Attachment 14. BCA Technical Memorandum

City of Gastonia Duharts Creek, Critical Infrastructure Protection and Stream Restoration – FY2021 BRIC

TECHNICAL MEMORANDUM

FEMA Building Resilient Infrastructure and Communities Grant Program

City of Gastonia Critical Infrastructure Protection and Stream Restoration

Benefit-Cost Analysis Memorandum

November 22, 2021
v.0

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1. Introduction

FEMA requires that all projects funded through the Building Resilient Infrastructure and Communities (BRIC) program are cost-effective and designed to increase resilience and reduce risk of injuries, loss of life, and damage and destruction of property, including critical services and facilities.

This technical report documents that the Critical Infrastructure Protection and Stream Restoration project submitted by the City of Gastonia, North Carolina under the BRIC Fiscal Year 2021 application cycle satisfies applicable cost-effectiveness requirements in compliance with OMB Circular A-94 using FEMA benefit-cost analysis (BCA) methods and tools. The report covers the proposed mitigation activity, BCA approach including pre-mitigation and post-mitigation losses, and analysis results. Analysis documentation also includes a completed FEMA BCA Toolkit Version 6.0, and a BCA Report.

2. Proposed Mitigation Activity

The City of Gastonia proposes to stabilize and rehabilitate approximately 8,000 linear feet of Duhart's Creek from Redbud Drive to US 74/29. In addition to the stabilization, some realignment of existing 18" and 8" gravity sewer lines and a 24" force main will be performed to move them further away from the creek and reduce the risk of impacts due to flooding. The combined creek restoration and sewer realignment measures will use nature-based solutions to mitigate erosion of the streambank and provide increased resiliency to the sewer infrastructure, mitigating any future loss of service to community lifelines and critical facilities.

2.1 Historic Events and Vulnerability

In accordance with the FEMA BCA Reference Guide and Supplement, expected losses associated with modeled events may be used in the BCA Toolkit. The proposed project will mitigate streambank erosion, which has yet to damage property or infrastructure, but may soon, based on increasing rates of erosion witnessed in the stream and increasing intensity and frequency of rainfall events due to climate change. Therefore, the BCA is based upon expected losses that will be avoided by restoring and stabilizing the streambank and channel and realigning the sewer lines.

A high percentage of impervious cover in a watershed can induce additional erosion and more severe flooding by routing water into the stream faster than it would naturally enter during heavy precipitation events and reduce the absorption of water by vegetation. The stream was also straightened at some point, which has disconnected the stream from a floodplain that is accessible at lower-frequency storm events. These conditions are combined with the fact that precipitation events are becoming more severe. As a result of the flashy flows and confined channel, bank erosion is widespread along the project reach as the stream attempts to adjust against the current confines of the bank. This erosion threatens the following critical infrastructure and property:

- Sewer infrastructure: Two 18" gravity sewer lines run parallel to the creek throughout most of the project area and have become fully exposed in at least two places leaving them vulnerable to waterborne debris and shifting stones along the streambed. A sanitary sewer aerial crossing results in a frequent debris jams that place stress on the pipe. Another 24" sanitary sewer force main runs throughout most of the project area.

- Electrical power system: Power lines run alongside much of the creek with at least one 45-foot class 3 pole vulnerable to erosion. In addition, high-tension power cable towers run across the creek at one end of the project area, which could result much larger outages if damaged by flooding and/or erosion.

Expected losses are estimated using loss of function avoided for sewer and electrical power infrastructure through implementation of the proposed project.

2.2 Project Overview

The proposed restoration will construct a new stream channel sized to the appropriate bankfull width and depth. In-stream structures, such as vegetated soil lifts, construction riffles, and wood toe, will be used to both stabilize the new channel and provide aquatic habitat. In addition to the channel modifications, floodplain grading will be completed to recreate a stream corridor that will accommodate flashy storms on an adjacent floodplain. While this will require significant grading, the process will lower the flood elevations throughout the project corridor and provide stormwater capacity for larger storms in a watershed with the potential for more development. Due to the stream realignment, the gravity sewer and force mains that currently run along the creek will be relocated further north. The sewer relocation will be done in conjunction with the grading and excavation of the stream realignment.

2.3 Project and Maintenance Costs

Table 1 provides total project and annual maintenance costs for implementing the proposed mitigation activity. Project costs were estimated in accordance with FEMA Hazard Mitigation Assistance (HMA) Guidance and do not include management costs requested. In accordance with the FEMA BCA Reference Guide and Supplement, annual maintenance costs are assumed to between .5 and 1% of the mitigation project costs and and will cover inspections, stream clearing, and vegetation maintenance.

Table 1. Project and Maintenance Costs

Mitigation Activity	Project Cost	Annual Maintenance Cost
Stream Restoration and Utility Infrastructure Protection	$7,906,000	$50,000

2.4 Project Useful Life

According to the FEMA 2009 BCA Reference Guide Appendix D: Project Useful Life Summary, a project useful life of 50 years should be applied to Utility Mitigation Projects – Major, e.g., power lines and sewer lines. However, Benefit-Cost Calculator V.6.0 applies a default project useful life of 30 years to floodplain and stream restoration actions. As such, a useful life of 30 years, the lower of the two values, was applied for Critical Infrastructure Protection and Stream Restoration project.

2.5 Number of Customers Served

Losses avoided for municipal utilities are accounted for in the Benefit-Cost Calculator using the number of customers served and number of impact days if compromised by heavy rainfall and erosion. Analysts estimated the service area for sewer and electrical utilities at risk due to the project stream using geospatial analysis and expert judgement. Where only the number of utility connections was known, 2019 US Census data for Gastonia, NC was applied to estimate the total number of people served.

Families & Living Arrangements	
Households, 2015-2019	28,973
Persons per household, 2015-2019	2.57
Living in same house 1 year ago, percent of persons age 1 year+, 2015-2019	83.5%
Language other than English spoken at home, percent of persons age 5 years+, 2015-2019	12.4%

Table 2 presents the results of this analysis and the service population inputs for the Benefit-Cost Calculator for sewer and electrical utility systems that will benefit from the proposed project.

Utility	Number of Customers Served
Wastewater	25,839
Electrical	9,800

Table 2. Utility Population Served

3. Benefit-Cost Analysis Approach

3.1 Software and References

Following the FEMA BCA Reference Guide and Supplement, this analysis uses a combination of precipitation data, erosion rates, and professional expected damages for municipal utility failure to calculate the damages before and after the proposed mitigation project is implemented. The expected damage scenarios use engineering assessments, statistical determinations of likely occurrence, and associated damages during expected events. This is consistent with FEMA's expected damages approach as detailed in the FEMA BCA Reference Guide and Supplement to the Benefit-Cost Analysis Reference Guide.

The proposed Critical Infrastructure Protection and Stream Restoration project addresses three primary vulnerabilities:

- Disruption in sewer services due to heavy rainfall and erosion within the stream that threatens exposed pipelines.
- Disruption in electrical power services due to erosion to an electrical pole along the streambank.

This BCA methodology document and the Benefit-Cost Estimator is split into two mitigation actions to represent the two utility types being mitigated by the proposed project. The benefits from the two mitigation actions are aggregated to determine the overall project BCR.

3.2 Sewer Service Disruption due to Heavy Rainfall

Two 18" gravity sewer lines and a 24" sanitary sewer force main run parallel to the creek throughout most of the project area. The gravity sewer lines are fully exposed at several points along the channel and vulnerable to failure if their bedding is scoured by high velocity flows or they are impacted by floating debris or the downstream movement of large stones along the streambed. Numerous stormwater pipes also discharge to the channel, and an upward trend in the number of heavy rainfall events (days with more than 3 inches of rain) observed by the North Carolina Climate Science Report indicates that higher flow within the stream is a likely future condition that could cause damage to the sewer lines. Point Frequency Estimates for Gastonia, a heavy rainfall event with approximately 3.71 inches of rain correlates to a 5-year, 12-hour precipitation event.

Image 1. Exposed underground sewer pipe in Duhart's Creek at a point of active erosion.

Appendix B contains the Gastonia, North Carolina NOAA PDS-based point precipitation frequency estimates with 90-percent confidence intervals.

The bankfull elevation is defined as that associated with channel-forming discharge that is typically between the 1- and 2-year storm events. According to the NOAA point precipitation frequency estimates, a 2-year, 12-hour precipitation event in Gastonia could produce between 2.72 and 3.24 inches of rain. Because the bankfull elevation is that which shapes the channel, BCA analysts assume that the 2-year precipitation event produces enough rain to carry debris and cause further erosion of the stream. Based on the above findings and the North Carolina Climate Science Report, BCA analysts used the rainfall return periods presented in Table 3 for the sewer disruption analysis. Table 3 also provides functional downtime estimates for each return period based on expert judgement and typical repair and restoration times for such infrastructure. A timeline for a likely 10-year, scattered site emergency sewer liner repair event follows.

Table 3. Precipitation Return Periods and Sewer Functional Downtime Assumptions

Rainfall Amount	Return Period	Pipeline Damage Expected	Functional Downtime Estimates
2.96 inches	2-year	High-velocity flow scours bedding beneath exposed gravity sewer pipe causing it to collapse and become uncoupled. Influent leak into the stream.	1 Day for permanent repair.
4.32 inches	5-year	Pipelines are ruptured by larger stream debris carried by higher velocity flows.	2 Days for sourcing of repair materials, site stabilization and repair preparation, permanent repair, and restoration and final stabilization.
5.02 inches	10-year	Substantial ruptures likely occur in multiple places across the pipeline.	5 Days for temporary bypass operations, sourcing of repair materials, site stabilization

			and repair preparation, permanent repair, and restoration and final stabilization.

Expected Timeline of Repairs to Gravity Sewer Line, Duhart's Creek – 10-year Event

Day 1: Identification of Loss of Service

Flood event happens and washes out gravity sewer line pipe, 24-36 hrs. for flood waters to fully recede until sewer line failure can be identified and accessed by City of Gastonia staff.

Day 2: Begin Temporary Bypass Operations

The City of Gastonia will locate a manhole upstream of the break, plug the manhole and begin to pump and haul the wastewater to the treatment plant until the repairs are completed. The City of Gastonia will stabilize access to the broken pipe location and access the damage

Day 3: Site Stabilization and Repair Prep

Once the City has access, the city will need to determine if they have adequate supplies (pipe, fittings, etc.) to perform the repair and order any supplies that they do not have on hand. Due to the large size of the gravity line, repair materials may be difficult to source due to current national supply chain issues. The city will stabilize the stream bank, bring in the repair equipment and supplies and prepare to start the repair. Pump and haul operations would continue during this time.

Day 4: Permanent repair

Begin permanent repair activities, including new pipe installation, concrete blocking (if required), pipe bedding and backfill, etc. The city should complete the permanent repair in approximately 24 hrs.

Day 5: Restoration and Final Stabilization

Once the repair has been completed, the city will remove the plug in the upstream manhole and stop the pump and haul operations. The city will stabilize the stream bank, remove remaining equipment and supplies, and return the construction area to preconstruction characteristics.

The proposed project will bury the exposed sewer pipelines, therefore mitigating infrastructure damage and service disruption posed by stream debris and high velocity flows. By relocating the sewer lines away from the floodway and restoring the streambank, eliminates residual risk to critical lifelines over the useful life of the project in all but the most severe events. As such, analysts assume that the 25-year functional disruption expected for the sewer system will be completely mitigated by the project. Disruption may occur with higher precipitation events. Analysts assumed that the 25-year precipitation event would damage and disrupt municipal utility services similar to a 10-year event before mitigation. Table 4 shows the pre-and post-mitigation entries into the Benefit-Cost Estimator for sewer structures.

Table 4. Pre- and Post-Mitigation Assumptions for Sewer Utility Protection

Event	Loss of Function Before Mitigation	Loss of Function After Mitigation
2-Year	1 Day	0 Days
5-Year	2 Days	0 Days
10-Year	5 Days	0 Days
25-Year	[redacted]	5 Days

3.3 Electrical Power Service Disruption due to Erosion

The primary threat facing infrastructure in the project area is erosion of Duhart's Creek due to heavy rain events and significant increase in creek discharges and flow volume. Over the last several years, erosion has occurred at an exponentially higher rate due to increased severity of storms in the region and increased rainfall frequencies. Due to the composition of soils in the area, vertical erosion has reached its peak and lateral erosion is now the primary concern along the creek.

To estimate an annual rate of erosion, engineers used two different methods. First, engineers averaged the rate of channel loss from monitored stream cross-sections from the measurements taken in 2017 and 2021. Second, engineers used a bank erosion curve from North Carolina State University (NCSU) to estimate the loss rate assuming "Very High" Bank Erosion Hazard Index (BEHI) and "Very High" Near-Bank Stress (NBS) scores. Severe bank erosion will undermine existing mature trees at and at least one electrical utility pole at the top of a streambank along Duhart's Creek. Table 5 shows the results of these analyses. Appendix C contains a preliminary engineering report from KCI Engineering with these findings and future conditions analysis.

Table 5. Estimate of bank erosion rates for the project reach of Duhart's Creek.

Bank Erosion Rate Method	Bank Erosion Rate	Tons/Linear Foot Channel Per Year	Total for Project Reach (8,000 lf)
1. On-Site Cross-Section Measurements	1.00 ft/yr	0.76 tons/lf	6,080 tons/year
2. NCSU Bank Erosion Curve	1.14 ft/yr	0.87 tons/lf	6,976 tons/year

The 45-foot class 3 utility pole is within inches of the top of actively eroding banks (Image 2). The utility pole is at risk of falling in the creek if the footing is undermined by eroding soil. This hazard threatens electrical power service for the expected service population in Table 2 above.

Image 2. Electrical utility pole next to streambank of Duhart's Creek

BCAs for erosion mitigation projects associate a likelihood of occurrence (or return period) with the time at which damage occurs based on the erosion rate. Based on a 1.0-foot average annual rate of streambed erosion, the more conservative of the two estimates, and the proximity of the electrical pole to the streambed, analysts estimate that the electrical equipment could fail in the next 5 years if left unprotected. Table 6 presents the assumptions for expected catastrophic failure estimates.

Table 6. Electric Power Failure Due to Erosion

Rate of Erosion	Distance from Stream Bank	Expected Failure Timeline
1.0 feet (12 inches)	8 feet	8 Years

The distance from the utility pole to the stream bank was conservatively estimated based on photographs to be 8 feet. If the utility pole were to fall into the creek due to erosion of the streambank, analysts assume at least one day of power service disruption for the utility company to dispatch workers, inspect the site, and repair the utility pole. This is a conservative estimate of functional disruption time, as a utility pole and other supplies may not be readily available if full replacement is needed. Additionally, this does not account for damage experienced by the exposed electrical service line, which would extend the repair time and restoration of power service if it were to occur. Table 7 shows the Benefit-Cost Estimator entries related to erosion and power service disruption. The stream restoration and stabilization project is assumed to protect against erosion for the full length of its project useful life of 30 years.

Table 7. Pre- and Post-Mitigation Assumptions for Sewer Utility Protection

Return Period	Pre-Mitigation		Post-Mitigation	
	Functional Downtime	Power Service Losses	Functional Downtime	Power Service Losses
8-year	1	$4,495,986	0	$0
31-year	-	-	1	$4,495,986

4. Erosion Level of Protection

After mitigation the sewer lines will be protected via streambank stabilization measures from current and future erosion. To ensure a conservative analysis, it has been assumed that the stabilization measures will last at least until the end of its identified project useful life of 30 years. This would mean that at the end of the useful service life of the erosion stabilization measures, erosion will have continued as normal.

Therefore, analysts assumed that the estimated erosion time for the electrical utilities to experience "full loss" would still be required before the properties are again threatened by erosion. This should be deemed a conservative estimate as it relies on the predication that the City of Gastonia would ignore continued maintenance and future improvements of the erosion stabilization measures implemented. Analysts added 30 years to the failure event for the post-mitigation erosion assessment, and similar damages and outage times were applied.

5. Analysis Results

The benefit-cost ratio for the project is listed in Table 10 below. Costs provided in the determination of the BCR include maintenance costs over the project useful life of the mitigation project. The total project BCR is 1.47 which demonstrates that the mitigation project is a cost-effective solution. The BCA Report is provided in Appendix A and the BCA Excel Spreadsheet is attached to the project application.

Table 8. Critical Infrastructure Protection and Stream Restoration Project Benefit-Cost Ratio

Description	Benefits	Costs	BCR
Critical Infrastructure Protection and Stream Restoration	$12,513,067	$8,526,452	1.47

Attachments

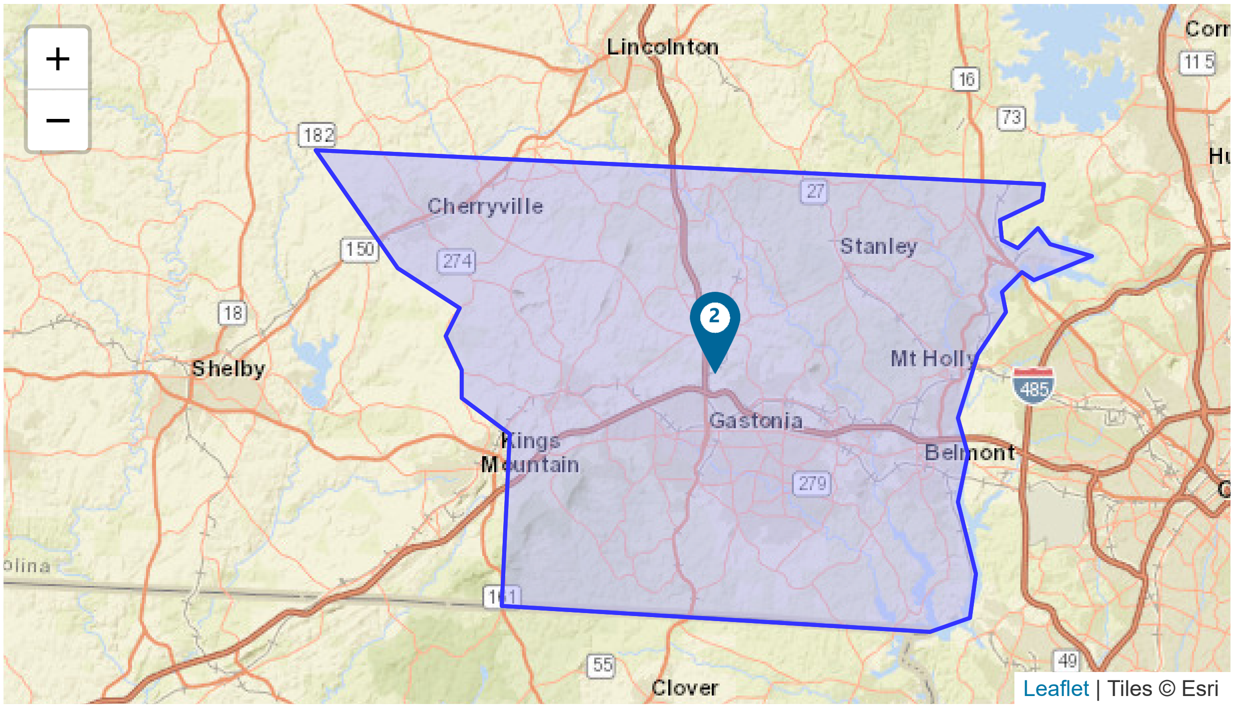
Appendix A Benefit-Cost Estimator Report
Appendix B NOAA Point Frequency Estimates
Appendix C Preliminary Engineering Report
Appendix D North Carolina Climate Science Report

Benefit-Cost Calculator

V.6.0 (Build 20211021.0641)

Benefit-Cost Analysis

Project Name: Gastonia Duhart's Creek Critical Infrastructure Protection and Stream Restoration



Map Marker ▲	Mitigation Title	Property Type	Hazard	Benefits (B)	Costs (C)	BCR (B/C)
1	Floodplain and Stream Restoration @ Gaston County, North Carolina		DFA - Riverine Flood	$ 7,338,906	$ 8,526,451	0.86
2	Floodplain and Stream Restoration @ Gaston County, North Carolina		DFA - Riverine Flood	$ 5,174,161	$ 1	5,174,161.00
TOTAL (SELECTED)				**$ 12,513,067**	**$ 8,526,452**	**1.47**
TOTAL				**$ 12,513,067**	**$ 8,526,452**	**1.47**

Property Configuration

Property Title:	Floodplain and Stream Restoration @ Gaston County, North Carolina
Property Location:	28034, Gaston, North Carolina
Property Coordinates:	35.2941747, -81.1801586
Hazard Type:	Riverine Flood
Mitigation Action Type:	Floodplain and Stream Restoration
Property Type:	Utilities
Analysis Method Type:	Professional Expected Damages

Cost Estimation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Project Useful Life (years):	30
Project Cost:	$7,905,999
Number of Maintenance Years:	30 Use Default:Yes
Annual Maintenance Cost:	$50,000

Damage Analysis Parameters - Damage Frequency Assessment

Floodplain and Stream Restoration @ Gaston County, North Carolina

Year of Analysis Conducted:	2021
Year Property was Built:	0
Analysis Duration:	10 Use Default:Yes

Utilities Properties

Floodplain and Stream Restoration @ Gaston County, North Carolina

Type of Service:	Wastewater
Number of Customers Served:	9,800
Value of Unit of Service ($/person/day):	$58 Use Default:Yes
Total Value of Service Per Day ($/day):	$568,400

Professional Expected Damages Before Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

	WASTEWATER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Impact (days)	Category 1 ($)	Category 2 ($)	Category 3 ($)	Number of Volunteers	Number of Days	Damages ($)
2	1	0	0	0	0	0	568,400
5	2	0	0	0	0	0	1,136,800
10	5	0	0	0	0	0	2,842,000

Annualized Damages Before Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	568,400	241,152
5	1,136,800	179,744
10	2,842,000	284,200
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	4,547,200	705,096

Professional Expected Damages After Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

	WASTEWATER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Impact (days)	Category 1 ($)	Category 2 ($)	Category 3 ($)	Number of Volunteers	Number of Days	Damages ($)
25	5	0	0	0	0	0	2,842,000

Annualized Damages After Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
25	2,842,000	113,680
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	2,842,000	113,680

Standard Benefits - Ecosystem Services

Floodplain and Stream Restoration @ Gaston County, North Carolina

Total Project Area (acres):	0
Percentage of Green Open Space:	0.00%
Percentage of Riparian:	0.00%
Percentage of Wetlands:	0.00%
Percentage of Forests:	0.00%
Percentage of Marine Estuary:	0.00%
Expected Annual Ecosystem Services Benefits:	$0

Benefits-Costs Summary

Floodplain and Stream Restoration @ Gaston County, North Carolina

Total Standard Mitigation Benefits:	$7,338,906
Total Social Benefits:	$0
Total Mitigation Project Benefits:	$7,338,906
Total Mitigation Project Cost:	$8,526,451
Benefit Cost Ratio - Standard:	0.86
Benefit Cost Ratio - Standard + Social:	0.86

Property Configuration

Property Title:	Floodplain and Stream Restoration @ Gaston County, North Carolina
Property Location:	28034, Gaston, North Carolina
Property Coordinates:	35.2941747, -81.1801586
Hazard Type:	Riverine Flood
Mitigation Action Type:	Floodplain and Stream Restoration
Property Type:	Utilities
Analysis Method Type:	Professional Expected Damages

Cost Estimation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Project Useful Life (years):	30
Project Cost:	$1
Number of Maintenance Years:	30 Use Default:Yes
Annual Maintenance Cost:	$0

Damage Analysis Parameters - Damage Frequency Assessment

Floodplain and Stream Restoration @ Gaston County, North Carolina

Year of Analysis Conducted:	2021
Year Property was Built:	0
Analysis Duration:	10 Use Default:Yes

Utilities Properties

Floodplain and Stream Restoration @ Gaston County, North Carolina

Type of Service:	Electrical
Number of Customers Served:	25,839
Value of Unit of Service ($/person/day):	$174 Use Default:Yes
Total Value of Service Per Day ($/day):	$4,495,986

Professional Expected Damages Before Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

	ELECTRICAL	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Impact (days)	Category 1 ($)	Category 2 ($)	Category 3 ($)	Number of Volunteers	Number of Days	Damages ($)
8	1	0	0	0	0	0	4,495,986

Annualized Damages Before Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
8	4,495,986	561,998
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	4,495,986	561,998

Professional Expected Damages After Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

	ELECTRICAL	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Impact (days)	Category 1 ($)	Category 2 ($)	Category 3 ($)	Number of Volunteers	Number of Days	Damages ($)
31	1	0	0	0	0	0	4,495,986

Annualized Damages After Mitigation

Floodplain and Stream Restoration @ Gaston County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
31	4,495,986	145,031
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	4,495,986	145,031

Standard Benefits - Ecosystem Services

Floodplain and Stream Restoration @ Gaston County, North Carolina

Total Project Area (acres):	0
Percentage of Green Open Space:	0.00%
Percentage of Riparian:	0.00%
Percentage of Wetlands:	0.00%
Percentage of Forests:	0.00%
Percentage of Marine Estuary:	0.00%
Expected Annual Ecosystem Services Benefits:	$0

Benefits-Costs Summary

Floodplain and Stream Restoration @ Gaston County, North Carolina

Total Standard Mitigation Benefits:	$5,174,161
Total Social Benefits:	$0
Total Mitigation Project Benefits:	$5,174,161
Total Mitigation Project Cost:	$1
Benefit Cost Ratio - Standard:	5,174,161.00
Benefit Cost Ratio - Standard + Social:	5,174,161.00

NOAA Atlas 14, Volume 2, Version 3
Location name: Gastonia, North Carolina, USA*
Latitude: 35.2622°, Longitude: -81.187°
Elevation: 806.88 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.395 (0.364-0.429)	0.466 (0.429-0.508)	0.546 (0.501-0.594)	0.605 (0.554-0.657)	0.675 (0.615-0.733)	0.725 (0.657-0.788)	0.773 (0.696-0.840)	0.817 (0.731-0.890)	0.871 (0.770-0.952)	0.910 (0.797-0.999)
10-min	0.631 (0.581-0.685)	0.746 (0.687-0.813)	0.874 (0.802-0.952)	0.967 (0.886-1.05)	1.08 (0.980-1.17)	1.16 (1.05-1.25)	1.23 (1.11-1.34)	1.30 (1.16-1.41)	1.38 (1.22-1.51)	1.43 (1.26-1.57)
15-min	0.789 (0.726-0.856)	0.938 (0.863-1.02)	1.11 (1.01-1.20)	1.22 (1.12-1.33)	1.36 (1.24-1.48)	1.46 (1.32-1.59)	1.55 (1.40-1.69)	1.64 (1.46-1.78)	1.73 (1.53-1.90)	1.80 (1.58-1.98)
30-min	1.08 (0.995-1.17)	1.30 (1.19-1.41)	1.57 (1.44-1.71)	1.77 (1.62-1.93)	2.02 (1.84-2.19)	2.20 (2.00-2.39)	2.38 (2.14-2.59)	2.55 (2.27-2.77)	2.76 (2.44-3.02)	2.91 (2.55-3.20)
60-min	1.35 (1.24-1.46)	1.63 (1.50-1.77)	2.01 (1.85-2.19)	2.31 (2.11-2.51)	2.69 (2.45-2.92)	2.98 (2.70-3.24)	3.28 (2.95-3.56)	3.57 (3.19-3.89)	3.96 (3.50-4.33)	4.25 (3.73-4.67)
2-hr	1.57 (1.44-1.72)	1.90 (1.74-2.09)	2.37 (2.17-2.60)	2.74 (2.49-3.00)	3.23 (2.92-3.53)	3.61 (3.25-3.95)	4.00 (3.58-4.38)	4.40 (3.91-4.83)	4.95 (4.34-5.45)	5.38 (4.67-5.95)
3-hr	1.68 (1.53-1.85)	2.02 (1.85-2.23)	2.53 (2.31-2.79)	2.94 (2.67-3.23)	3.50 (3.16-3.84)	3.95 (3.55-4.34)	4.42 (3.94-4.85)	4.92 (4.34-5.41)	5.61 (4.88-6.20)	6.18 (5.31-6.85)
6-hr	2.04 (1.88-2.24)	2.46 (2.26-2.70)	3.08 (2.82-3.37)	3.57 (3.26-3.90)	4.25 (3.86-4.64)	4.81 (4.34-5.25)	5.40 (4.83-5.90)	6.01 (5.32-6.58)	6.89 (6.00-7.55)	7.60 (6.54-8.36)
12-hr	2.45 (2.26-2.68)	2.96 (2.72-3.24)	3.71 (3.40-4.05)	4.31 (3.94-4.70)	5.15 (4.68-5.61)	5.84 (5.27-6.35)	6.56 (5.87-7.13)	7.33 (6.48-7.96)	8.42 (7.33-9.15)	9.32 (8.00-10.1)
24-hr	2.86 (2.66-3.06)	3.44 (3.21-3.71)	4.32 (4.03-4.65)	5.02 (4.67-5.39)	5.97 (5.53-6.40)	6.72 (6.22-7.21)	7.50 (6.92-8.04)	8.30 (7.63-8.90)	9.40 (8.60-10.1)	10.3 (9.36-11.0)
2-day	3.37 (3.13-3.61)	4.05 (3.77-4.36)	5.05 (4.71-5.43)	5.84 (5.43-6.28)	6.92 (6.41-7.43)	7.78 (7.19-8.35)	8.65 (7.97-9.29)	9.55 (8.78-10.3)	10.8 (9.87-11.6)	11.8 (10.7-12.6)
3-day	3.57 (3.33-3.83)	4.29 (4.01-4.60)	5.32 (4.96-5.70)	6.14 (5.71-6.57)	7.25 (6.73-7.76)	8.13 (7.53-8.71)	9.03 (8.34-9.68)	9.96 (9.18-10.7)	11.2 (10.3-12.0)	12.2 (11.2-13.1)
4-day	3.78 (3.53-4.04)	4.53 (4.24-4.85)	5.59 (5.22-5.98)	6.43 (5.99-6.87)	7.58 (7.05-8.09)	8.49 (7.87-9.07)	9.41 (8.72-10.1)	10.4 (9.57-11.1)	11.7 (10.7-12.5)	12.7 (11.6-13.6)
7-day	4.36 (4.09-4.63)	5.20 (4.88-5.52)	6.33 (5.94-6.72)	7.23 (6.77-7.67)	8.46 (7.90-8.98)	9.44 (8.80-10.0)	10.4 (9.72-11.1)	11.5 (10.6-12.2)	12.9 (11.9-13.7)	14.0 (12.9-14.9)
10-day	4.98 (4.70-5.30)	5.92 (5.59-6.30)	7.12 (6.71-7.56)	8.06 (7.59-8.55)	9.32 (8.75-9.89)	10.3 (9.66-10.9)	11.3 (10.6-12.0)	12.3 (11.5-13.1)	13.7 (12.7-14.6)	14.8 (13.7-15.7)
20-day	6.66 (6.30-7.05)	7.86 (7.44-8.32)	9.28 (8.78-9.82)	10.4 (9.83-11.0)	11.9 (11.2-12.6)	13.1 (12.3-13.8)	14.3 (13.4-15.1)	15.5 (14.5-16.4)	17.1 (15.9-18.1)	18.4 (17.1-19.5)
30-day	8.19 (7.78-8.63)	9.64 (9.15-10.1)	11.2 (10.6-11.8)	12.4 (11.8-13.1)	14.0 (13.3-14.8)	15.3 (14.4-16.1)	16.5 (15.5-17.4)	17.7 (16.6-18.7)	19.3 (18.1-20.4)	20.6 (19.2-21.7)
45-day	10.3 (9.85-10.8)	12.1 (11.5-12.6)	13.8 (13.1-14.4)	15.1 (14.4-15.8)	16.8 (16.0-17.6)	18.1 (17.2-19.0)	19.4 (18.4-20.3)	20.6 (19.5-21.6)	22.2 (21.0-23.3)	23.4 (22.1-24.6)
60-day	12.2 (11.7-12.8)	14.3 (13.7-14.9)	16.1 (15.5-16.8)	17.6 (16.8-18.3)	19.4 (18.6-20.3)	20.8 (19.9-21.7)	22.1 (21.1-23.1)	23.4 (22.3-24.5)	25.1 (23.9-26.3)	26.4 (25.0-27.7)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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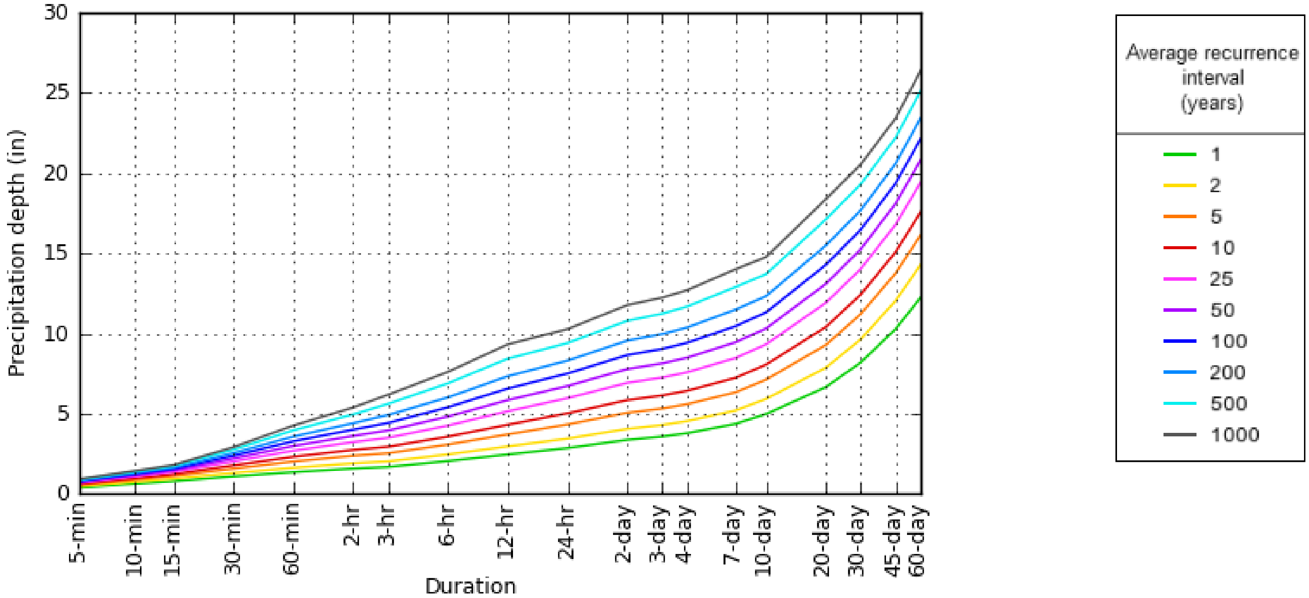
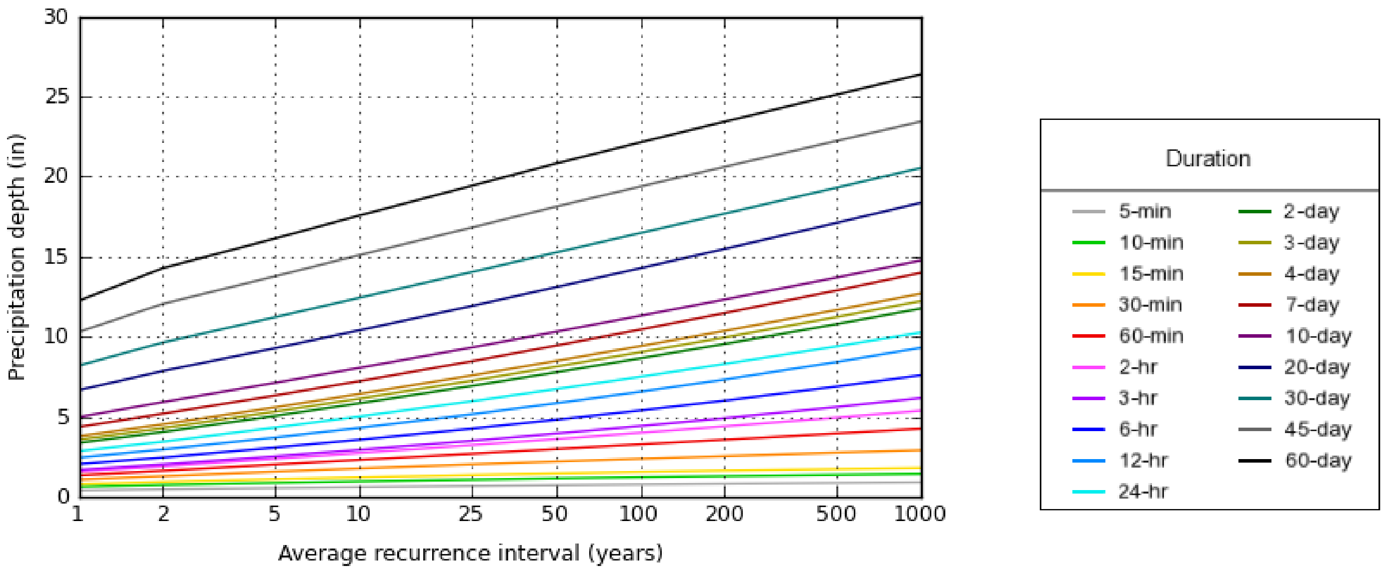
PF graphical

PDS-based depth-duration-frequency (DDF) curves
Latitude: 35.2622°, Longitude: -81.1870°





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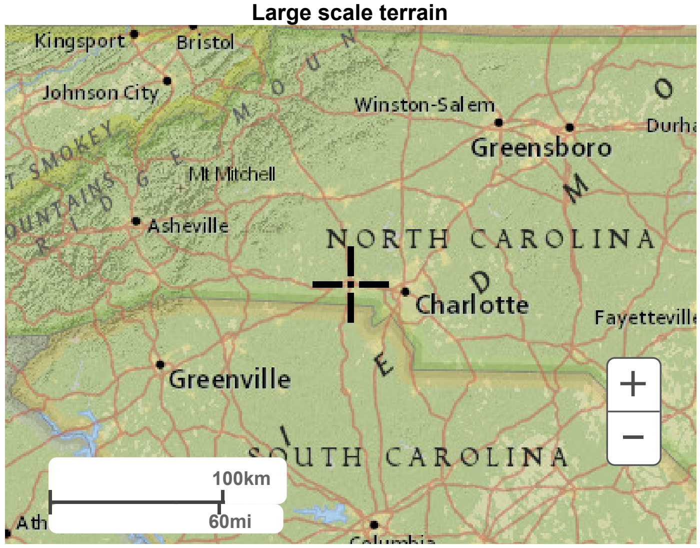
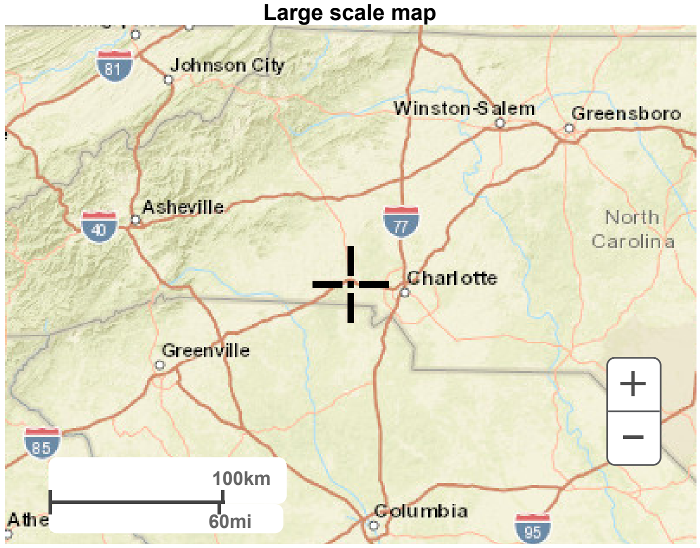
Maps & aerials

Small scale terrain

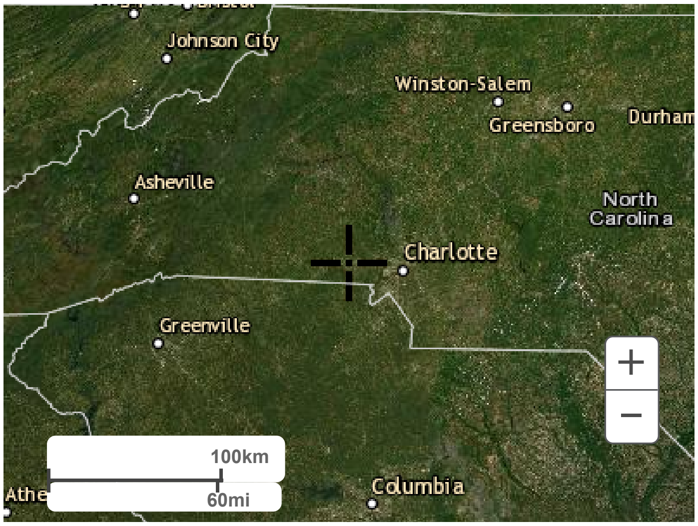
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

PRELIMINARY ENGINEERING REPORT

CITY OF GASTONIA DUHARTS CREEK STREAM RESTORATION AND SANITARY SEWER RELOCATION

KCI

TWO RIVERS UTILITIES

We are TRU to our customers!

Prepared for:

City of Gastonia

KCI Project No:

962106226

NOVEMBER.2021

City of Gastonia Duharts Creek Stream Restoration and Sanitary Sewer Relocation

Preliminary Engineering Report

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Appendices

1. Background and Introduction

The purpose of this report is to evaluate the pervasive stream erosion and frequent flooding of Duharts Creek and to propose restoration of the stream and floodplain in order to prevent infrastructure damage caused by an unstable stream corridor.

Duharts Creek is located on the eastern side of Gastonia, North Carolina, near the border with Belmont. The reach of stream that is being considered for this project runs from US 74 (E. Franklin Boulevard) to Redbud Drive, covering a distance of roughly 8,000 linear feet of stream. Due to upstream development and alternations to the stream and watershed, the stream is experiencing severe erosion and bank instability that is threatening the nearby infrastructure and encroaching on private property. Rain events have been becoming more severe in recent years, contributing an increasing rate of bank erosion and larger flood volumes. This has directly jeopardized two gravity sewer lines, a forcemain and power infrastructure.

To reduce the risk of failure and to improve the overall stream stability and ecosystem, we propose 8,000 linear feet of stream and floodplain restoration that will create a stable stream form with associated floodplain that will reduce in-stream bank stress that induces erosion. Along with the stream restoration, a realignment will be performed on both gravity sewers and the forcemain to reroute them away from the stream. All existing sewer structure runs along the entire length of the project area with several aerial crossings.

2. Duharts Creek Existing Conditions

From E. Franklin Blvd to the upstream side of Redbud Drive, Duharts Creek flows approximately 8,000 feet as the project reach. As a part of a plan to protect the stream corridor and mitigate risk from flooding to sewer infrastructure, the City of Gastonia has acquired 49.2 acres of land along the stream, most of it covering the FEMA Zone AE floodplain extents along with existing easements along the sewer lines.

According to the US Geological Survey (USGS) StreamStats, the drainage area for Duharts Creek upstream of Redbud Drive is approximately 5.7 square miles. The average elevation is 754 feet and ranges from 894 feet to 654 feet. There is a high percentage of impervious cover in the project watershed, which has increased substantially in the last ten years. Table 1 shows the percentage of impervious cover from 2001 to 2019 based on the USGS National Land Cover Dataset (NLCD). Future development has continued since 2019, including the conversion of a parcel adjacent to the site, which has increased the impervious surface since 2019. There is the potential for future development as well in the northeastern corner of the watershed where there is undeveloped land.

Year	Watershed Impervious Area (%)	Relative Change (%)
2001	29.8%	-
2006	30.2%	1.4
2011	30.5%	0.9
2016	33.4%	9.5
2019	33.7%	0.9

Table 1. Total impervious area for project watershed over 2001-2019.

A high percentage of impervious cover in a watershed can induce additional erosion and more severe flooding by routing water into the stream faster than it would naturally enter during heavy precipitation events and reduce the absorption of water by vegetation. The stream was also straightened at some point, which has disconnected the stream from a floodplain that is accessible at lower-frequency storm events. These conditions are combined with the fact that precipitation events are becoming more severe. Table 2 shows that over a two-year period, the project watershed has experienced at least five storms that have exceeded the one-year recurrence interval.

Event	Precipitation (in)	Recurrence Interval (yr)	Duration (hr)
10/11/2018	2.67	1-2	12
4/13/2019	1.56	1	3
2/6/2020	3.44	5-10	6
5/27/2020	1.98	1	6
11/12/2020	2.83	2-5	6

Table 2. Recent large storm events recorded at the USGS 351452081055245 rain gage at Duharts Creek.

Date	Peak Stage (ft)	Peak Elevation (ft)*	Peak Streamflow (cfs)
4/13/2019	6.49	641.38	1,170
2/6/2020	8.55	643.44	2,700
11/12/2020	6.48	641.37	1,300

**FEMA Zone AE Elev. at gage = 647.8*

Table 3. Recent peak streamflow events recorded at the USGS 02145268 stream gage at Duharts Creek.

As a result of the flashy flows and confined channel, bank erosion is widespread along the project reach as the stream attempts to adjust against the current confines of the bank. We surveyed three stream cross-sections that the City of Gastonia has also measured in recent years and compared the 2017 measurements to those in 2021. Cross-section #1 in particular showed a loss of 89 square feet of channel where a tree fell, taking part of the bank with it.

River Basin:	Catawba
Site	Duharts Creek
XS ID	DC-xs1
Drainage Area (sq mi):	2.76
Date:	9/24/2021
Field Crew:	K. Knight-Meng, A. Gutierrez

Station	Elevation*
47.27	676.96
54.25	677.32
71.10	677.10
76.62	677.33
90.01	677.26
90.29	677.50
95.19	677.45
97.59	677.20
98.47	676.73
99.10	670.37
100.84	669.28
102.86	668.39
103.33	667.94
103.72	666.96
104.82	666.24
106.32	666.05
110.22	666.55
112.17	667.02
115.38	667.65
117.72	668.33
120.77	667.87
122.00	667.38
123.38	667.64
123.6	667.93
125.2	669.32
127.4	670.36
128.3	670.44
128.7	672.12
129.6	673.10
130.7	673.73
131.6	676.61
132.9	676.80
134.9	677.21
136.9	677.34
145.0	677.37
154.2	676.96

SUMMARY DATA	
Bankfull Elevation (ft):	670.4
Bankfull Cross-Sectional Area (ft^2):	73.7
Bankfull Width (ft):	28.5
Flood Prone Area Elevation (ft):	674.7
Flood Prone Width (ft):	32.3
Max Depth at Bankfull (ft):	4.3
Mean Depth at Bankful (ft)l:	2.6
W / D Ratio:	11.0
Entrenchment Ratio:	1.1
Bank Height Ratio:	2.4

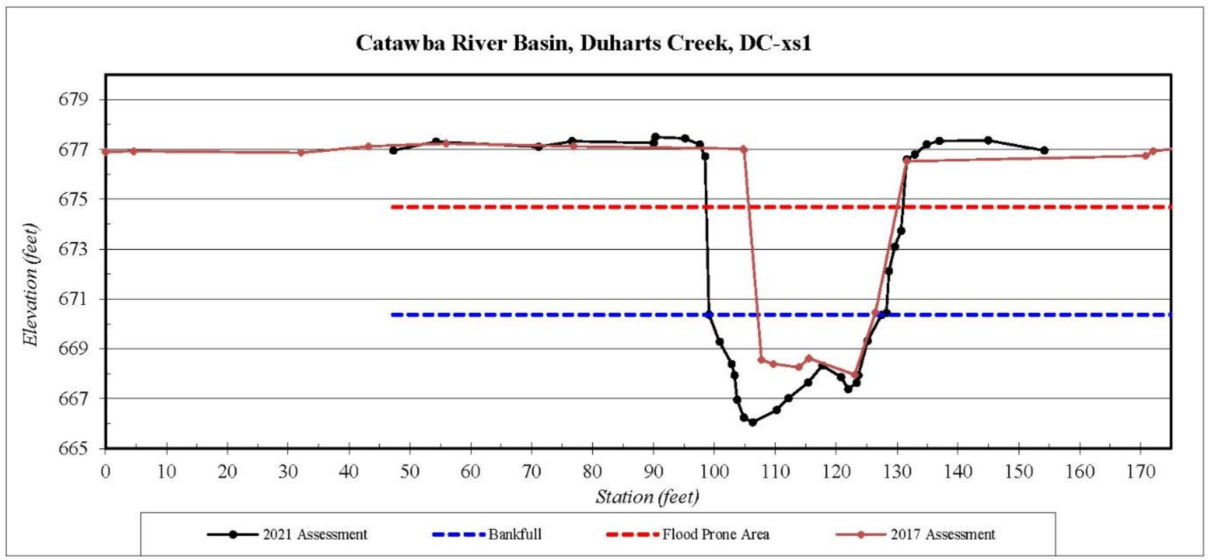

Figure 1. Cross-Section #1.

River Basin:	Catawba
Site	Duharts Creek
XS ID	DC-xs2
Drainage Area (sq mi):	2.94
Date:	9/24/2021
Field Crew:	K. Knight-Meng, A. Gutierrez

Station	Elevation*
34.75	672.43
45.68	672.10
56.31	672.40
63.08	672.34
73.20	672.72
76.74	673.06
79.67	673.31
81.62	673.24
82.36	673.00
83.13	672.16
84.60	667.66
85.86	665.78
86.46	664.48
87.82	664.54
90.91	664.16
92.58	664.44
93.94	664.46
96.64	664.28
99.23	664.07
102.33	664.21
104.18	664.51
105.17	665.57
106.66	667.60
107.54	669.33
108.2	671.87
108.7	672.22
110.0	672.76
113.1	672.98
131.1	672.80
161.2	673.03

SUMMARY DATA	
Bankfull Elevation (ft):	667.6
Bankfull Cross-Sectional Area (ft^2):	65.0
Bankfull Width (ft):	22.0
Flood Prone Area Elevation (ft):	671.1
Flood Prone Width (ft):	24.5
Max Depth at Bankfull (ft):	3.5
Mean Depth at Bankful (ft)l:	3.0
W / D Ratio:	7.5
Entrenchment Ratio:	1.1
Bank Height Ratio:	2.3

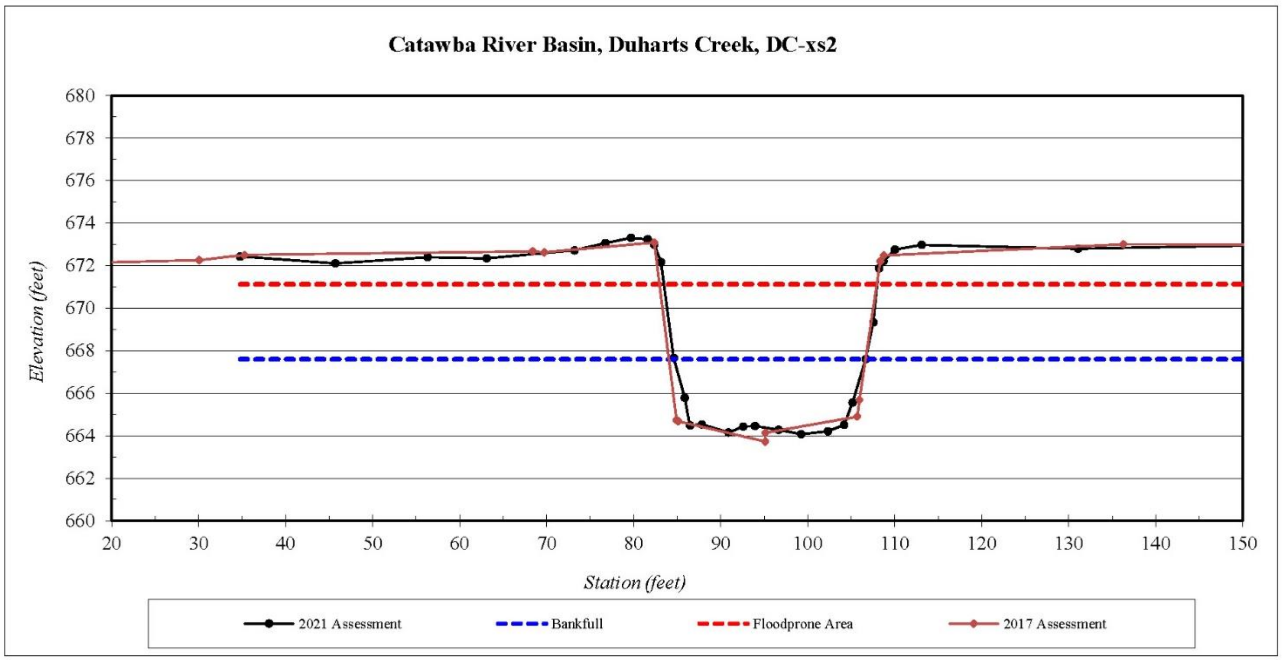

Figure 2. Cross-Section #2.

River Basin:	Catawba
Site	Duharts Creek
XS ID	DC-xs3
Drainage Area (sq mi):	4.08
Date:	9/24/2021
Field Crew:	K. Knight-Meng, A. Gutierrez

Station	Elevation*
14.72	668.15
28.96	668.41
45.57	668.65
54.28	668.75
75.84	668.63
97.12	669.08
102.40	669.25
111.15	669.81
114.96	669.62
117.50	665.08
117.16	663.83
118.75	662.83
118.85	661.26
119.82	660.73
123.40	660.82
126.95	660.91
128.96	661.29
133.32	661.56
138.83	661.89
144.11	662.02
146.13	664.13
149.53	665.99
151.03	666.73
152.20	667.16
153.45	667.51
160.22	668.48
170.89	669.88
179.47	669.24

* 2021 XS right bank extent varied slightly from 2017 due to site constaints.

SUMMARY DATA	
Bankfull Elevation (ft):	663.83
Bankfull Cross-Sectional Area (ft^2):	64.2
Bankfull Width (ft):	28.7
Flood Prone Area Elevation (ft):	666.9
Flood Prone Width (ft):	35.1
Max Depth at Bankfull (ft):	3.1
Mean Depth at Bankful (ft)l:	2.2
W / D Ratio:	12.8
Entrenchment Ratio:	1.2
Bank Height Ratio:	2.9

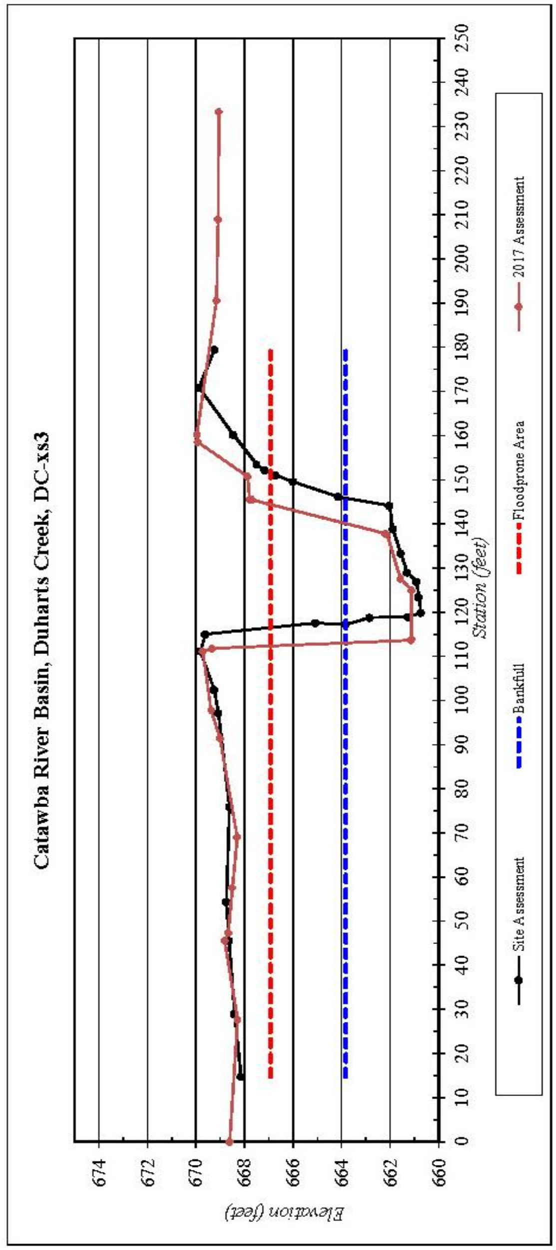

Figure 3. Cross-Section #3.

To estimate an annual rate of erosion, we used two different methods. One, we averaged the rate of channel loss from monitored stream cross-sections from the measurements taken in 2017 and 2021. Second, we used a bank erosion curve from North Carolina State University (NCSU) to estimate the loss rate assuming "Very High" Bank Erosion Hazard Index (BEHI) and "Very High" Near-Bank Stress (NBS) scores. Table 2 shows that they are in a similar range of 6,000-7,000 tons/sediment being lost per year.

Bank Erosion Rate Method	Bank Erosion Rate	Tons/Linear Foot Channel Per Year	Total for Project Reach (8,000 lf)
1. On-Site Cross-Section Measurements	1.00 ft/yr	0.76 tons/lf	6,080 tons/year
2. NCSU Bank Erosion Curve	1.14 ft/yr	0.87 tons/lf	6,976 tons/year

Table 4. Estimate of bank erosion rates for the project reach of Duharts Creek.

Severe bank erosion will undermine existing mature trees at the top of a streambank, which is happening all along Duharts Creek. As the trees lose their rooting strength, they fall into the channel, which causes a large amount of sediment to enter the channel and induces a new weak spot in the bank profile for further erosion. In addition, the downed trees can create localized blockages or become mobilized and create debris jams further downstream that can damage infrastructure. Figure 4 shows a problem area on Duharts Creek where an aerial sewer line crossing is catching a large amount of woody debris, further threatening the stability of this line in an already vulnerable location.

Figure 4. An aerial sewer line cross on Duharts Creek that is catching large amounts of woody debris.

There is also the potential for power disruption from Duharts Creek flooding, which is seen in **Figure 5**, showing a power line alongside and crossing the creek. There is also a high-tension power cable tower nearby, which could cause much larger outages if damaged by flooding.

Figure 5. This photo shows the power lines that could potentially suffer flood damages.

Buried sewer lines are also at a risk from stream erosion if the line is close the existing bank. The ground around the pipe can be eroded away, leaving them exposed and more likely to suffer damage and leaking. Figure 6 shows a line at Duharts Creek that is exposed on an outer bend in the lower portion of the channel, which is where a high amount of shear stress occurs during higher flows.

Figure 6. Photo of exposed underground sewer pipe in Duharts Creek at a point of active erosion.

3. Duharts Creek Mitigation Concept Design Approach

The existing channel of Duharts Creek has been impacted by both watershed and on-site changes. At some point, the stream was straightened during the 20th century, which reduced the amount of floodplain available to the stream. Further development and a changing climate have further induced downcutting and bank erosion in the stream. The proposed restoration will construct a new stream channel sized to the appropriate bankfull width and depth. In-stream structures, such as vegetated soil lifts, construction riffles, and wood toe, will be used to both stabilize the new channel and provide aquatic habitat. Figure 7 shows an example of another project where a vegetated soil lift. The layers of soil are placed at a stable bank angle and then planted with native vegetation. Following one year after construction, the stream bank has become stabilized with vegetation.

Figure 7. Before, immediately after, and one year following construction of a vegetated soil lift with boulder toe.

In addition to the channel modifications, floodplain grading will be completed to recreate a stream corridor that will accommodate flashy storms on an adjacent floodplain. While this will require significant grading, the process will lower the flood elevations throughout the project corridor and provide stormwater capacity for larger storms in a watershed with the potential for more development. Figure 8 shows a before and after photo of a stream with an incised channel and no floodplain and then less than a year following construction that included an excavated floodplain.

Figure 8. Before (above) and less than one year (below) after construction showing a stream with restored floodplain.

Table 5 presents the conceptual-level design morphological criteria for the restoration of Duharts Creek alongside the existing impaired stream parameters documented with the surveyed stream cross-sections. The proposed design represents a stable bankfull stream cross-section that would flood frequently at lower elevations than currently into an adjacent floodplain below the existing elevations of the neighboring residential properties.

	Stream Morphological Parameters	Existing Stream Duharts Creek	Stable Design Ratios		Proposed Stream Duharts Creek
	Stream Type (Rosgen)	C4/B4c	B4c	C4	C4/B4c
	Drainage Area (mi^2)	2.76, 2.94, 4.08		~	5.7
	Bankfull Width (W_{bkf}) (ft)	28.5, 22.0, 28.7		~	32.0
	Bankfull Mean Depth (D_{bkf}) (ft)	2.6, 3.0, 2.2		~	2.1
	Bankfull Cross-Sectional Area (A_{bkf}) (ft^2)	73.7, 65.0, 64.2		~	66.5
	Width / Depth Ratio (W_{bkf} / D_{bkf})	11.0, 7.5, 12.8	12 -- 18	10 -- 15	15.4
	Maximum Depth (d_{mbkf}) (ft)	4.3, 3.5, 3.1	1.2-1.4 / bkf	~	2.6
	Width of Flood Prone Area (W_{fpa}) (ft)	32.3, 24.5, 35.1		~	64.0+
	Entrenchment Ratio (ER)	2.4, 1.1, 1.2	1.4 -- 2.2	>2.2	2.0+
	Sinuosity (stream length/valley length) (K)	1.3	1.1 -- 1.3	1.2 -- 1.4	1.1-1.3
Dimension	Pool Mean Depth (ft)	N/A		~	4.2
	Riffle Mean Depth (ft) (Dbkf)	2.6, 3.0, 2.2		~	2.1
	Pool Width (ft)	N/A		~	42.0
	Riffle Width (ft)	28.5, 22.0, 28.7		~	32.0
	Pool XS Area (sf)	N/A		~	178.4
	Riffle XS Area (sf)	73.7, 65.0, 64.2		~	66.5
	Pool Width / Riffle Width	N/A	1.1 -- 1.5	1.2 -- 1.7	1.3
	Pool Max Depth / D_{bkf}	N/A	2.0 -- 3.5	1.5 -- 3.5	3.0
	Bank Height Ratio	2.4, 2.3, 2.9	1.0 -- 1.1	1.0 -- 1.1	1.0
	Mean Bankfull Velocity (V) (fps)	4.5, 4.8, 4.1	4.0 -- 6.0	3.5 -- 5.0	4.7
	Bankfull Discharge (Q) (cfs)	336.4, 310.3, 263.9		~	315.0

Table 5. Conceptual proposed design criteria for a restoration of Duharts Creek.

4. Sewer Relocation

Due to the stream realignment, the gravity sewer and force mains that currently run along the creek will be relocated further north. The sewer relocation will be done in conjunction with the grading and excavation of the stream realignment.

5. Community Context and Resilience

There are several community factors that make this project desirable. The City already has several partners through the Adopt-A-Stream program, bolstering community engagement. The city has also partnered with the Gaston-Cleveland-Lincoln Metropolitan Planning Organization to plan for a greenway along the creek. This project would be beneficial for the local community and could help reinforce the community value of Duharts Creek. The restored stream would serve as a learning laboratory for schools or other youth groups that would want to explore the changes in a newly restored stream. Educational signage, viewing platforms, or nature trails could also be developed as part of the project.

The project impacts several aspects of infrastructure and civic administration defined by FEMA as "lifelines". Namely, the gravity sewer lines and forcemain serve over 25 medical facilities, three fire stations, two police departments, two schools and one government building. There are also numerous homes and businesses connected to this sewer service. The damage of the sewer lines could suspend services at these buildings, which would negatively impact the surrounding area. A Norfolk and Southern rail station could also be affected, disrupting travel.

6. Estimated Cost and Schedule

An estimated construction budget and schedule are attached in Appendix C.

Appendix A- Maps

StreamStats Report

Region ID: NC
Workspace ID: NC20211012174446909000
Clicked Point (Latitude, Longitude): 35.25186, -81.11022
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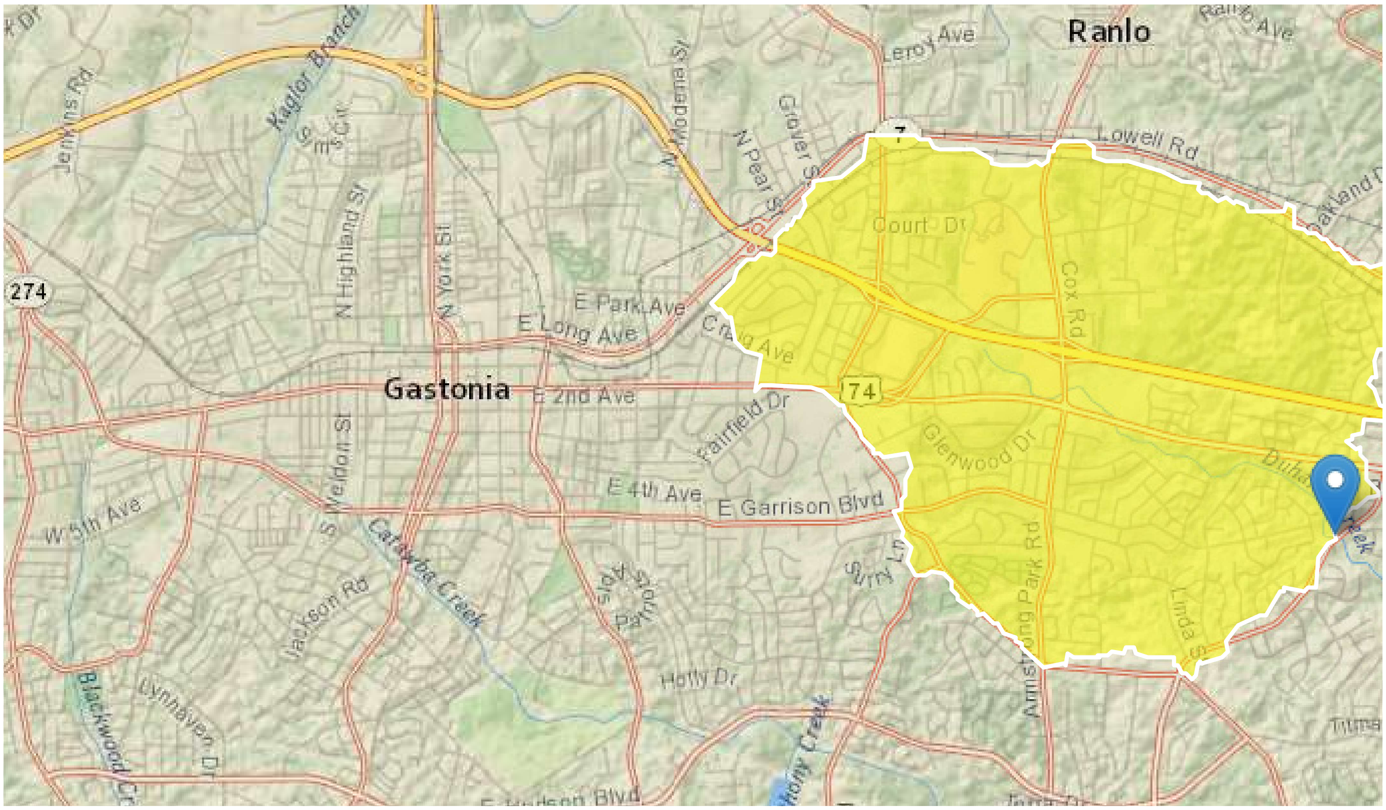


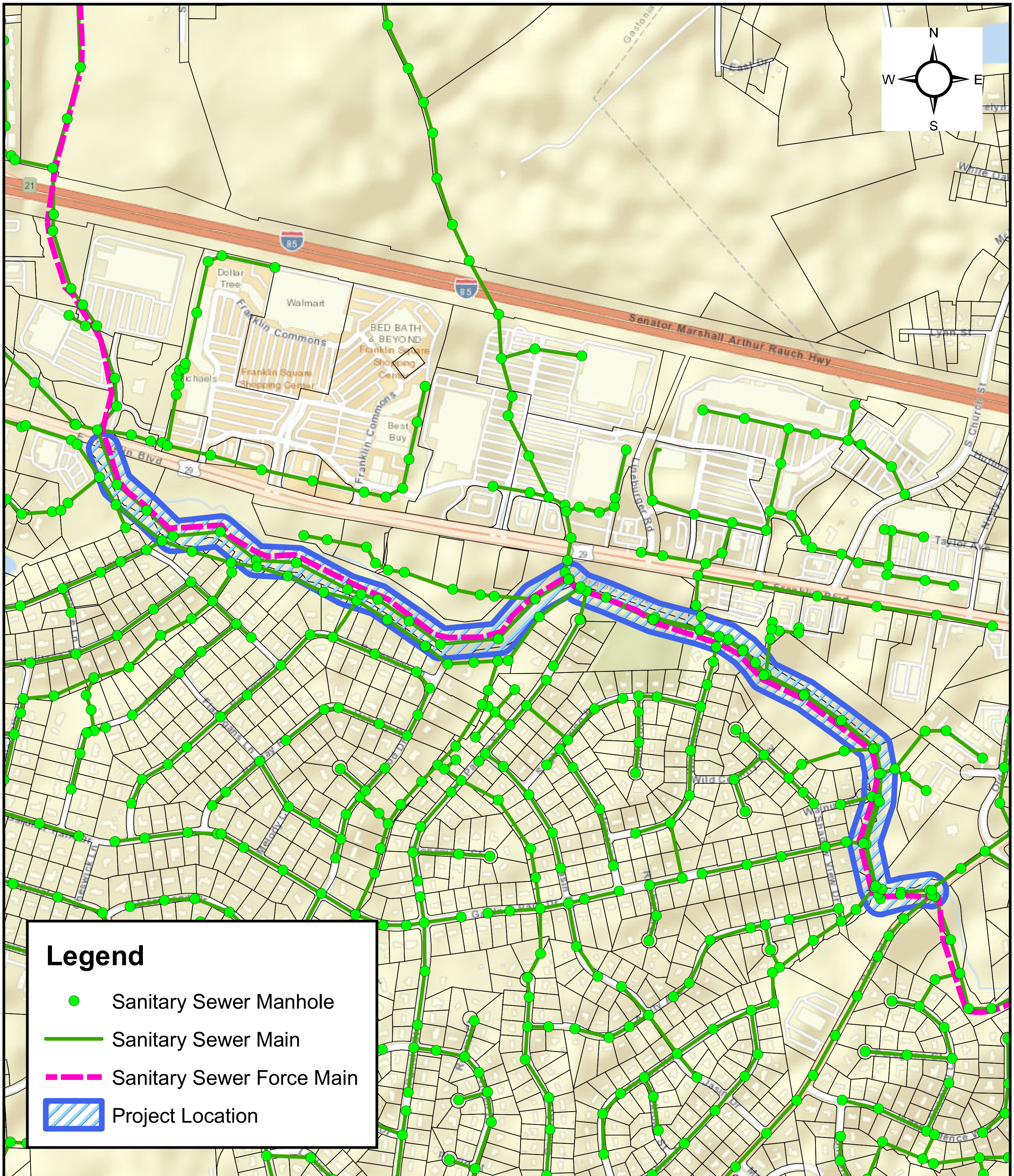
Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BASINPERIM	Perimeter of the drainage basin as defined in SIR 2004-5262	14.8	miles
BSLDEM30FT	Mean basin slope, based on slope percent grid	6.95	percent
CSL10_85fm	Change in elevation between points 10 and 85 percent of length along main channel to basin divide divided by length between points ft per mi	34.94	feet per mi
DRNAREA	Area that drains to a point on a stream	5.68	square miles
ELEV	Mean Basin Elevation	754	feet

Parameter Code	Parameter Description	Value	Unit
ELEVMAX	Maximum basin elevation	894	feet
I24H50Y	Maximum 24-hour precipitation that occurs on average once in 50 years	6.64	inches
LC01BARE	Percentage of area barren land, NLCD 2001 category 31	0	percent
LC01CRPHAY	Percentage of cultivated crops and hay, classes 81 and 82, from NLCD 2001	1.7	percent
LC01DEV	Percentage of land-use from NLCD 2001 classes 21-24	83.2	percent
LC01FOREST	Percentage of forest from NLCD 2001 classes 41-43	13.4	percent
LC01HERB	Percentage of herbaceous upland from NLCD 2001 class 71	0.9	percent
LC01IMP	Percent imperviousness of basin area 2001 NLCD	29.82	percent
LC01SHRUB	Percent of area covered by shrubland using 2001 NLCD	0.1	percent
LC01WATER	Percentage of open water, class 11, from NLCD 2001	0	percent
LC01WETLND	Percentage of wetlands, classes 90 and 95, from NLCD 2001	0.6	percent
LC06BARE	Percent of area covered by barren rock using 2006 NLCD	0.2	percent
LC06DEV	Percentage of land-use from NLCD 2006 classes 21-24	83.4	percent
LC06FOREST	Percentage of forest from NLCD 2006 classes 41-43	13.1	percent
LC06GRASS	Percent of area covered by grassland/herbaceous using 2006 NLCD	1.1	percent
LC06IMP	Percentage of impervious area determined from NLCD 2006 impervious dataset	30.23	percent
LC06PLANT	Percent of area in cultivation using 2006 NLCD	1.4	percent
LC06SHRUB	Percent of area covered by shrubland using 2006 NLCD	0.1	percent
LC06WATER	Percent of open water, class 11, from NLCD 2006	0	percent
LC06WETLND	Percent of area covered by wetland using 2006 NLCD	0.6	percent
LC11BARE	Percentage of barren from NLCD 2011 class 31	0	percent
LC11CRPHAY	Percentage of cultivated crops and hay, classes 81 and 82, from NLCD 2011	1.4	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	83.7	percent
LC11FOREST	Percentage of forest from NLCD 2011 classes 41-43	13	percent
LC11GRASS	Percent of area covered by grassland/herbaceous using 2011 NLCD	1	percent

Parameter Code	Parameter Description	Value	Unit
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	30.5	percent
LC11SHRUB	Percent of area covered by shrubland using 2011 NLCD	0.3	percent
LC11WATER	Percent of open water, class 11, from NLCD 2011	0	percent
LC11WETLND	Percentage of wetlands, classes 90 and 95, from NLCD 2011	0.6	percent
LC92FOREST	Percentage of forest from NLCD 1992 classes 41-43	27.3	percent
LFPLENGTH	Length of longest flow path	4.116	miles
LU92BARE	Percent of area covered by barren rock using 1992 NLCD	1.5	percent
LU92DEV	Percent of area covered by all densities of developed land using 1992 NLCD	65.2	percent
LU92PLANT	Percent of area in cultivation using 1992 NLCD	4.9	percent
LU92WATER	Percent of area covered by water using 1992 NLCD	0	percent
LU92WETLN	Percent of area covered by wetland using 1992 NLCD	1.1	percent
MINBELEV	Minimum basin elevation	654	feet
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88	657	feet
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley	100	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge	0	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills	0	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains	0	percent
PCTREG5	Percentage of drainage area located in Region 5 - Lower Tifton Uplands	0	percent
PRECIP	Mean Annual Precipitation	46.1	inches
PROTECTED	Percent of area of protected Federal and State owned land	0	percent
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	0	percent
SSURGOB	Percentage of area of Hydrologic Soil Type B from SSURGO	75.3	percent
SSURGOC	Percentage of area of Hydrologic Soil Type C from SSURGO	8.2	percent
SSURGOD	Percentage of area of Hydrologic Soil Type D from SSURGO	0.5	percent

Application Version: 4.6.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.1.2



GASTONIA NC

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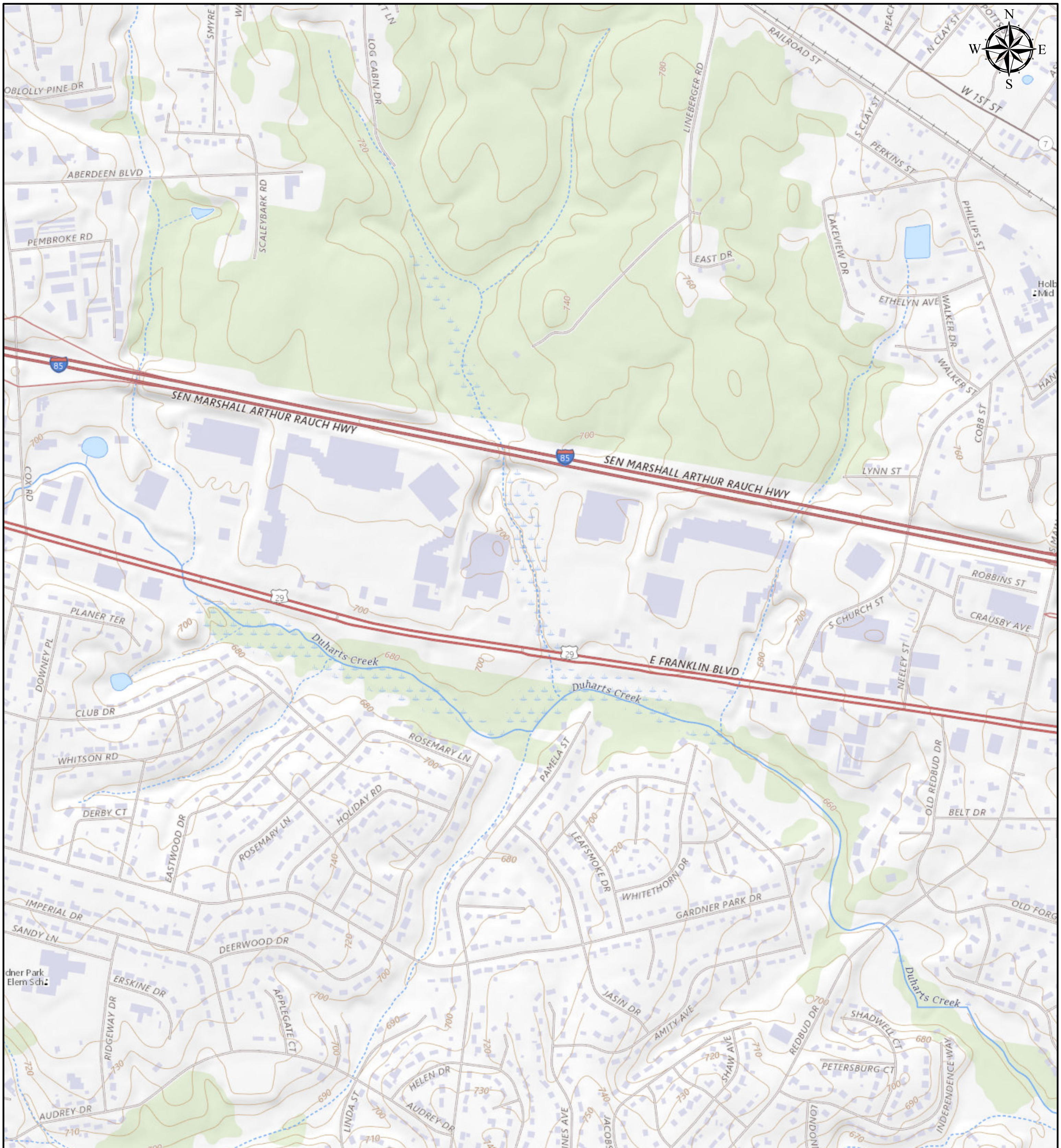
0 750 1,500 3,000 Feet

Project Location Map
City of Gastonia
Gastonia, North Carolina



Topographic Map
City of Gastonia
Gastonia, North Carolina

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0 950 1,900 3,800
Feet

Appendix B – Drawings

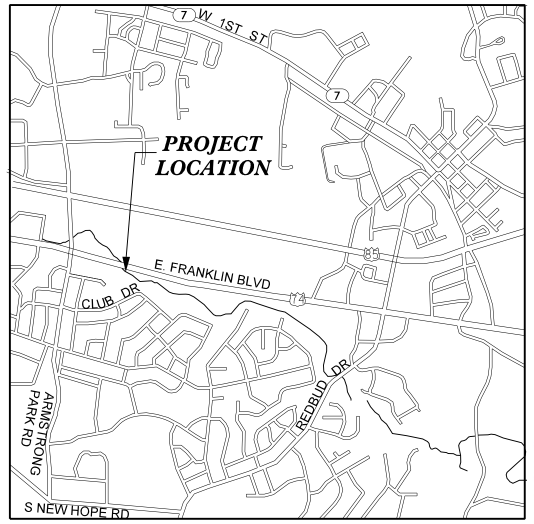
KCI JOB# : 962106226

STATE		SHEET NO.	TOTAL SHEETS
N.C.		1	18

CITY OF GASTONIA

DUHARTS CREEK

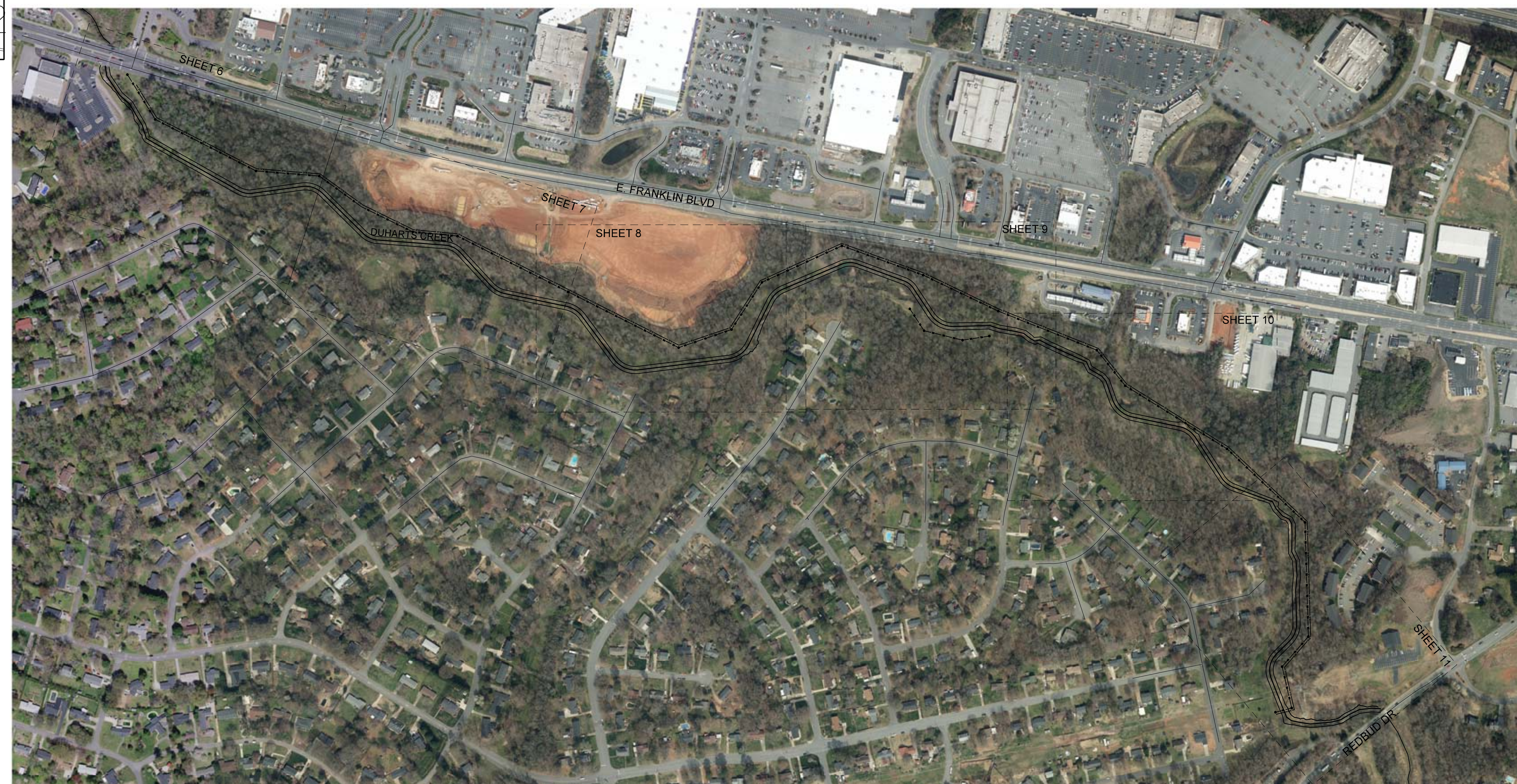
GASTON COUNTY, NORTH CAROLINA
CATAWBA RIVER BASIN



VICINITY MAP
NOT TO SCALE

NC GRID NAD '83

–300′ 0′ 300′ 600′
GRAPHIC SCALE



DIRECTIONS TO SITE

FROM GASTONIA, HEAD EAST ON W FRANKLIN BLVD TOWARDS S CHESTER ST. CONTINUE STRAIGHT ONTO E FRANKLIN BLVD FOR 2.5 MILES. BEGINNING OF PROJECT SITE WILL ON THE RIGHT.

INDEX OF SHEETS

Prepared in the Office of:
KCI ASSOCIATES OF NC
ENGINEERS•PLANNERS•ECOLOGISTS
4505 FALLS OF NEUSE ROAD
SUITE 400
RALEIGH, NC 27609

Prepared for:
CITY OF GASTONIA

Prepared by:
KRISTIN E. KNIGHT, PE
PROJECT ENGINEER

PROJECT ENGINEER

DRAFT

SIGNATURE: P.E.

GENERAL NOTES:

BEARINGS AND DISTANCES:
ALL BEARINGS ARE NAD 1983 GRID BEARINGS.
ALL DISTANCES AND COORDINATES SHOWN ARE HORIZONTAL (GROUND) VALUES.

UTILITY/SUBSURFACE PLANS:
NO SUBSURFACE PLANS ARE AVAILABLE ON THIS PROJECT.
EXISTING UNDERGROUND UTILITIES HAVE NOT BEEN VERIFIED.
THE CONTRACTOR IS RESPONSIBLE FOR CONTACTING A UTILITY LOCATOR AND ESTABLISHING THE EXACT LOCATION OF ANY AND ALL EXISTING UTILITIES IN THE PROJECT REACH.

PROJECT LEGEND:

Proposed Thalweg w/Approximate Bankfull Limits	12+00 13+00
Existing Thalweg w/Top of Bank	12+00 13+00
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Existing Sanitary Sewer Gravity Line	SS
Existing Sanitary Sewer Force Main	SFM
Proposed Sanitary Sewer Gravity Line	SS
Proposed Sanitary Sewer Force Main	SFM
Power Easement	
Proposed Floodplain Grading (Stream Restoration)	
City-Owned Property	

REVISIONS

SYM. | DESCRIPTION | DATE

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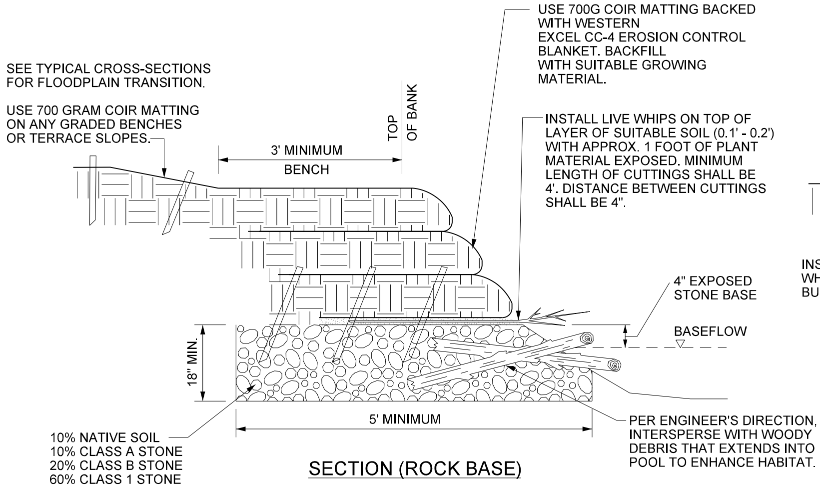
DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

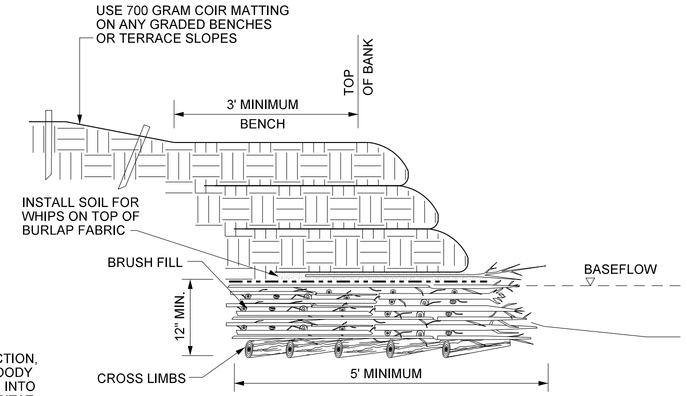
DATE: NOV 2021
SCALE: N.T.S.

GENERAL NOTES & PROJECT LEGEND

SHEET 2 OF 18



SECTION (ROCK BASE)



SECTION (WOOD BASE)

NOTES:

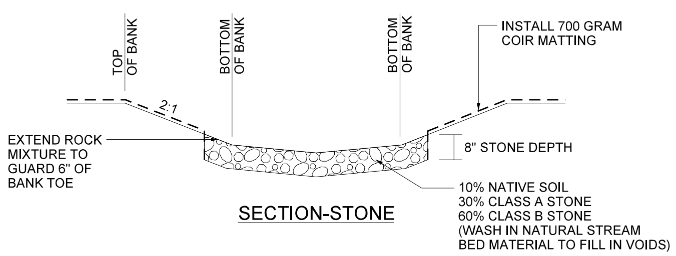
LIFTS INSTALLED ALONG DUHARTS CREEK SHALL HAVE 3 LAYERS OF LIFTS. TRIBUTARIES WILL BE TWO LIFTS.

WOOD BASE INSTALLED ON LIFTS ALONG DUHARTS CREEK AND TRIBUTARIES AT THE DIRECTION OF THE ENGINEER; OTHERWISE, INSTALL ROCK BASE.

USE 1.5'x1"x2" WOODEN STAKES ON 2' CENTERS. STAKES SHALL HAVE A 'ROOFING' NAIL AT TOP TO KEEP FABRIC FROM SLIPPING OFF.

LIVE LIFT

SCALE: NTS



SECTION-STONE

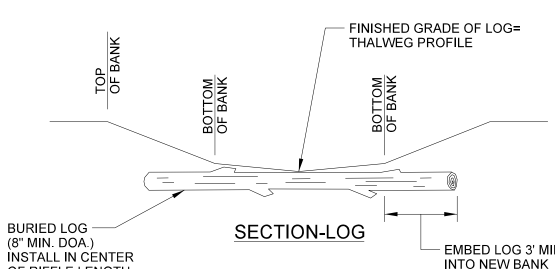
NOTES:

BURIED LOGS TO BE INSTALLED AT THE DIRECTION OF THE ENGINEER. TOTAL NUMBER OF INSTALLED LOGS DEPENDENT ON QUANTITY ACCRUED DURING CLEARING AND GRUBBING ALONG NEW STREAM PATH. BEFORE FILLING EXISTING STREAM, CONTRACTOR SHALL HARVEST BED MATERIAL AND SAVE FOR USE IN STONE MIXTURE FOR PROPOSED RIFFLE STRUCTURES. THIS ACTIVITY SHALL ONLY OCCUR IN PORTIONS OF THE STREAM THAT WILL NO LONGER BE USED TO CONVEY STREAM FLOW.

STONE INSTALLATION:

START BY INSTALLING STONE / SOIL MIXTURE. FINISH BY WASHING IN NATURAL STREAM BED MATERIAL TO FILL IN VOIDS AND OBTAIN FINAL GRADE. ENSURE THAT THE MIXTURE IS WELL PACKED TO MINIMIZE WATER PIPING.

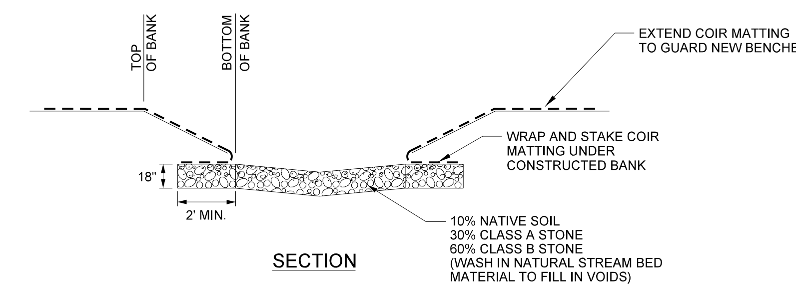
SEE CROSS-SECTION SHEET FOR EXACT DIMENSIONS.



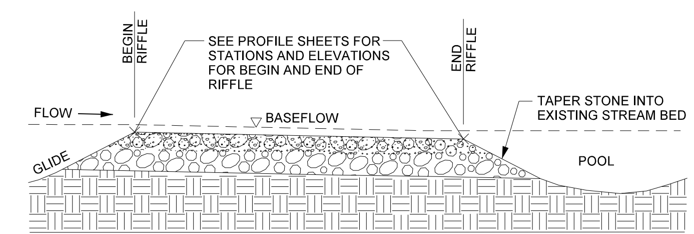
SECTION-LOG

RIFFLE ENHANCEMENT

SCALE: NTS



SECTION



PROFILE

NOTE:
BEFORE FILLING EXISTING STREAM, CONTRACTOR SHALL HARVEST BED MATERIAL AND SAVE FOR USE IN STONE MIXTURE FOR PROPOSED RIFFLE STRUCTURES. THIS ACTIVITY SHALL ONLY OCCUR IN PORTIONS OF THE STREAM THAT WILL NO LONGER BE USED TO CONVEY STREAM FLOW.

STONE INSTALLATION:

START BY INSTALLING STONE / SOIL MIXTURE. FINISH BY WASHING IN NATURAL STREAM BED MATERIAL TO FILL IN VOIDS AND OBTAIN FINAL GRADE. ENSURE THAT THE MIXTURE IS WELL PACKED TO MINIMIZE WATER PIPING.

SEE CROSS-SECTION SHEET FOR EXACT DIMENSIONS.

RIFFLE GRADE CONTROL

SCALE: NTS

SYM.	DESCRIPTION	DATE
	REVISIONS	

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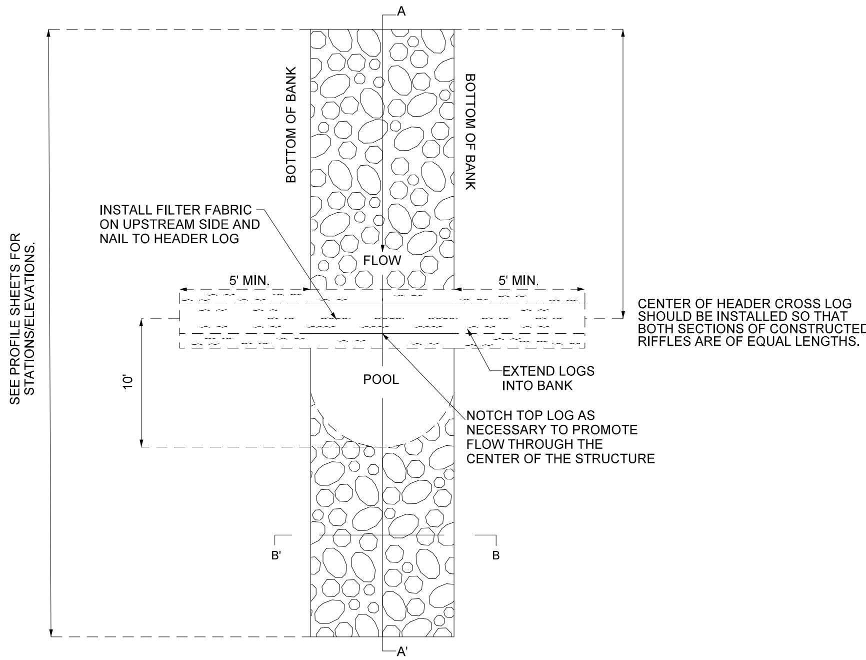
RALEIGH, NORTH CAROLINA 27609

DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

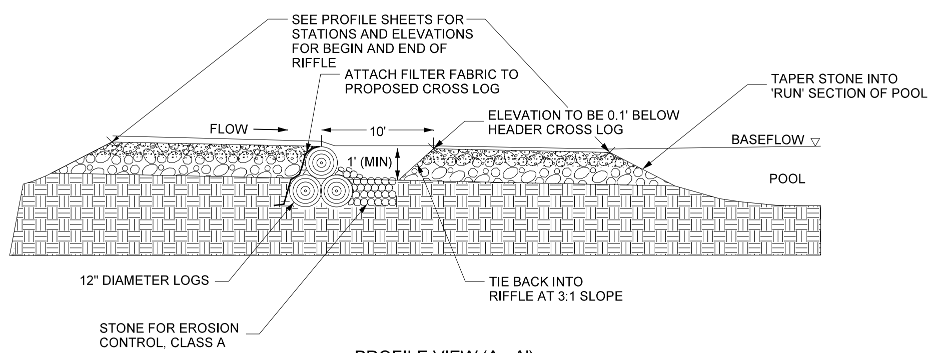
DATE: NOV 2021
SCALE: N.T.S.

DETAILS

SHEET 3 OF 18



PLAN VIEW



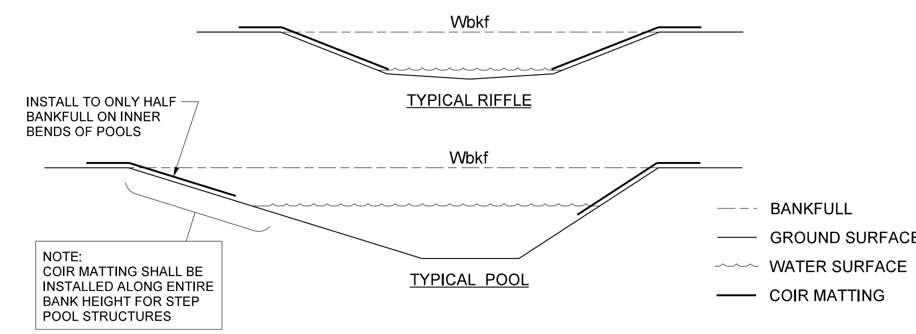
PROFILE VIEW (A - A')

RIFFLE ENHANCEMENT WITH IN-LINE POOL

SCALE: NTS

NOTE:

1. BEGIN BY INSTALLING CLASS B STONE. THEN ADD A MIX OF 57 STONE AND CLASS A TO FILL IN VOIDS AND TO OBTAIN FINAL GRADE. FINISH BY WASHING IN NATURAL STREAM MATERIAL TO FILL ANY REMAINING VOIDS. DEPTH OF STONE SHOULD BE 1' MINIMUM.

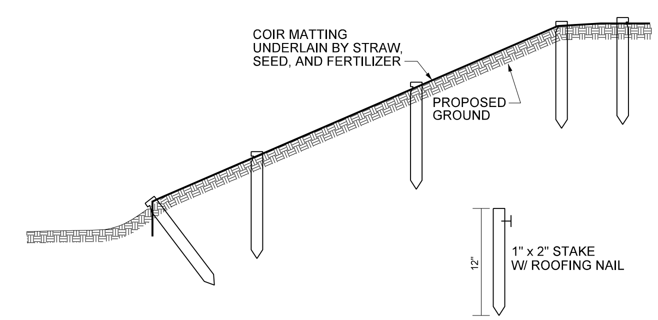


EXAMPLE COIR MATTING PLACEMENT

SCALE: NTS

NOTES:

- MATTING SHALL BE INSTALLED PRIOR TO THE INTRODUCTION OF WATER TO A STREAM SECTION.
- MATTING SHALL BE INSTALLED ALONG BOTH SIDES OF NEW STREAM LENGTH.
- MATTING SHALL EXTEND FROM TOE OF SLOPE TO THE TOP OF BANK.



COIR MATTING

SCALE: NTS

SYM.	DESCRIPTION	DATE
	REVISIONS	

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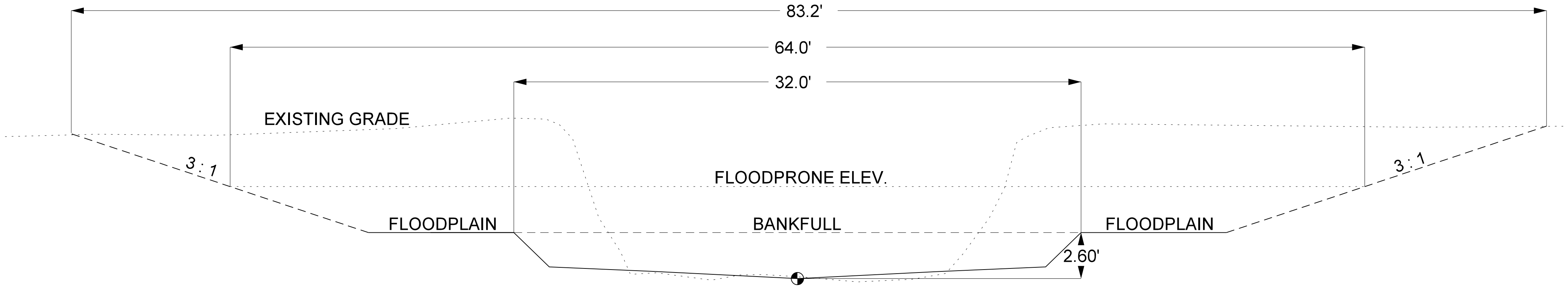
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: N.T.S.

DETAILS

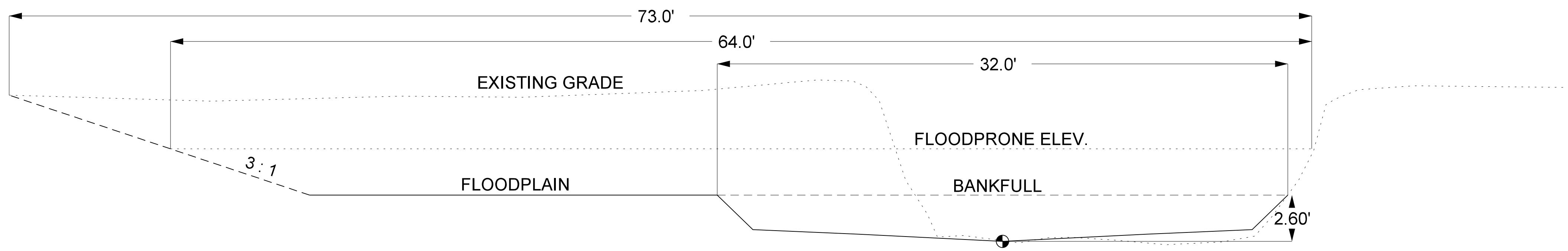
SHEET 4 OF 18

PROPOSED TYPICAL STREAM CROSS-SECTIONS
DUHARTS CREEK
"B4c/C4" STREAM TYPE



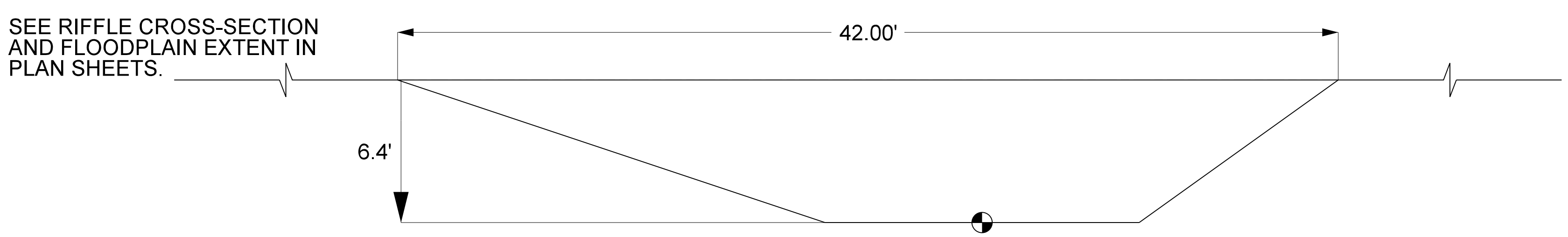
TYPICAL RIFFLE - FLOODPLAIN GRADING BOTH SIDES

= THALWEG LOCATION

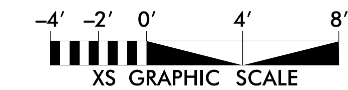


TYPICAL RIFFLE - FLOODPLAIN GRADING ONE SIDE ONLY

= THALWEG LOCATION



TYPICAL POOL - RIGHT MEANDER (MIRROR FOR LEFT MEANDER)



SYM.	DESCRIPTION	DATE
	REVISIONS	

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

TYPICAL STREAM CROSS-SECTIONS

PROJECT LEGEND:

Existing Thalweg	
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Existing Sanitary Sewer Gravity Line	SS
Existing Sanitary Sewer Force Main	SFM
City-Owned Property	
Bedrock	

NC GRID NAD 83

-40′ 0′ 40′ 80′
GRAPHIC SCALE

SYM.	DESCRIPTION	DATE

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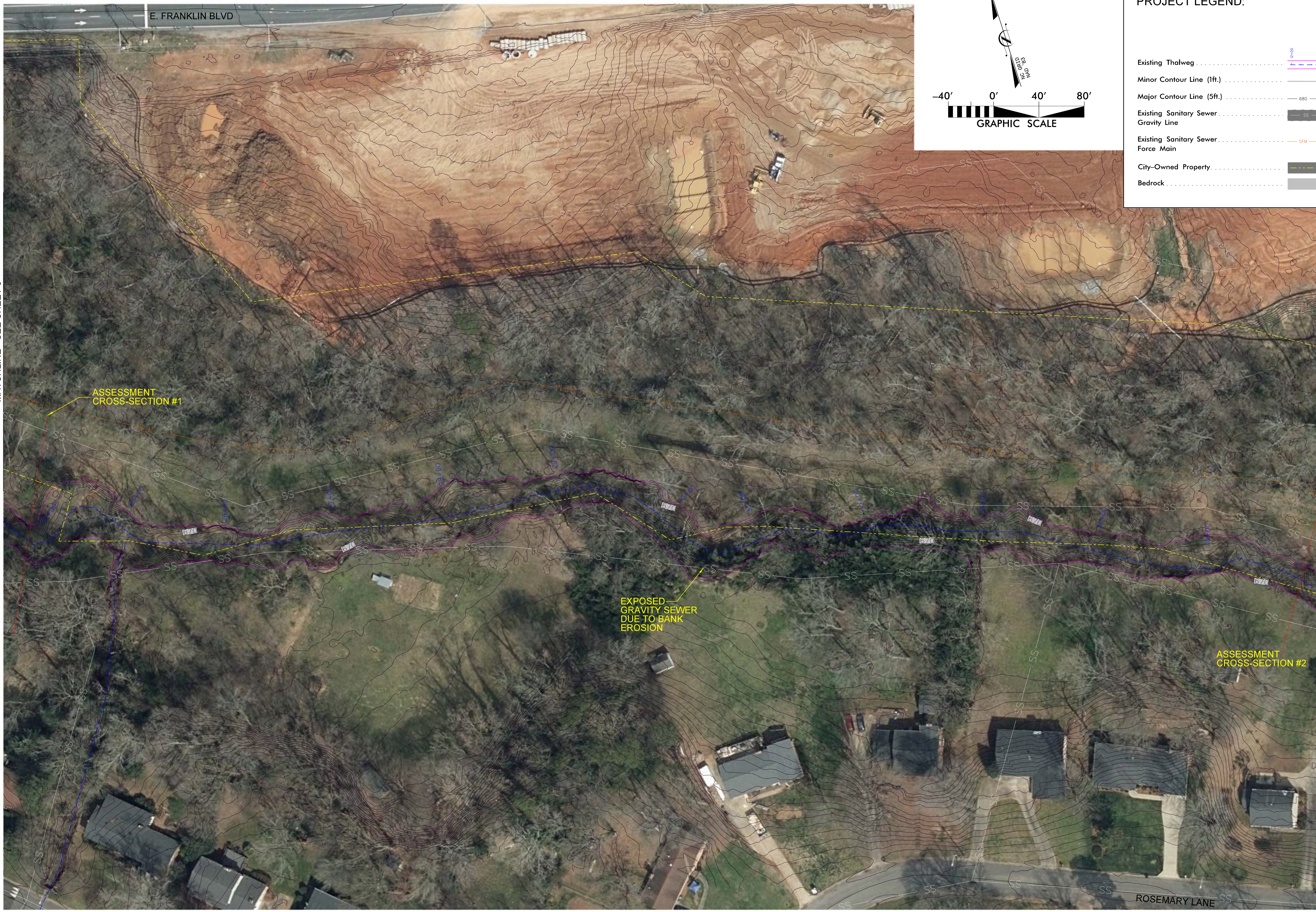
DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS



NC GRID NAD '83

–40′ 0′ 40′ 80′

GRAPHIC SCALE

PROJECT LEGEND:

- Existing Thalweg
- Minor Contour Line (1ft.)
- Major Contour Line (5ft.)
- Existing Sanitary Sewer Gravity Line
- Existing Sanitary Sewer Force Main
- City–Owned Property
- Bedrock

SYM.	DESCRIPTION	DATE

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION

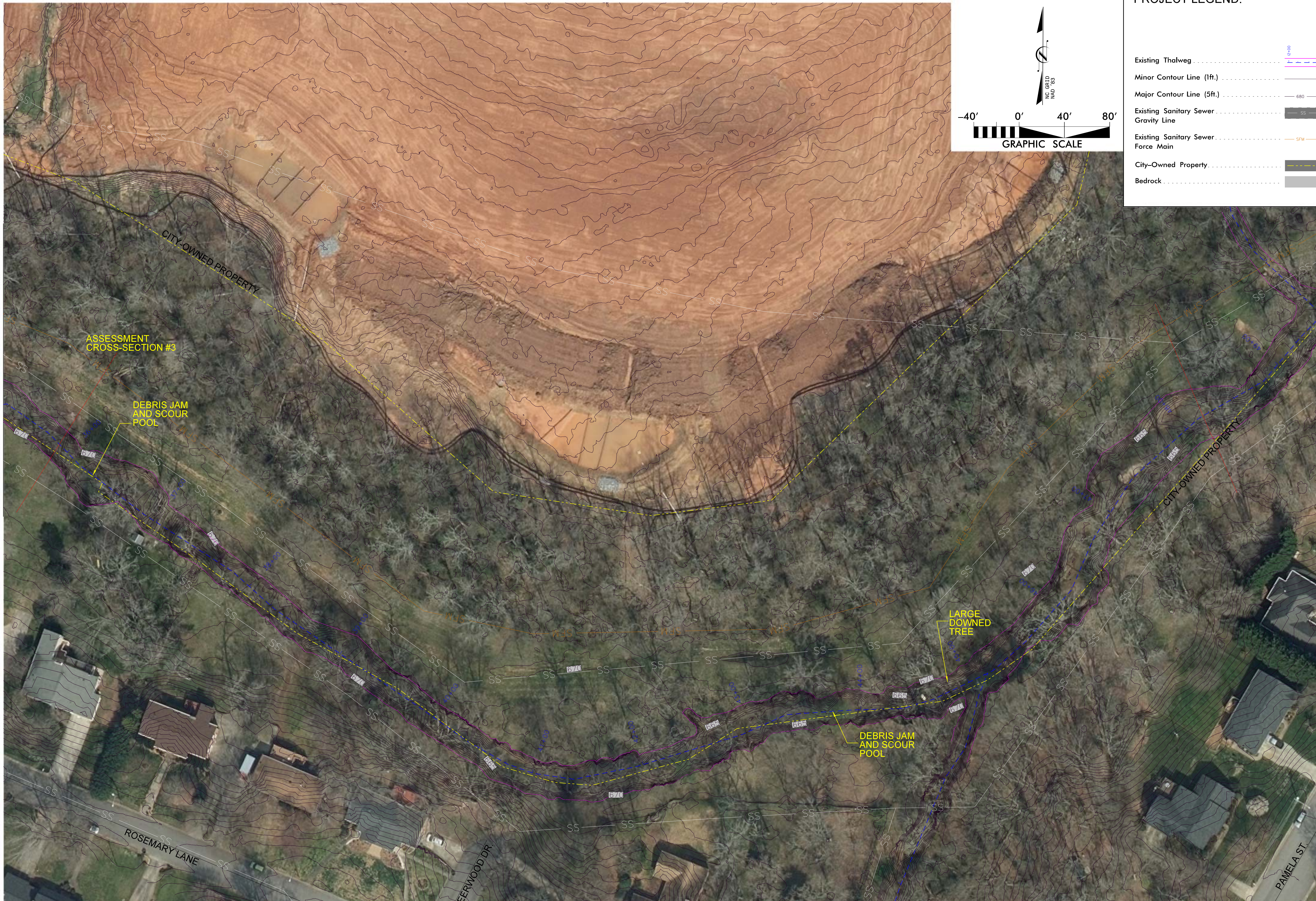
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS

SHEET 07 OF 18

MATCHLINE - SEE SHEET 7



MATCHLINE - SEE SHEET 9

NC GRID NAD '83

–40′ 0′ 40′ 80′

GRAPHIC SCALE

PROJECT LEGEND:

Existing Thalweg	
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Existing Sanitary Sewer Gravity Line	SS
Existing Sanitary Sewer Force Main	SFM
City-Owned Property	
Bedrock	

SYM. DESCRIPTION DATE

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS

SHEET 08 OF 18

PROJECT LEGEND:

Existing Thalweg
Minor Contour Line (1ft.)
Major Contour Line (5ft.)
Existing Sanitary Sewer Gravity Line
Existing Sanitary Sewer Force Main
City-Owned Property
Bedrock

NC GRID NAD '83

-40' 0' 40' 80'
GRAPHIC SCALE

REVISIONS

SYM.	DESCRIPTION	DATE

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DUHARTS CREEK STREAM RESTORATION & SEWER RELOCATION

GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS

PROJECT LEGEND:

Existing Thalweg	
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Existing Sanitary Sewer Gravity Line	SS
Existing Sanitary Sewer Force Main	SFM
City-Owned Property	
Bedrock	

NC GRID NAD '83

-40' 0' 40' 80'

GRAPHIC SCALE

REVISIONS

SYM.	DESCRIPTION	DATE

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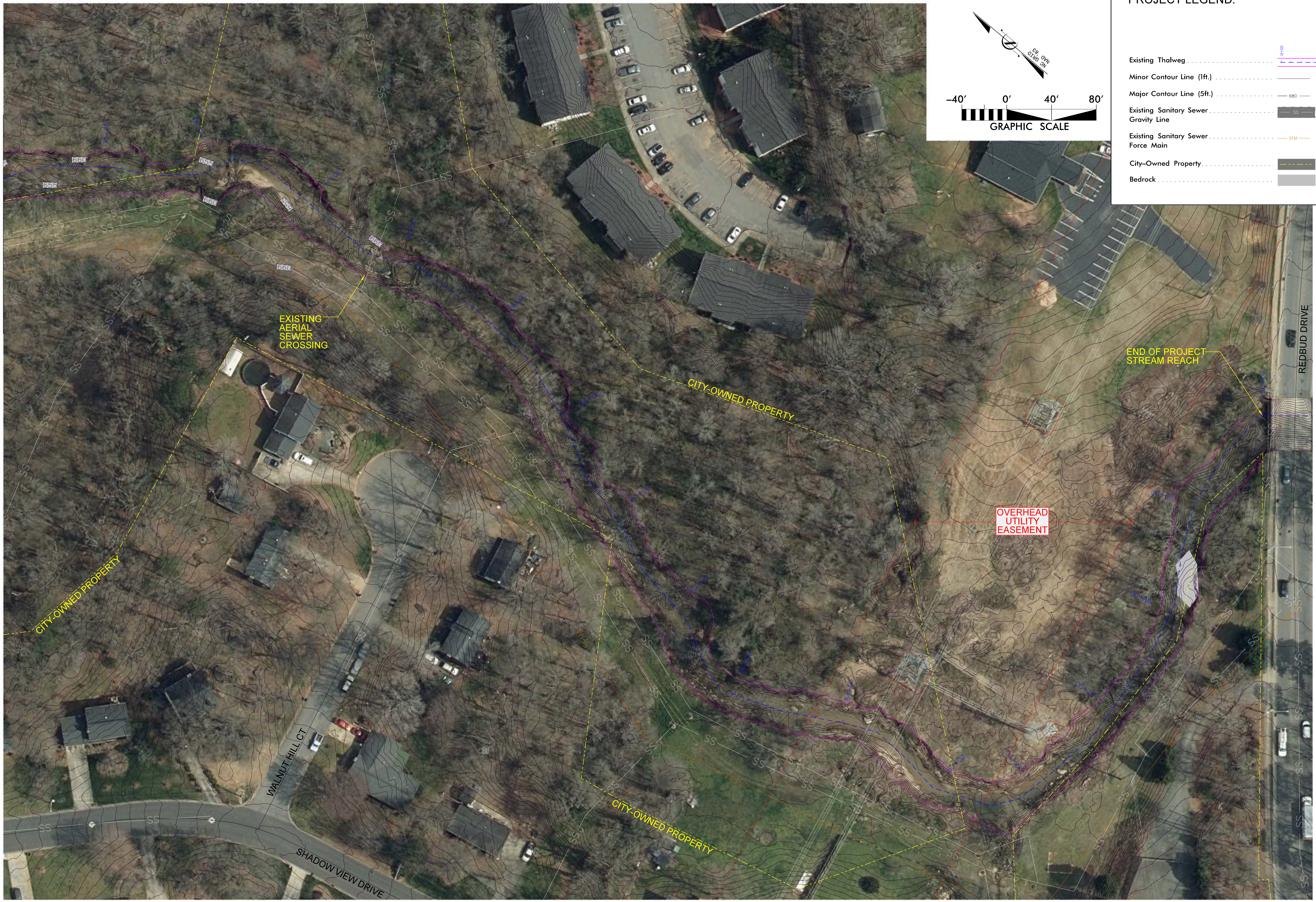
DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS



PROJECT LEGEND:

- Existing Thalweg
- Minor Contour Line (1ft.)
- Major Contour Line (5ft.)
- Existing Sanitary Sewer Gravity Line
- Existing Sanitary Sewer Force Main
- City-Owned Property
- Bedrock

SYM.	DESCRIPTION	DATE

REVISIONS

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4505 FALLS OF NEUSE ROAD, SUITE 400
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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

EXISTING CONDITIONS

SHEET 11 OF 18

PROJECT LEGEND

Proposed Thalweg w/Approximate Bankfull Limits	
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Proposed Sanitary Sewer Gravity Line	SS
Proposed Sanitary Sewer Force Main	SFM
Power Easement	
Proposed Riffle Enhancement	
Proposed Riffle Enh. w/In-Line Pool	
Proposed Live Lift	
City-Owned Property	

NC GRID NAD 83

−40′ 0′ 40′ 80′

GRAPHIC SCALE

SYM.	DESCRIPTION	DATE

REVISIONS

GASTONIA

TWO RIVERS

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4505 FALLS OF NEUSE ROAD, SUITE 400
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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN

SHEET 12 OF 18

SYM.	DESCRIPTION	DATE
	REVISIONS	

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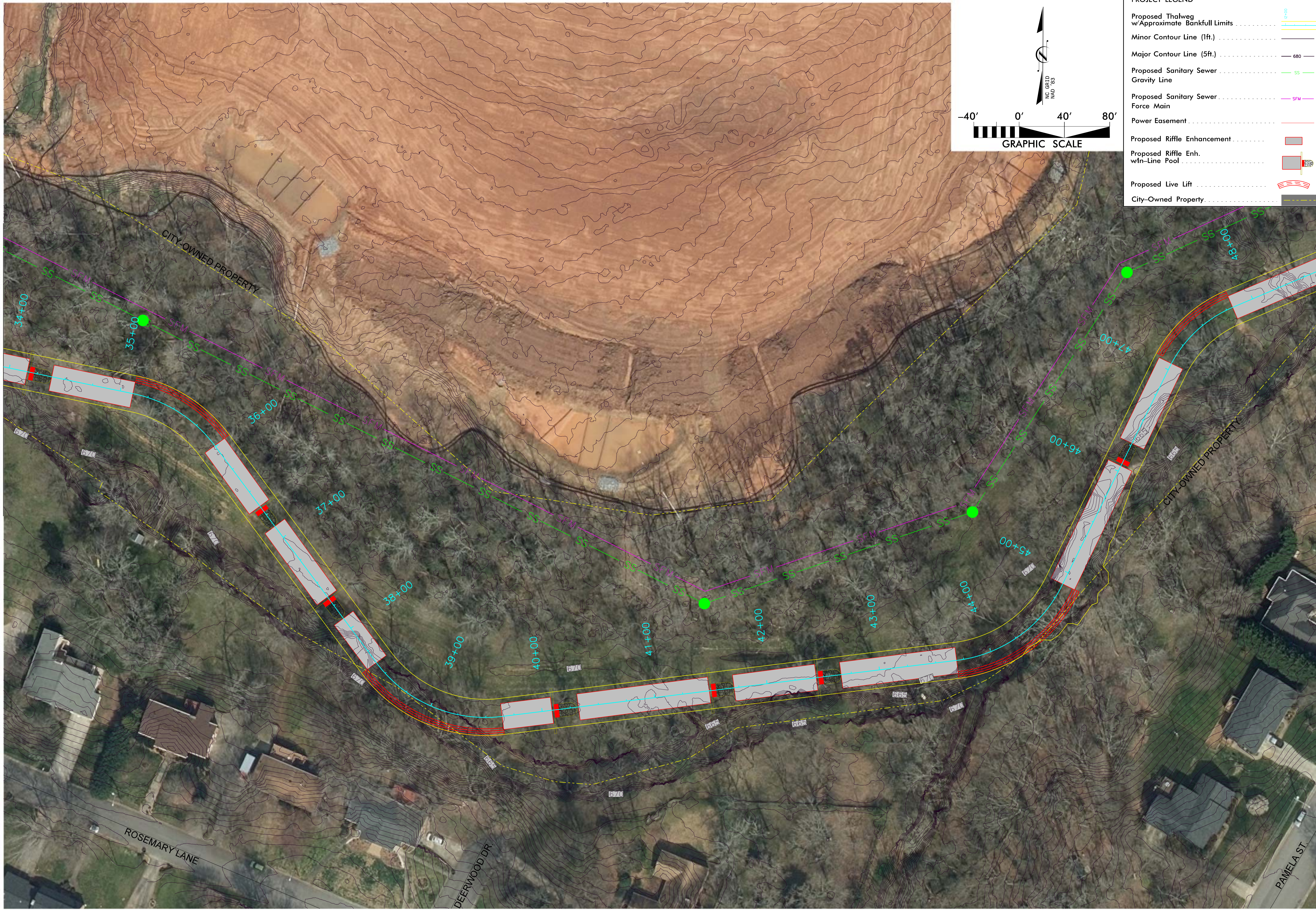
DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN



PROJECT LEGEND

Proposed Thalweg w/Approximate Bankfull Limits
Minor Contour Line (1ft.)
Major Contour Line (5ft.) 680
Proposed Sanitary Sewer Gravity Line SS
Proposed Sanitary Sewer Force Main SFM
Power Easement
Proposed Riffle Enhancement
Proposed Riffle Enh. w/In-Line Pool
Proposed Live Lift
City-Owned Property

REVISIONS

SYM.	DESCRIPTION	DATE

GASTONIA

TWO RIVERS

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4505 FALLS OF NEUSE ROAD, SUITE 400
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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN

SHEET 14 OF 18

PROJECT LEGEND

Proposed Thalweg w/Approximate Bankfull Limits	
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Proposed Sanitary Sewer Gravity Line	SS
Proposed Sanitary Sewer Force Main	SFM
Power Easement	
Proposed Riffle Enhancement	
Proposed Riffle Enh. w/In-Line Pool	
Proposed Live Lift	
City-Owned Property	

SYM.	DESCRIPTION	DATE

REVISIONS

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN

SHEET 15 OF 18

PROJECT LEGEND

- Proposed Thalweg w/Approximate Bankfull Limits
- Minor Contour Line (1ft.)
- Major Contour Line (5ft.) — 680 —
- Proposed Sanitary Sewer Gravity Line — SS —
- Proposed Sanitary Sewer Force Main — SFM —
- Power Easement
- Proposed Riffle Enhancement
- Proposed Riffle Enh. w/In-Line Pool
- Proposed Live Lift
- City-Owned Property

NC GRID NAD '83

−40′ 0′ 40′ 80′

GRAPHIC SCALE

SYM.	DESCRIPTION	DATE
	REVISIONS	

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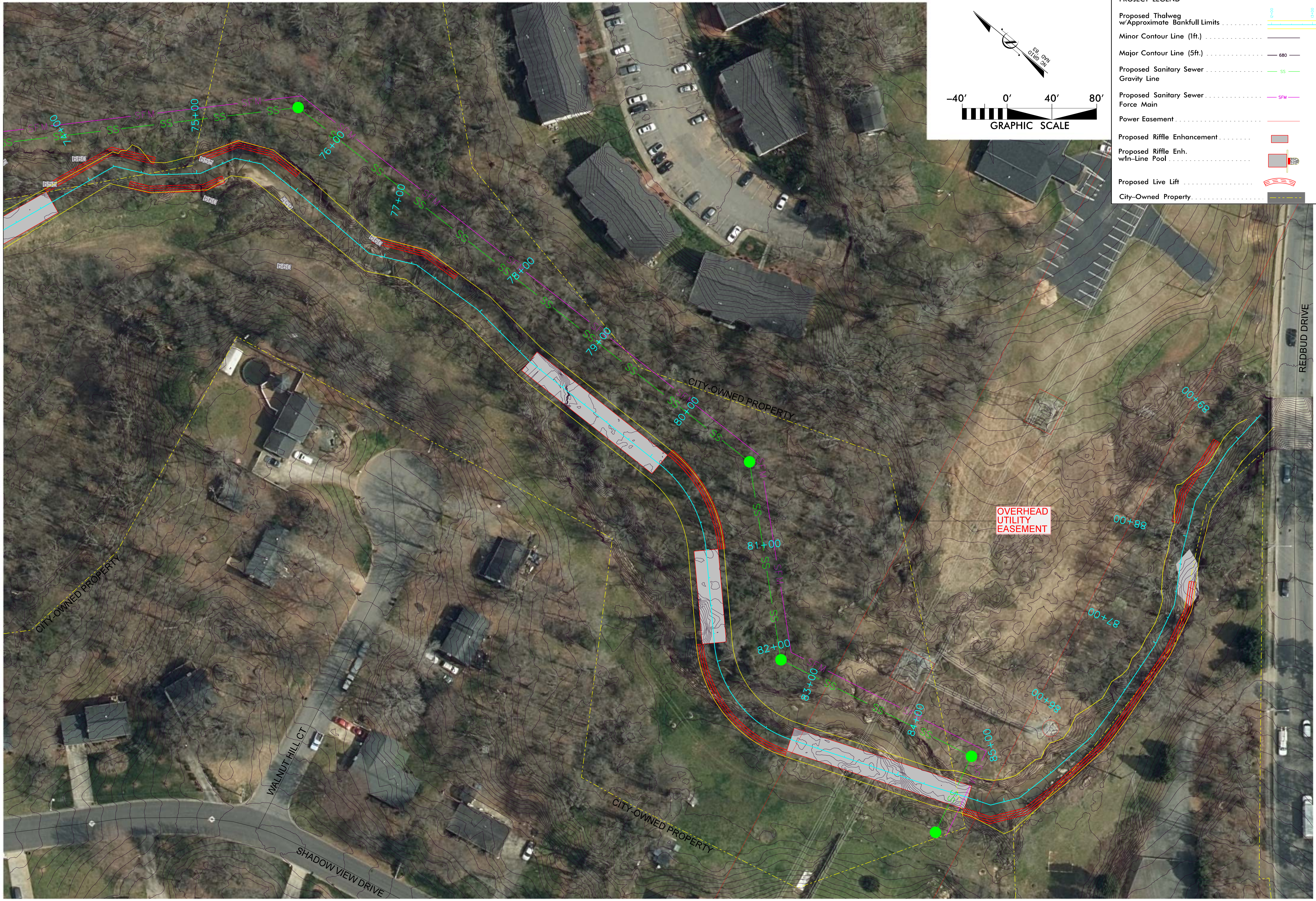
RALEIGH, NORTH CAROLINA 27609

DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN

SHEET 16 OF 18



PROJECT LEGEND

Proposed Thalweg w/Approximate Bankfull Limits	12+00 13+00
Minor Contour Line (1ft.)	
Major Contour Line (5ft.)	680
Proposed Sanitary Sewer Gravity Line	SS
Proposed Sanitary Sewer Force Main	SFM
Power Easement	
Proposed Riffle Enhancement	
Proposed Riffle Enh. w/In-Line Pool	
Proposed Live Lift	
City-Owned Property	

REVISIONS

SYM.	DESCRIPTION	DATE

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

PROPOSED STREAM AND SEWER PLAN

SHEET 17 OF 18

SYM.	DESCRIPTION	DATE
	REVISIONS	

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DUHARTS CREEK
STREAM RESTORATION & SEWER RELOCATION
GASTONIA, NORTH CAROLINA

DATE: NOV 2021
SCALE: GRAPHIC

GRADING PLAN

SHEET 18 OF 18

PREPARED BY:
KCI TECHNOLOGIES
ENGINEERS | PLANNERS | SCIENTISTS | CONSTRUCTION MANAGERS
KCI TECHNOLOGIES, INC.
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RALEIGH, NC 27609
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www.kci.com

DUHARTS CREEK BANK STABILIZATION
CITY OF GASTONIA, NORTH CAROLINA

GROUND DISTURBANCE AND
VEGETATION DISTURBANCE MAP

Appendix C – Schedule

ESTIMATED PROJECT SCHEDULE

PREPARED FOR: City of Gastonia
PROJECT: Duharts Creek
REVISION: 1, Grant Application
DATE: October 22, 2021

			2022				2023												2024											
ITEM #	**DESCRIPTION**	**Duration**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
	PHASE 1																													
1.1	Notice of Grant Award	n/a																												
1.2	Design Team Contract	1 Month																												
1.3	Assessment and Preliminary Design	3 Months																												
1.4	60% Design Documents	2 Months																												
1.5	Permitting Phase	6 Months																												
1.6	Final Design Documents	3 Months																												
	PHASE 2																													
2.1	Bidding and Award	3 Months																												
2.2	Construction - Sewer Relocation	12 Months																												
2.3	Construction - Stream Restoration	15 Months																												

Appendix D – Cost Estimate

PREPARED FOR: **Two Rivers Utilities, Gastonia, NC**

PROJECT: **Duharts Creek Stream Restoration and Sanitary Sewer Relocation**

ISO 9001:2015 CERTIFIED
ENGINEERS • PLANNERS • SCIENTISTS • CONSTRUCTION MANAGERS
106 Clair Drive • Piedmont, SC 29673 • Phone 864-269-0890

DATE: **11/18/2021**

ITEM #	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL AMT. (Budget)
Stream Restoration					
1.1	**Mobilization**	**LS**	1	$115,500.00	$115,500
1.2	**Erosion & Sediment Control**	**LS**	1	$77,000.00	$77,000
1.3	**Maintenance of Stream Flow**	**LS**	1	$115,500.00	$115,500
1.4	**Site Grading and Excavation**	**LS**	1	$1,925,000.00	$1,925,000
1.5	**Vegetated Soil Lift**	**LS**	1	$577,500.00	$577,500
1.6	**Riffle Enhancement**	**LS**	1	$577,500.00	$577,500
1.7	**Natural Fiber Matting**	**LS**	1	$80,850.00	$80,850
1.8	**Planting and Seeding**	**LS**	1	$88,550.00	$88,550
1.9	**CONTRACTOR'S OVERHEAD AND PROFIT (14%)**	**LS**	1	$498,036.00	$498,036
Gravity Sewer and FM relocation					
2.1	**18" PVC GRAVITY SEWER[2]**	**LF**	6,800	$150.00	$1,020,000
2.2	**MANHOLES, 8-12 FT. DEPTH**	**EA**	25	$13,000.00	$325,000
2.3	**24" PVC Force Main[2]**	**LF**	6,500	$200.00	$1,300,000
2.4	**Combination Air/Vacuum Valves**	**EA**	2	$22,000.00	$44,000
2.5	**BYPASS PUMPING**	**LS**	1	$55,000.00	$55,000
SUBTOTAL FOR ITEMS 1 THROUGH 2 INCLUSIVE, IN THE AMOUNT OF [3]					**$6,800,000**
	Construction Contingency (5%)				**$340,000**
TOTAL ESTIMATED CONSTRUCTION COST [3]					**$7,140,000**
	Phase 1				
1	**Design**	**LS**	1	$214,200.00	$214,200.00
2	**Permitting**	**LS**	1	$35,700.00	$35,700.00
3	**Enviromental, Geotech, and Other Surveying**	**LS**	1	$107,100.00	$107,100.00
4	**Project Management**	**LS**	1	$71,400.00	$71,400.00
	Phase 2				
5	**Construction Procurement**	**LS**	1	$35,700.00	$35,700.00
6	**Construction Admin and Resident Project Rep**	**Hours**	2000	$110.00	$220,000.00
7	**Legal Fees**	**LS**	1	$10,000.00	$10,000
8	**Project Management**	**LS**	1	$71,400.00	$71,400
TOTAL ESTIMATED PROJECT COST [3]					**$7,906,000**

[1] MANHOLE SPACING WILL BE NO MORE THAN 400 FT.

[2] COST ASSUMES A MAJORITY OF EXCAVATION FOR PIPE INSTALLATION WILL BE COVERED UNDER ITEM 1.4. ONLY MINOR TRENCHING WILL BE REQUIRED.

[3] COST IS ROUNDED UP TO NEAREST THOUSAND. CONSTRUCTION COSTS ONLY WITH NO CONTINGENCY, ENGINEERING, ETC.

Appendix E - Photos

Gastonia NC
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BRIC 2021
City of Gastonia – Duharts Creek Restoration

Latitude: 35.25738 Longitude:-81.12395

Description: Exposed Gravity Main Sewer Line on Right Bank (Sewer ID:7506)

BRIC 2021

City of Gastonia – Duharts Creek Restoration

Latitude: 35.25702 Longitude: -81.12312

Description: Exposed Gravity Main Sewer Pipe (Sewer ID:7503) Located on Right Bank Drainage Channel

BRIC 2021
City of Gastonia – Duharts Creek Restoration

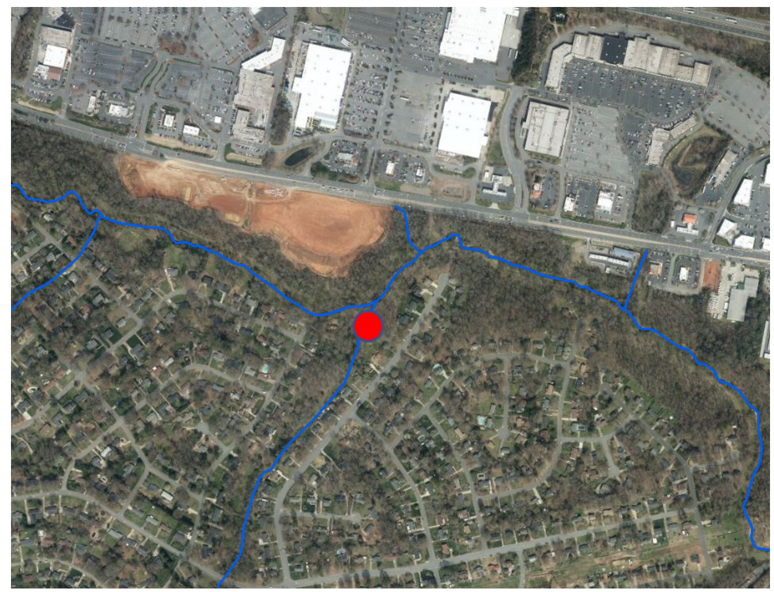
Latitude: 35.25682 Longitude: -81.12212

Description: Debris Jam at Scour Hole (Facing Downstream)

BRIC 2021
City of Gastonia – Duharts Creek Restoration

Latitude: 35.25598 Longitude: -81.11952

Description: Exposed Pipe On Tributary 2 (Sewer ID: 17018) (Facing Upstream)



BRIC 2021

City of Gastonia – Duharts Creek Restoration

Latitude: 35.25742 Longitude: -81.11793

Description: Scour Hole with Debris Jam (Facing Downstream)

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BRIC 2021
City of Gastonia – Duharts Creek Restoration

Latitude: 35.25671 Longitude: -81.1153

Description: Exposed Gravity Main Sewer Pipe (Sewer ID:8978)/Debris Jam

BRIC 2021
City of Gastonia – Duharts Creek Restoration

Latitude: 35.25591 Longitude: -81.11367

Description: Aerial Crossing with Undermined Footers (Facing Upstream)

North Carolina

Climate Science Report

Report Findings and Executive Summary

North Carolina
Climate Science Report

Authors

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Revised September 2020—See Errata for Details

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NCICS

Foreword

The North Carolina Climate Science Report is a scientific assessment of historical climate trends and potential future climate change in North Carolina under increased greenhouse gas concentrations. It supports Governor Cooper's Executive Order 80 (EO80), "North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy," by providing an independent peer-reviewed scientific contribution to the EO80.

The report was prepared independently by North Carolina–based climate experts informed by (i) the scientific consensus on climate change represented in the United States Fourth National Climate Assessment and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, (ii) the latest research published in credible scientific journals, and (iii) information in the North Carolina State Climate Summary.

An advisory panel ("Climate Science Advisory Panel") was formed to provide oversight and review of the report. This panel consisted of North Carolina university and federal research scientists with national and international reputations in their specialty areas of climate science.

The report underwent several rounds of review and revision, including an anonymous peer review organized by NOAA's National Centers for Environmental Information (NCEI). The report is available via ncics.org/nccsr.

Report Findings

These findings present key conclusions of this report about observed and projected changes in the climate of the state of North Carolina.

Quantitative projections for temperature, precipitation, and sea level rise are provided for two future scenarios: a higher scenario (RCP8.5), in which greenhouse gas emissions continue to increase through the end of this century, and a lower scenario (RCP4.5), in which emissions increase at a slower rate, peak around the middle of this century, and then begin to decrease. Future increases in temperature are dependent on greenhouse gas emissions, with higher emissions resulting in greater warming. Qualitative projections are based on expert judgment and assessment of the relevant scientific literature and draw on multiple lines of scientific evidence as well as model simulations.

Global average temperature has increased about 1.8°F since 1895. Scientists have ***very high confidence*** that this warming is largely due to human activities that have significantly increased atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases. It is ***virtually certain*** that global warming will continue, assuming greenhouse gas concentrations continue to increase. By the end of this century (2080–2099), global average temperature is projected to increase by about 4°–8°F compared to the recent climate (1996–2015) under the higher scenario (RCP8.5) and by about 1°–4°F under the lower scenario (RCP4.5).

Global average sea level has increased by about 7–8 inches since 1900, with almost half of this increase occurring since 1993. It is ***virtually certain*** that global sea level will continue to rise due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets.

Observed and Projected Changes for North Carolina

Except where noted, statements about future changes refer to projections through the end of this century.

- Our scientific understanding of the climate system strongly supports the conclusion that large changes in North Carolina's climate, much larger than at any time in the state's history, are ***very likely*** by the end of this century under both the lower and higher scenarios.

Temperature

- North Carolina annual average temperature has increased by about 1.0°F since 1895, somewhat less than the global average. The most recent 10 years (2009–2018), however, represent the warmest 10-year period on record in North Carolina, averaging about 0.6°F warmer than the warmest decade in the 20th century (1930–1939). Recently released data indicate that 2019 was the warmest year on record for North Carolina.

- Although regional changes in temperature can vary from global changes, it is ***very likely*** that North Carolina temperatures will also increase substantially in all seasons. Annual average temperature increases relative to the recent climate (1996–2015) for North Carolina are projected to be on the order of 2°–5°F under a higher scenario (RCP8.5) and 2°–4°F under a lower scenario (RCP4.5) by the middle of this century. By the end of this century, annual average temperature increases relative to the recent climate (1996–2015) for North Carolina are projected to be on the order of 6°–10°F under a higher scenario (RCP8.5) and 2°–6°F under a lower scenario (RCP4.5).
- North Carolina has not experienced an increase in the number of hot (daytime maximum temperature of 90°F or higher) and very hot (daytime maximum temperature of 95°F or higher) summer days since 1900. However, it has seen an increase in the number of warm (nighttime minimum temperature of 70°F or higher) and very warm nights (nighttime minimum temperature of 75°F or higher).
- It is ***very likely*** that the number of warm and very warm nights will increase.
- It is ***very likely*** that summer heat index values will increase because of increases in absolute humidity.
- It is ***likely*** that the number of hot and very hot days will increase.
- It is ***likely*** that the number of cold days (daytime maximum temperature of 32°F or lower) will decrease.

Precipitation

- There is no long-term trend in annual total precipitation averaged across the state. However, there is an upward trend in the number of heavy rainfall events (3 inches or more in a day), with the last four years (2015–2018) having seen the greatest number of events since 1900.
- It is ***likely*** that annual total precipitation for North Carolina will increase.
- It is ***very likely*** that extreme precipitation frequency and intensity in North Carolina will increase due to increases in atmospheric water vapor content.

Sea Level

- Sea level along the northeastern coast of North Carolina has risen about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade since 1935 at Wilmington, NC.
- It is ***virtually certain*** that sea level along the North Carolina coast will continue to rise due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets. Under a higher scenario (RCP8.5), storm-driven water levels that have a 1% chance of occurring each year in the beginning of the 21st

century may have as much as a 30%–100% chance of occurring each year in the latter part of the century. High tide flooding, defined as water levels of 1.6–2.1 feet (0.5–0.65 m) above Mean Higher High Water, is projected to become a nearly daily occurrence by 2100 under both the lower and higher scenarios.

Hurricanes

- On a global scale, the intensity of the strongest hurricanes is ***likely*** to increase with warming. The confidence in this outcome is ***high***. For individual regions such as North Carolina, the confidence in this outcome is ***medium***. While confidence for North Carolina is lower than for the entire globe, there is no known reason that North Carolina would be protected from stronger hurricanes, and this potential risk should be considered in risk assessments.
- Heavy precipitation accompanying hurricanes that pass near or over North Carolina is ***very likely*** to increase, which would in turn increase the potential for freshwater flooding in the state.
- There is ***low confidence*** concerning future changes in the number of landfalling hurricanes in North Carolina.

Storms

- It is ***likely*** that the frequency of severe thunderstorms in North Carolina will increase.
- It is ***likely*** that total snowfall and the number of heavy snowstorms in North Carolina will decrease due to increasing winter temperatures.
- There is ***low confidence*** concerning future changes in the number of winter coastal storms.
- There is ***low confidence*** concerning future changes in the number of ice storms in North Carolina.

Floods, Droughts, and Wildfire

- It is ***virtually certain*** that rising sea level and increasing intensity of coastal storms, especially hurricanes, will lead to an increase in storm surge flooding in coastal North Carolina.
- It is ***likely*** that increases in extreme precipitation will lead to increases in inland flooding in North Carolina.
- It is ***likely*** that future severe droughts in their multiple forms in North Carolina will be more frequent and intense due to higher temperatures leading to increased evaporation. As a result, it is ***likely*** that the frequency of climate conditions conducive to wildfires in North Carolina will increase.

Other Compound Events

- It is ***likely*** that future urban growth will increase the magnitude of the urban heat island effect, with stronger warming in North Carolina urban centers.
- There is ***low confidence*** concerning future changes in conditions favorable for near-surface ozone formation in North Carolina because of counteracting influences from increases in both temperature and water vapor.

Engineering Design Standards

- It is ***very likely*** that some current climate design standards for North Carolina buildings and other infrastructure will change by the middle of the 21st century. This includes increases in design values for precipitation, temperature, and humidity. Several professional societies, however, are actively working on methods to incorporate climate change into national standards, and updated standards appropriate for use in a changing climate may be available in the near future.

Executive Summary

Our scientific understanding of the climate system strongly supports the conclusion that North Carolina's climate has changed in recent decades and the expectation that large changes—much larger than at any time in the state's history—will occur if current trends in greenhouse gas concentrations continue. Even under a scenario where emissions peak around 2050 and decline thereafter, North Carolina will experience substantial changes in climate. The projected changes with the highest level of scientific confidence include increases in temperature, increases in summer absolute humidity, increases in sea level, and increases in extreme precipitation. It is also ***likely*** that there will be increases in the intensity of the strongest hurricanes.

A full appreciation for past and future changes in North Carolina's climate requires a global perspective. Earth's climate has warmed substantially since the late 19th century, with most of that warming occurring in the last 50 years. This warming trend is clear from global temperature records and many other indicators, including rising global sea levels and rapid decreases in arctic sea ice cover. Scientists have ***very high confidence*** that this warming is largely due to human activities that have significantly increased atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases. Extensive research has examined other potential causes of this warming, and the increase in greenhouse gas concentrations is the only plausible cause that is consistent with the observed data and the physics that govern the climate system.

Observed Changes

In North Carolina, annual average temperature has increased about 1°F since 1895, compared to the global average increase of about 1.8°F during that period. Annual average temperatures have been consistently above normal since the 1990s, with the most recent 10 years (2009–2018) representing the warmest 10-year period on record—about 0.6°F warmer than the warmest decade of the 1900s (1930–1939). Data for 2019, which were released during the review of this report, indicate that 2019 was the warmest year on record for North Carolina.

Most other temperature indicators also show warming. Average temperatures have increased in all four seasons. There has been an increase in the number of very warm nights. The length of the growing season has increased and is now about 1.5 weeks longer than the long-term average. There is an upward trend in the number of cooling degree days (a temperature indicator related to air conditioning demand) and a downward trend in the number of heating degree days (an indicator of heating demand)—both changes are consistent with a warming climate. However, a few indicators that would be expected to change with warmer conditions have not. For example, the number of very hot days has not increased, and there is no overall trend in the number of cold days and cold nights.

There is no long-term trend in annual total precipitation averaged across the state; however, 2018 was the wettest year on record, in part due to the torrential rainfall from Hurricane Florence. There has been an upward trend in the number of heavy rainfall events (days with more than 3 inches of rain), indicating that a larger portion of the annual total precipitation is occurring in heavy events. Temperature and precipitation trends in the three regions of the state (Coastal Plain, Piedmont, and Western Mountains) are generally similar to statewide trends.

Most observing stations outside of the mountains have experienced a downward trend in snowfall. In the Western Mountains, there is no century-long trend in snowfall, although stations in the southern mountains have seen decreasing trends over the last 50 years. Conditions favorable for snow-cover maintenance and snowmaking in the Western Mountains have been highly variable since 1981, but recent years have seen below average percentages of time when conditions are favorable.

Global average sea level has increased by about 7–8 inches since 1900, with almost half of this increase occurring since 1993—a rate of about 1.2 inches per decade. Sea level along the northeastern coast of North Carolina is rising about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade at Wilmington, NC, mainly due to different rates of land subsidence.

Projected Changes

The projections of North Carolina climate conditions presented in this report are based on the ***virtual certainty*** that greenhouse gas concentrations, particularly CO_2, will continue to rise. It may take decades for non-carbon-based sources of energy to replace most of the production based on fossil fuels. The basic principles of physics dictate that increases in greenhouse gas concentrations will have a warming effect, with ***virtual certainty***, due to the increase in atmospheric absorption of infrared energy.

Quantitative projections for temperature, precipitation, and sea level rise are provided for two future scenarios: a higher scenario (RCP8.5), in which greenhouse gas emissions continue to increase through the end of this century, and a lower scenario (RCP4.5), in which emissions increase at a slower rate, peak around the middle of this century, and then begin to decrease. RCP8.5 and RCP4.5 are Representative Concentration Pathways—scenarios used in climate model simulations to examine how Earth's climate would respond to differing levels of greenhouse gas concentrations. The numbers 8.5 and 4.5 refer to the magnitude of the energy imbalance in the climate system (in units of watts per square meter) that would result in the year 2100 from the increases in greenhouse gas concentrations specified by the respective scenarios. By comparison, the increase in concentrations since the initiation of the Industrial Revolution has resulted in an imbalance of approximately 2.3 watts per square meter.

A very low scenario (RCP2.6) is also used occasionally in this report, but this scenario is very unlikely because there has been no slowdown in the annual growth rate of CO_2. Qualitative projections are based on expert judgment and assessment of the relevant scientific literature and draw on multiple lines of scientific evidence as well as model simulations. Except where noted, statements below about future changes refer to projections through the end of this century.

By the end of this century (2080–2099), global average temperature is projected to increase by about 4°–8°F compared to the current climate (1996–2015) under the higher scenario (RCP8.5) and by about 1°–4°F under the lower scenario (RCP4.5). The warming is projected to be greater in the middle and high latitudes and less at tropical latitudes.

Regional changes in temperature can differ from global changes, at least temporarily, as shown by the historical lower rate of warming in North Carolina compared to the global average. Seasonal and annual average temperatures, however, have been rising in North Carolina in recent decades, and it is ***very likely*** that North Carolina temperatures will continue to increase substantially in all seasons.

- By the middle of this century, annual average temperature increases relative to the current climate (1996–2015) for North Carolina are projected to be on the order of 2°–5°F under the higher scenario (RCP8.5) and 2°–4°F under the lower scenario (RCP4.5).
- By the end of this century, annual average temperature increases relative to the current climate (1996–2015) for North Carolina are projected to be on the order of 6°–10°F under the higher scenario (RCP8.5) and 2°–6°F under the lower scenario (RCP4.5).

Temperature extremes are also projected to change:

- It is ***very likely*** that the number of very warm nights will increase, continuing recent trends.
- It is ***likely*** that the number of very hot days will increase, although the level of confidence is lower than for very warm nights because of the lack of recent trends.
- It is ***likely*** that the number of cold days and very cold nights will decrease, but again the level of confidence is lower than for very warm nights because of the lack of recent trends.

Several additional climate features directly tied to temperature are also projected to change, with a high level of certainty:

- It is ***very likely*** that extreme precipitation frequency and intensity will increase because global ocean surface temperatures will continue to increase gradually. In turn, near-surface air temperature and absolute humidity will increase over the oceans because maximum water vapor content is strongly related to temperature, increasing by about 3.5% per °F.
- It is ***virtually certain*** that global sea level will continue to rise due to both the expansion of ocean water from warming and from the melting of ice on land, including the Greenland and Antarctic ice sheets. It is ***virtually certain*** that sea level along the North Carolina coast will also continue to rise. Under the higher scenario (RCP8.5), storm-driven water levels having a 1% chance of occurring each year in the beginning of the 21st century may have as much as a 30%–100% chance of occurring each year in the

latter part of the century. High tide flooding is projected to become nearly a daily occurrence by 2100 under both the lower and higher scenarios.

- It is ***very likely*** that summer heat index values will increase because of increases in absolute humidity.
- It is ***likely*** that the probability of snowfall and snow cover will decrease nearly everywhere in North Carolina because of warmer temperatures.

For climate variables where the temperature dependence is more complex, projected changes are less certain:

- Inland flooding depends not only on extreme precipitation but also on characteristics of the land surface, including land use, land cover, and soil moisture conditions. It also depends on whether deliberate adaptive measures are implemented proactively. It is ***likely*** that the frequency and severity of inland flooding will increase because of increases in the frequency and intensity of extreme precipitation. This lower level of certainty compared to projections for changes in extreme precipitation stems from the additional factors that determine flooding.
- It is ***likely*** that annual total precipitation in the state will increase, but there is less certainty for annual total precipitation than for projected increases in extreme precipitation because total precipitation is a function of both atmospheric water vapor and the frequency and intensity of weather systems that cause precipitation. Future changes in the intensity and frequency of such weather systems are more uncertain.

Hurricanes have some of the most important impacts on the state, often catastrophic (storm surge, wind, and flooding damage) but sometimes beneficial (rainfall recharging soil moisture and groundwater aquifers). An understanding of future changes in hurricanes has been the subject of extensive research by climate scientists. While that understanding continues to evolve, a recent assessment of the science leads to the conclusion that the intensity of the strongest hurricanes is ***likely*** to increase with warming, and this could result in stronger hurricanes impacting North Carolina. Confidence in this result is ***high*** for tropical cyclone changes on a global scale. For individual regions such as North Carolina, the confidence in this outcome is ***medium***. While confidence for North Carolina is lower than for the entire globe, there is no known reason that North Carolina would be protected from stronger hurricanes, and this potential risk should be considered in risk assessments.

It is ***virtually certain*** that rising sea level and increasing intensity of coastal storms, especially hurricanes, will lead to increases in storm surge flooding in coastal North Carolina. There is ***low confidence*** concerning future changes in the total number of hurricanes. The total number of hurricanes depends on a variety of meteorological factors, such as vertical wind shear (changes in wind speed or direction with height in the atmosphere), and not just ocean surface temperatures, and there is considerable uncertainty about changes in these other factors. Heavy precipitation accompanying hurricanes is ***very likely*** to increase, increasing the potential for freshwater floods.

Severe thunderstorms (hail, tornadoes, and strong winds) are a regular occurrence in North Carolina, particularly in the spring. Severe thunderstorms require two primary atmospheric conditions: an unstable atmosphere and high vertical wind shear. It is ***very likely*** that vertical instability will increase, but it is also ***likely*** that vertical wind shear will decrease. These may counteract one another. Recent research suggests that the increases in atmospheric instability will dominate. While this remains an active area of research, it is ***likely*** that there will be increases in the frequency of severe thunderstorms.

Other important weather systems include snowstorms, winter coastal storms, and ice storms. There is considerable uncertainty about future changes in the number and severity of extratropical cyclones—the weather phenomenon that causes each of these winter storm types. In the case of snow, temperature is an important factor, and it is ***likely*** that total snowfall and the number of heavy snowstorms will decrease because of increasing temperatures. There is ***low confidence*** concerning future changes in the number of ice storms and winter coastal storms.

Drought can have major impacts on the state, including agricultural production, water availability in rivers, lakes, and aquifers, and wildfires. The impacts on these different sectors and systems vary depending on the duration and spatial scale of the precipitation deficits. Although overall precipitation is projected to increase, this is principally a result of larger amounts during heavy rain events. Intervening dry periods are projected to become more frequent, and higher temperatures during those dry periods will more rapidly deplete soil moisture. Thus, it is ***likely*** that major droughts in their multiple forms will become more frequent and severe because of higher temperatures that will increase evaporation rates. As a result, it is ***likely*** that the climate conditions conducive to wildfires in North Carolina will increase in the future.

The major urban areas of the state have expanded substantially over the past few decades, and this trend shows no signs of abating. The urban heat island effect results from the conversion of vegetated surfaces (such as forests and farmland) to urban and suburban landscapes with substantial percentages of impervious, non-vegetated surfaces, reducing the amount of natural cooling from evapotranspiration (the combination of evaporation of water from the surface and transpiration of water vapor from vegetation) and increasing the amount of heat retained in darker, paved surfaces as compared to natural land cover. It is ***likely*** that future warming in urban areas will be enhanced by future growth of those areas.

Near-surface ozone is a major component of air pollution, and harmful levels of near-surface ozone result from a combination of climate conditions and human-caused emissions of compounds necessary for the formation of ozone, including nitrogen oxides, carbon monoxide, and volatile organic compounds (referred to as ozone precursor compounds). Near-surface ozone concentrations tend to increase with temperature. However, changes in other climate conditions, such as increased precipitation, can counteract the temperature effect. Overall, it is uncertain what the net effect will be. Thus, there is ***low confidence*** concerning future changes in the conditions favorable for near-surface ozone concentrations.

Climate design values, which provide information on the average and extreme climate conditions experienced in a given location, are important for planning and designing many types of infrastructure. Many climate design values are projected to change because of warming. Because of the high level of confidence in increased temperature and extreme precipitation, it is ***very likely*** that some current climate design standards for building and other infrastructure will change by the middle of this century. This includes increases in design values for precipitation, temperature, and humidity. In fact, current design values are based on historical data and do not incorporate recent trends; thus, some standards may already be out of date. Several professional societies, however, are actively working on methods to incorporate climate change into national standards, and updated standards appropriate for use in a changing climate may be available in the near future.