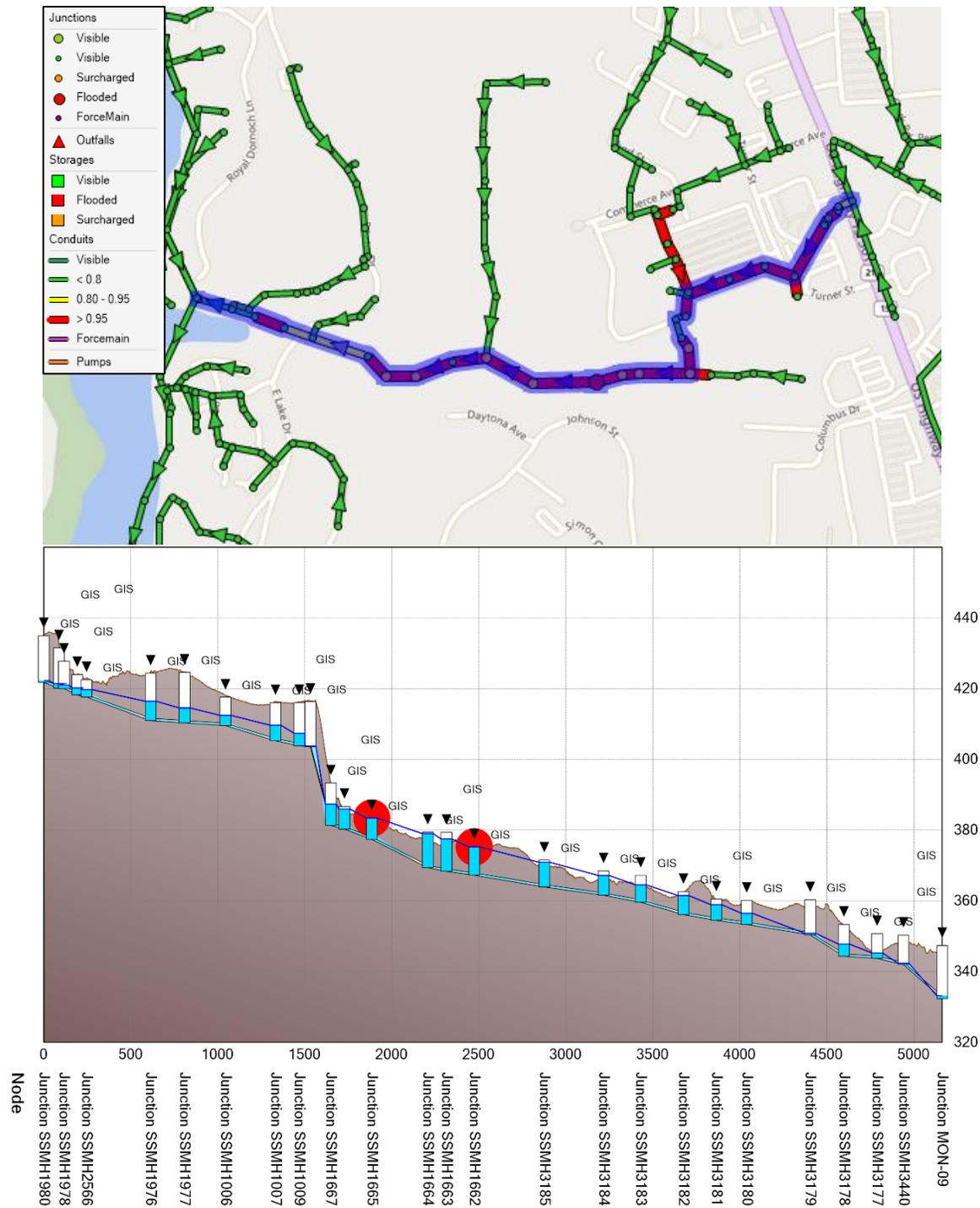


**Figure 29. SSOs at SPFM-05. (Top figure); Model overview displaying the critical pipes and associated manholes. (Bottom figure); Profile view showing sewer elevations in pipes and manholes at peak flow**

➤ **Downstream of Walmart area (north of the intersection of Daytona Avenue and Johnson Street)**

In subbasin SPFM-09, a minor SSOs or surcharging are predicted at specific manholes, SSMH1662 and SSMH1665. Although the volume of SSO is minimal, it still indicates that the system's capacity in this area is exceeded and unable to manage peak flows effectively. This condition suggests the need for targeted infrastructure upgrades to address localized capacity limitations and prevent future SSOs (Figure 30).

Typically, average dry weather flow is evenly distributed among manholes within each subbasin. However, for SPFM-09, sewer flow was allocated to manholes based on actual water usage data instead of equal distribution. This approach aimed to more accurately represent flow contributions and assess whether a usage-based distribution would improve hydraulic performance or alter SSO behavior in this basin.



**Figure 30. SSOs downstream of Walmart area. (Top figure); Model overview displaying the critical pipes and associated manholes. (Bottom figure); Profile view showing sewer elevations in pipes and manholes at peak flow**

### 5.2.2.2 5-year, 24-hour Design Rainfall Event

The 5-year, 24-hour rainfall event exacerbates existing capacity limitations within the sewer system, leading to more extensive SSOs. While no new capacity constraints are introduced compared to the 2-year event, the affected areas of surcharging and SSOs expanded. Peak flow rates challenge the system's ability to convey flows, with several segments approaching or exceeding their design capacity. The same one (1) manhole experiences flooding volumes exceeding 0.1 MG, while there are now three (3) manholes experiencing flooding equal to or less than 0.1 MG. This highlights the need for capacity improvements in specific areas to prevent further system strain during more intense rainfall events.

### 5.2.2.3 10-year, 24-hour Design Rainfall Event

The 10-year, 24-hour rainfall event generates the highest peak flow rates, significantly testing the system's capacity. Several segments experience flows that exceed their design limits, leading to surcharging. Flooding, both exceeding 0.1 MG and equal to or less than 0.1 MG, is predicted at the same manholes identified during the 5-year design storm. SSOs upstream of the Moore County Pump Station, particularly in basins SPFM-04 and SPFM-05, become more severe. These findings indicate that the pump station lacks sufficient capacity, highlighting the need for immediate attention to prevent further flooding and SSOs.

## 6 Conclusion and Recommendations

This hydraulic modeling effort developed a calibrated sanitary sewer model for the Town of Southern Pines using available GIS data and four months of flow and rainfall monitoring. While the model reflects current system behavior under both dry and wet weather conditions, certain limitations, such as a short flow monitoring duration, introduce some uncertainty. Despite these constraints, the model offers a powerful tool for identifying capacity constraints and planning capital improvements. Simulations of 2-year, 5-year, and 10-year design storms revealed localized surcharging, SSOs, and limited conveyance capacity in key areas such as the Moore County Pump Station basin, SPFM-05, and the Walmart area (north of the intersection of Daytona Avenue and Johnson Street).

To address these findings and improve the system's resilience, the following recommendations are provided:

#### **Recommendation 1: A year-round flow monitoring period**

Extending flow and rainfall monitoring to a full year would allow for the development of a more comprehensive set of RTK parameters and improve the accuracy of DWF and RDII predictions across a wider range of hydrologic conditions.

#### **Recommendation 2: Recalibrate model to represent current system conditions and benchmark effectiveness of RDII reduction**

As there has been recent rehabilitation in the Town, particularly in Basins 04 and 05 after the flow monitoring period, updated flow monitoring and recalibration are recommended to confirm the model reflects the current performance of the sewer system. The present results are based on pre-rehabilitation conditions; while rehabilitation is expected to reduce RDII and may help relieve some

of the stress on the Moore County Pump Station, it is not yet clear whether these improvements alone will fully resolve the capacity limitations. Continued monitoring and recalibration is recommended to confirm the extent of RDII reduction and to determine whether pump station upgrades are still required.

In addition, during the meeting with the client it was mentioned that a significant I&I source was recently identified in the Airport area, after the flow monitoring period. A damaged oil-water separator had allowed stormwater runoff from a large portion of the property to enter the sanitary sewer system, artificially inflating wet-weather flows. The issue has since been corrected, but this improvement is not represented in the calibration dataset. Incorporating both the rehabilitation activities and the removal of the Airport I&I source into updated flow monitoring and recalibration will provide a more reliable assessment of system performance.

**Recommendation 3: Evaluate and, if necessary, upgrade Moore County Pump Station capacity**

The Moore County Pump Station was identified as a key capacity bottleneck during all design storm scenarios, with modeled SSOs occurring upstream during the 2-, 5-, and 10-year events. While rehabilitation and I&I reduction may reduce the flows conveyed to the pump station, updated monitoring and recalibration (**Recommendation 2**) are advised to determine whether these improvements are sufficient. If capacity limitations persist, it is recommended to increase the station's pumping capacity to accommodate peak wet weather flows and reduce the risk of upstream surcharging and SSOs. Any upgrades should be coordinated with an evaluation of the downstream receiving system to validate that additional flows can be conveyed without creating new capacity constraints or shifting the bottleneck further downstream.

**Recommendation 4: Verify and correct critical manhole elevation data**

Several flooded or surcharged manholes, such as SSMH0624 and SSMH0677 in the SPFM-05 subbasin, and SSMH1010 and SSMH1667 downstream of the Walmart area, require field verification and updated GIS elevation data.

**Recommendation 5: Update models on regular basis, incorporating additional flow meter data**

Model updates are recommended every 3-5 years or more frequently when new major customers are added to the system and as additional flow meters are installed. Additional flow metering at strategic locations will improve the ability of the model to reflect actual flow conditions, resulting in more informed prioritization for capital improvements.

**Recommendation 6: Implement targeted I&I reduction**

Focused I&I reduction efforts are recommended in basins with high RDII response, particularly SPFM-04 and SPFM-05. Actions may include manhole rehabilitation, sealing of covers and joints, smoke testing, and correction of illicit stormwater connections.

## Appendix I – Work Orders and Rehabilitation Context

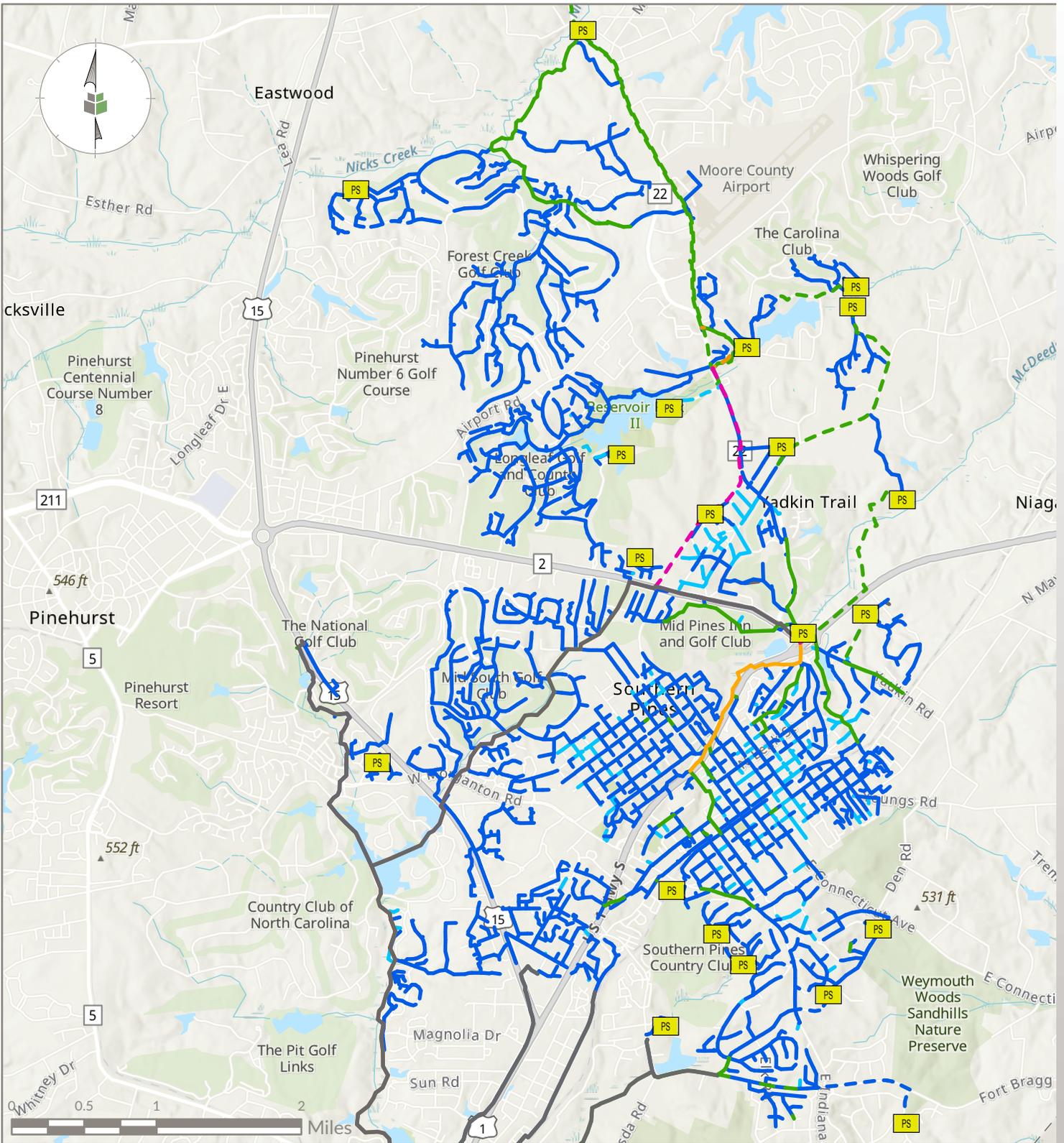
Work orders and rehabilitation efforts play a critical role in addressing operational challenges within the sewer system. These activities clear grease, debris, and roots, repair structural defects, and extend the service life of aging infrastructure. Together, they reduce the risk of blockages, backups, and SSOs, while enhancing flow conveyance and overall system reliability. Table 6 summarizes the Town's sewer rehabilitation activities by basin, and Figure 31 illustrates the distribution of work orders within the most active subbasins (SPFM-04 and SPFM-05). Most of the Town's rehabilitation work and work orders were completed after the flow monitoring period, with the greatest concentrations occurring in SPFM-04 and SPFM-05 (8.64% and 3.16% of total pipe length rehabilitated, respectively).

These targeted improvements likely reduced I&I, strengthened pipe integrity, and enhanced hydraulic performance. By removing grease, debris, root intrusion, and repairing localized defects, rehabilitation activities reduced unwanted groundwater and stormwater contributions that previously inflated base flows and peak wet-weather responses. Similarly, work orders such as jetting and point repairs improved local conveyance by restoring hydraulic capacity in pipes that had been partially obstructed by grease, debris, or root growth. Together, these actions not only improved structural integrity but also smoothed hydraulic gradients, reduced localized head losses, and allowed flows to move more efficiently toward downstream Moore County Pump Station. In practical terms, this means the system can convey higher volumes during storm events with less surcharging, fewer backups, and lower risk of SSOs, while also improving the reliability of flow monitoring and calibration results.

**Table 6. Pipe rehabilitation summary by basin**

Basin	Overall Pipe Length (ft)	Rehabbed Pipe Length (ft)	% of Rehabbed Pipes
SPFM05	77,149	2,437	3.16
SPFM04	130,633	11,281	8.64
SPFM03	57,478	0	0.00
SPFM02	43,941	1,031	2.35
SPFM01	76,590	0	0.00
MON-10	107,750	883	0.82
MON-12	7,810	0	0.00
MON-6	67,485	736	1.09
MON-9	42,358	0	0.00
MON-19	8,663	0	0.00
SPLM_A	81,283	0	0.00
SPLM_AA	42,104	0	0.00
SPLM_B	10,037	0	0.00
SPLM_C	13,152	0	0.00
SPLM_F	23,202	801	3.45
SPLM_G	31,620	0	0.00





## Town of Southern Pines, NC Sewer System Pipe Diameters



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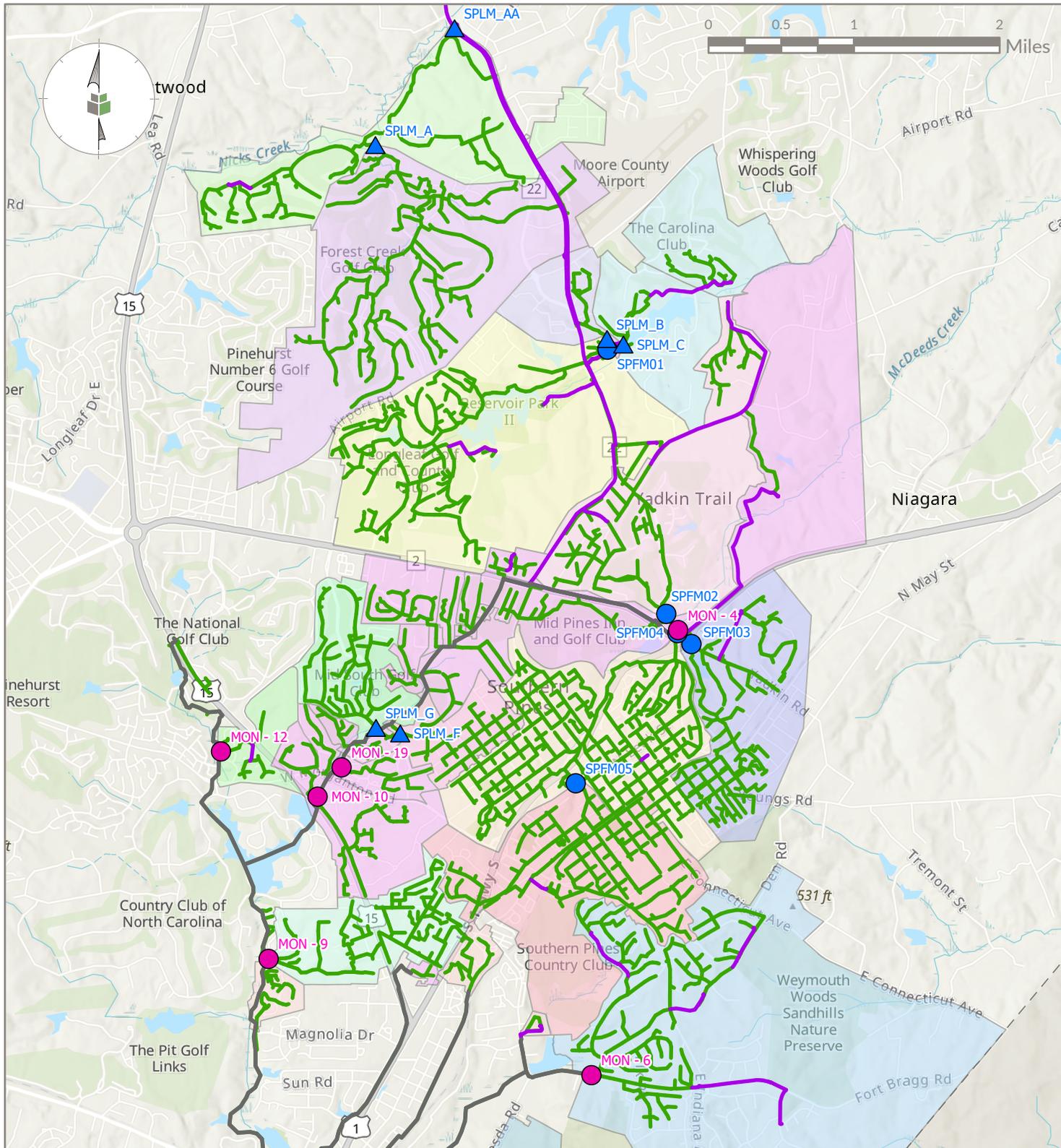
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- Pump Station
- Lines Not Owned by SP

Gravity Main Diameter	Force Main Diameter
4 - 6	1.25 - 2.5
8	3 - 4
10 - 12	6 - 8
16 - 18	10 - 12
24 - 27	14 - 18
30 - 36	
42 - 48	
Unknown	

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# Town of Southern Pines, NC

## Sewer System Flow Meters

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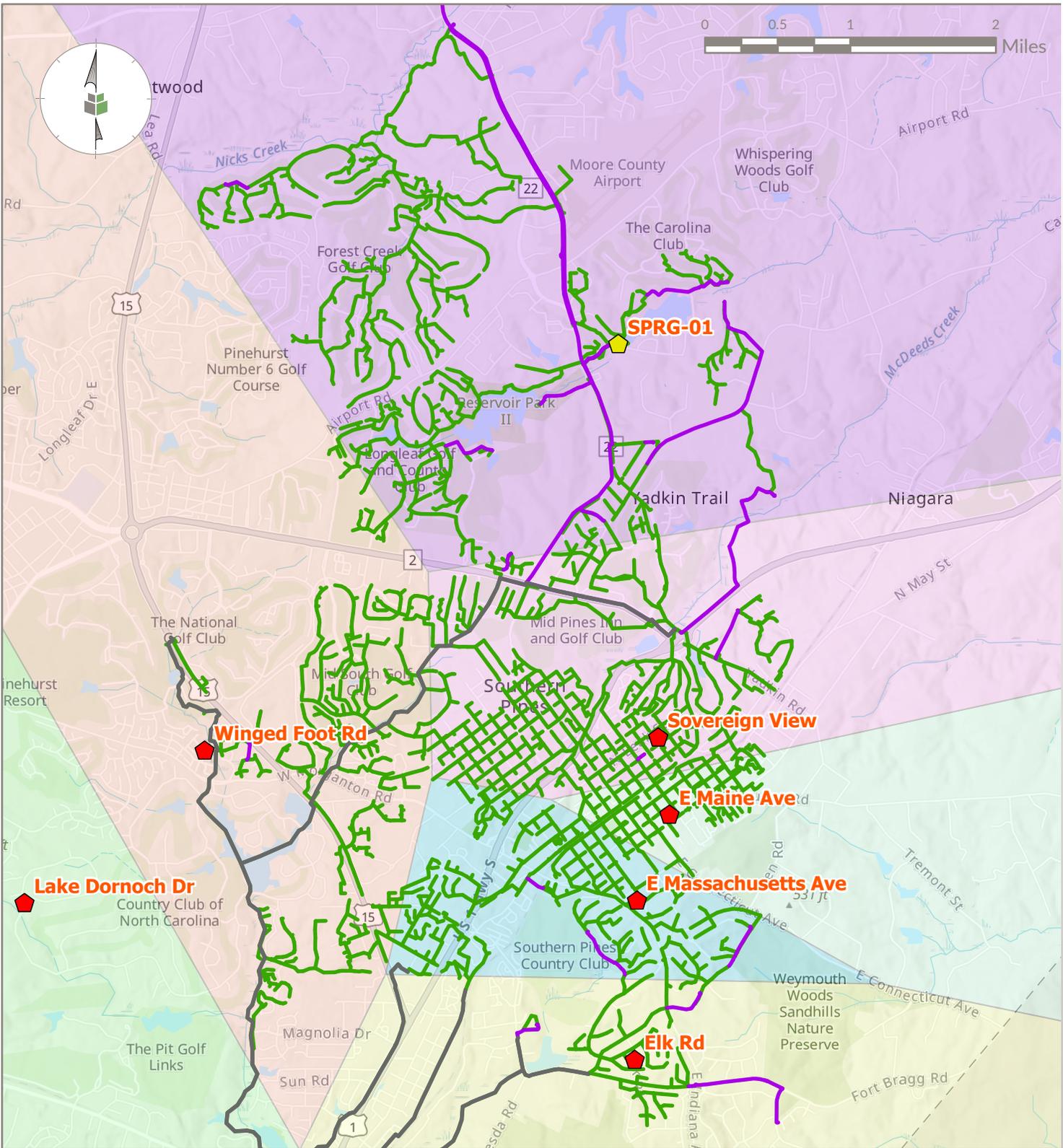
- Gravity Main
- Force Main
- Lines Not Owned by SP

### Southern Pines Flow Meters

- Flow-Type Meter
- ▲ Level-Type Meter

### Moore Flow Meters

- Flow-Type Meter



# Town of Southern Pines, NC

## ADS and Tempest Gauges with Thiessen Polygons

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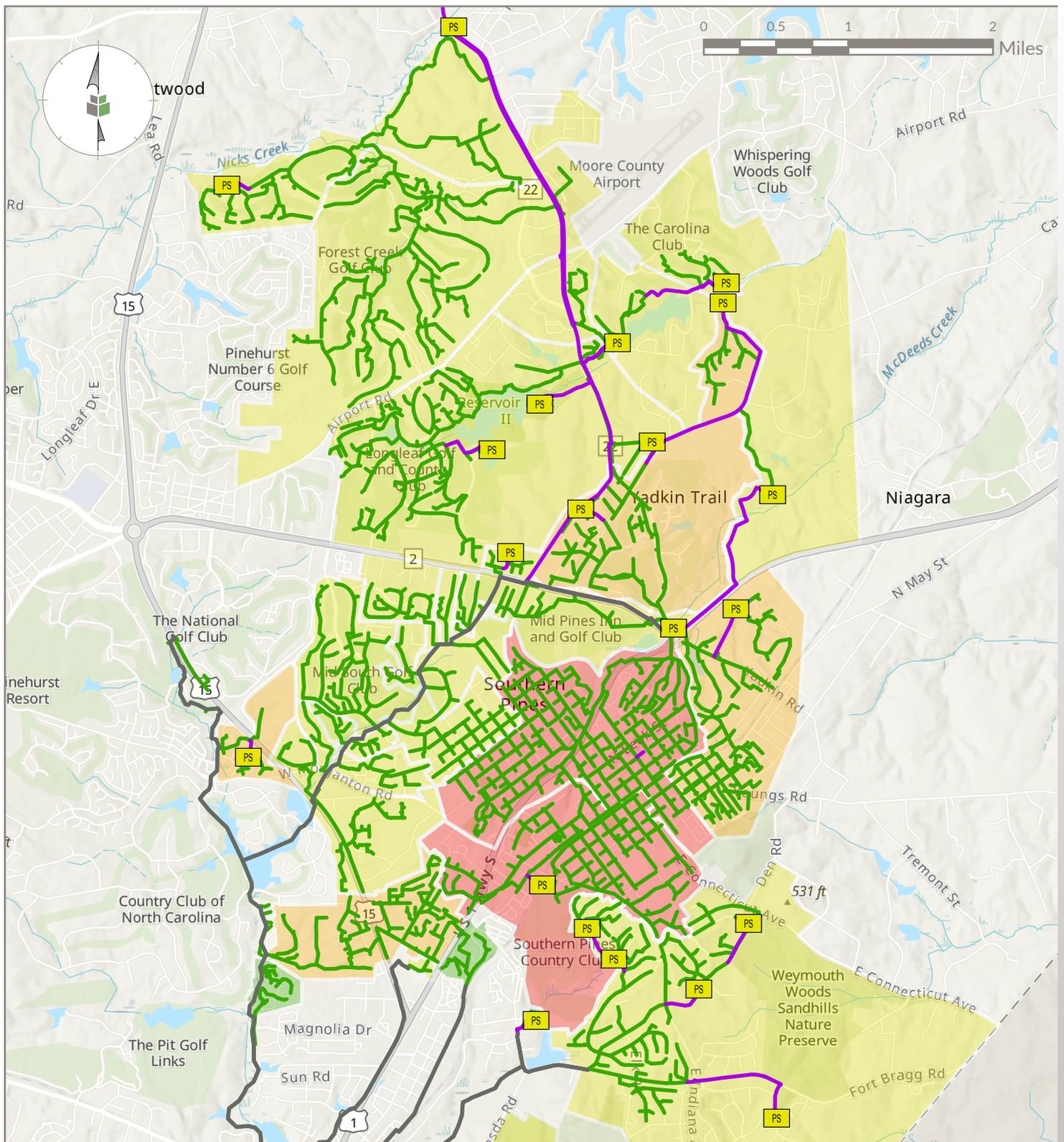
### Legend

#### Modeled Sewer Mains

- Gravity Main
- Force Main
- Lines Not Owned by SP

#### Rain Gauges

- ◆ Tempest Gauges
- ◆ ADS Gauges



# Town of Southern Pines, NC

## Sewer System Flow Meter Sub-Basin with sum of R-Values

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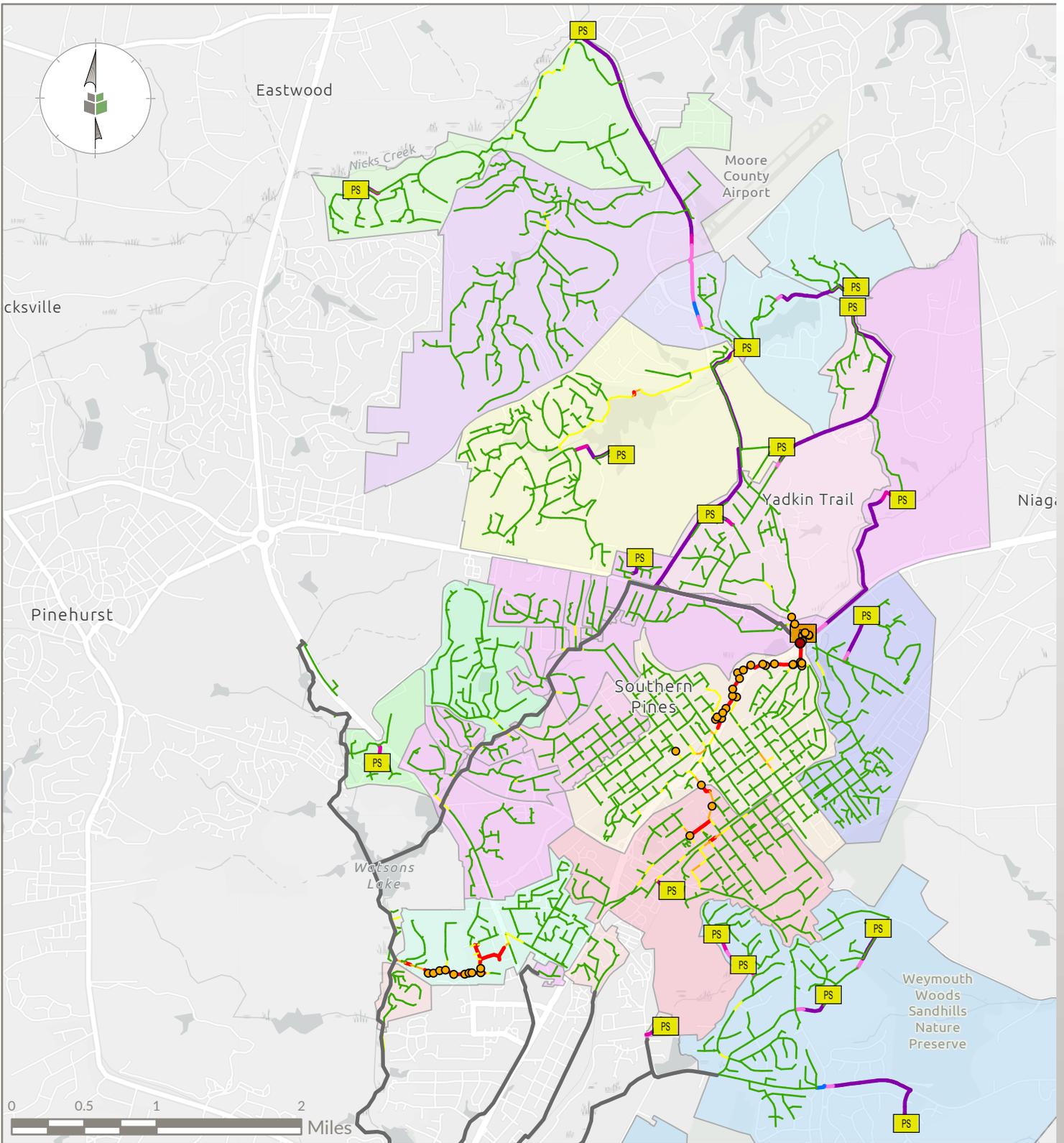
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### Legend

- PS Modeled Pump Stations
- Gravity Main
- Force Main
- Lines Not Owned by SP

### Flow Meter Sub-Basin by R Value

- 0%
- 0% - 1%
- 1% - 2%
- 2% - 3%



# Town of Southern Pines, NC

## 2 Year Design Storm

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.



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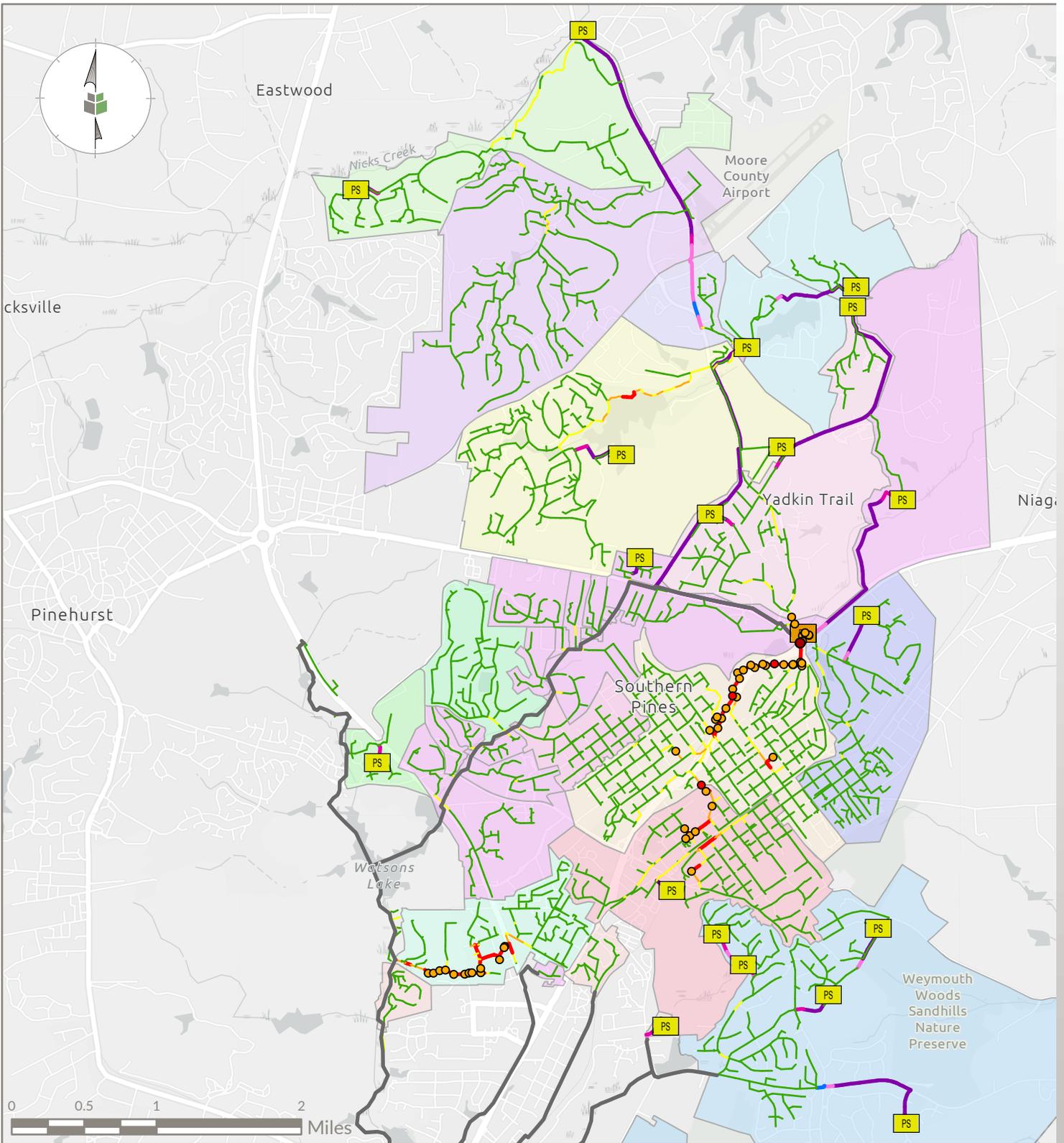
### Legend

- Critically Flooded Manholes
- Flooded Manholes
- Surcharged Manholes

- Surcharged Pump Stations
- Modeled Pump Stations
- Lines Not Owned by SP

- Force Mains (Max/ Full Depth)**
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99

- Gravity Mains (Max/ Full Depth)**
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99



# Town of Southern Pines, NC

## 5 Year Design Storm

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

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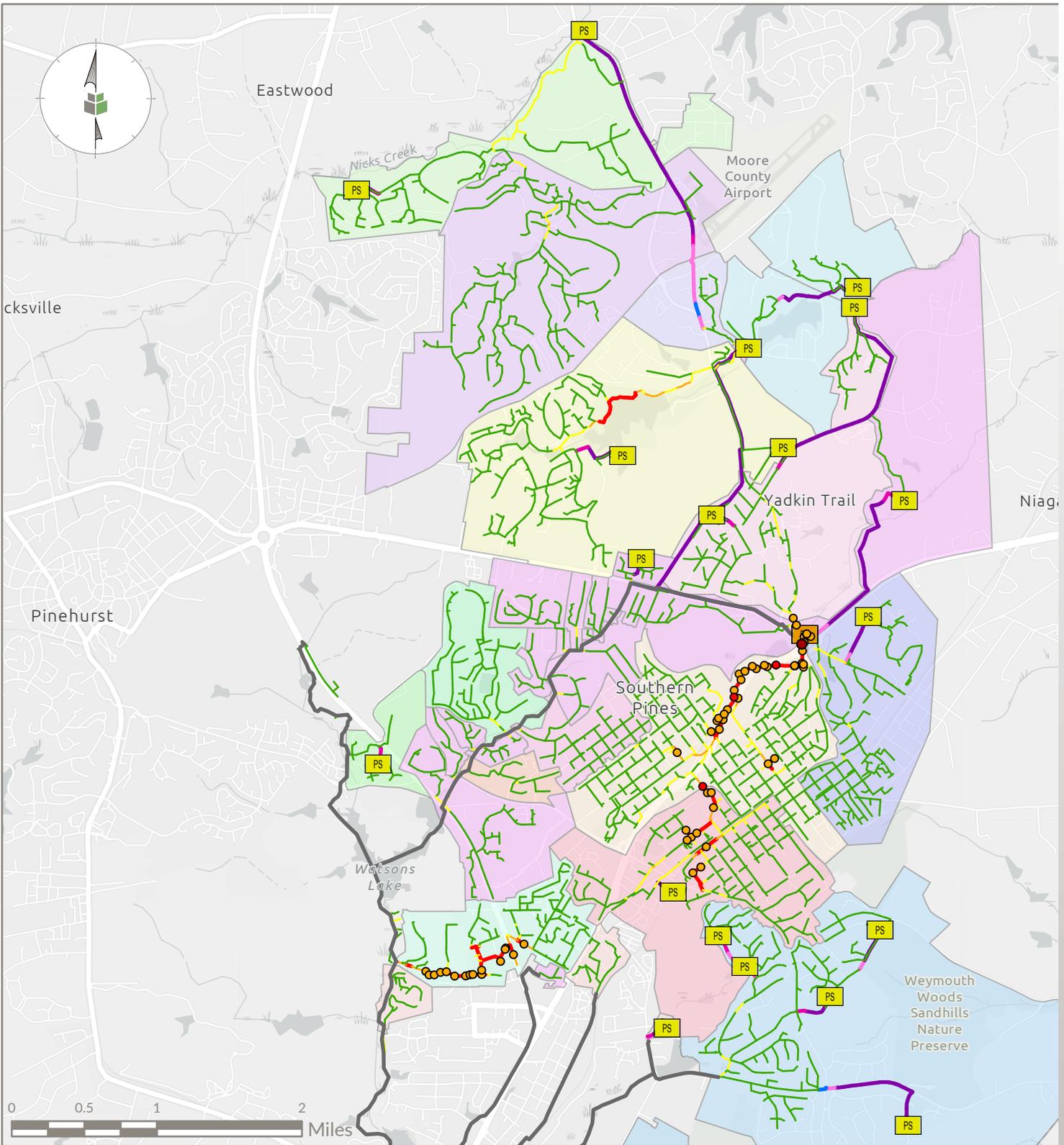
### Legend

- Critically Flooded Manholes
- Flooded Manholes
- Surcharged Manholes

- Surcharged Pump Stations
- Modeled Pump Stations
- Lines Not Owned by SP

- Gravity Mains (Max/ Full Depth)**
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99

- Force Mains (Max/ Full Depth)**
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99



# Town of Southern Pines, NC

## 10 Year Design Storm

This map is for informational purposes only. All feature locations displayed are approximate based on available data sources.

Data features are not based on professional field survey unless stated otherwise.



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### Legend

- Critically Flooded Manholes
- Flooded Manholes
- Surcharged Manholes

- Surcharged Pump Stations
- Modeled Pump Stations
- Lines Not Owned by SP

- #### Gravity Mains (Max/ Full Depth)
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99

- #### Force Mains (Max/ Full Depth)
- < 0.5
  - 0.5 - 0.75
  - 0.75 - 0.99
  - > 0.99

## Appendix II – Design Storms Results: Maps

# APPENDIX IV - References

1. NCDEQ Asset Assessment Guidance Document September 2020
2. NCDEQ DWR Southern Pines Local Water Supply Planning Document 2024