BRITTON CREEK
STORMWATER MASTER PLAN

CITY OF HENDERSONVILLE
HENDERSON COUNTY, NORTH CAROLINA

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TABLE OF CONTENTS

1.0 SUMMARY

Background

Located at the interface between the piedmont of the Upstate of South Carolina and the Southern Appalachian Mountains, Hendersonville, North Carolina has become a popular vacation and retirement community. It is also home for many native residents of the area and is an important component of the economic viability and cultural history of Western North Carolina. New commercial and residential development in town and on its outskirts has been an important factor recently in developing the City's character. While an increase in development density has occurred within the last three decades, agriculture in the surrounding area is still an important economic and community factor. With a total population of approximately 12,200, the City of Hendersonville, North Carolina encompasses a total land area of 6 square miles. Hendersonville rests at about 2,100 feet above sea level and receives approximately 57 inches of precipitation annually.

Development; growth; and the influx of visitors and new residents have affected the hydrology of the City's drainage basins. Due to the increase in impervious area within the City limits, response to rainfall events has become more pronounced. As a result, stormwater management, always an important factor within a city's drainage system, has become an even more crucial component of the City's drainage infrastructure. It is well known that there are times when local flooding impacts residential and commercial properties. The modification of natural drainage areas also can produce negative impacts to the water quality of the water courses within the city limits and downstream. The North Carolina Division of Water Quality has identified sections of Mud Creek, which includes the drainage from within the City, on the State's degraded stream list. In this regard; however, Hendersonville has been a leader in the State by adopting local ordinances to address floodplain areas, riparian areas along City streams, and the potential water quality impacts of stormwater runoff, well before such local programs were required under Federal and State law. That leadership continues since the City undertook an evaluation of its drainage and the stormwater systems in 2008. That evaluation identified some high priority areas within the City limits and extraterritorial jurisdiction (ETJ) that are the subject of this report. Britton Creek was designated by the leadership of the City as an area needing closer evaluation. This report describes the project to evaluate the Britton Creek watershed.

Description of Project

In order to promote the effort, this evaluation included significant efforts at reaching out to the community at large and specifically within this watershed to identify public and property owner issues related to stormwater or water quality. The City composed a questionnaire (Appendix 9.1) that was designed to assess the stormwater related concerns or issues that residents of the Britton Creek watershed might have. The questionnaire was accessible through the City's website (www.cityofhendersonville.org) and provided the residents a direct channel to convey useful information to the City about areas that need to be addressed. The City informed the public about this opportunity by mail, including a notification in their utility bill. During the course of the field surveys, residents who were interested in the work we were doing were often encountered. These residents were informed about the purpose of our project and provided with an official letter from the City which summarized the work and provided contact information for the City Engineer. The residents were also engaged in a conversation regarding any stormwater related issues or questions that they wished to have addressed. They were then encouraged to visit the City's website to fill out the questionnaire.

The 2,200 acre Britton Creek watershed is located in the northwestern section of the city. The drainage includes two streams: Britton Creek proper and its main unnamed tributary, identified by the North Carolina Floodplain Mapping Program as Britton Creek Tributary 2. Britton Creek and Tributary 2 begin flowing approximately ½ mile southeast of the Haywood Road / Mountain Road intersection. Tributary 2 runs along Stoney Mountain Road for about 1.4 miles and then crosses in a box culvert under Asheville Highway on the north side of Patton Park. Britton Creek runs along Haywood Road for over 2 miles where it then crosses in a box culvert under Haywood Road and Asheville Highway coursing through Patton Park where it joins with Tributary 2 and drains into Mud Creek (Figure 1.1).

As noted, this watershed is the focus of this report because stormwater related problems have become apparent along both streams. In particular, the crossing of Tributary 2 with Meadowbrook road has been the site of frequent flooding. Many other sections of the streams are suffering from inadequate crossing capacities, backwater impacts of downstream culverts, severe bank erosion and/ or sediment deposition.

The city identified a funding opportunity to develop a stormwater management plan for the Britton Creek watershed. An application was made to the Clean Water Management Trust Fund (CWMTF) in 2008 and the Fund provided a Stormwater Mini-Grant to aid the City of Hendersonville in this effort. The City created a project summary with water quality objectives that include the creation of a Stormwater Master Plan (SWMP) for the Britton Creek Watershed (Appendix 9.2) that was approved by CWMTF. The SWMP was to include a Capital Improvement Plan. The timeframe for this project initially gave a contract expiration date of January 31, 2011, but was delayed as a result of budget constraints. The revised timeframe gave a grant/contract expiration date of August 31, 2011. This report was developed to satisfy the goals of the grant.

The grant requires an inventory of the existing stormwater system throughout the watershed. The city already had a significant database of stormwater infrastructure throughout the city limits. However, under the grant, the database was updated and verified. Additional data was collected within the watershed to complement the city's information including, but not limited to culvert/ bridge invert elevations and dimensions as well as locating any new or existing structures not already included in the existing inventory.

In order to develop a reasonable and fact-based capital improvements plan, the updated inventory included the condition of structures, stream banks stability, channel bed characteristics, water quality issues, possible discharges of wastewater that should be connected to the sanitary sewer (illicit discharges under the NPDES Phase II Stormwater Program), and other potential conditions that could affect stormwater management and water quality impacts. This data in conjunction with results of other analyses gives a more complete picture of stormwater infrastructure condition and better documentation of existing water quality factors in the drainage

FIGURE 1.1 - DRAINAGE AREA TO CONFLUENCE WITH BRITTON CREEK TRIBUTARY 2.

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
DRAINAGE AREA TO CONFLUENCE WITH BRITTON CREEK TRIBUTARY 2

0 500 1,000 2,000 3,000 4,000 Feet

1 INCH = 1,000 FEET

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area. Recommendations in this report include sites where upgrades and/or replacements of deteriorating infrastructure need to be considered and potential locations for water quality improvement projects and conceptual ideas for the practices recommended.

Basic Conclusions and Recommendations

The watershed is moving toward a more intense state of urbanization. Existing development in the watershed has already dramatically affected storm flow levels and intensity over that expected from a rural watershed, resulting in a variety of structural and stream stability problems. While there remains significant area in the watershed that has more rural characteristic, particularly in the upper part of the basin, these areas will likely be targets for future development. This continued development will contribute to existing basin "hardening" and further increasing the intensity of storm events.

It is recommended that the City, within its available resources and those that can be secured, undertake projects in the watershed to improve existing stream stability and the infrastructure. It is also important that Hendersonville use its existing ordinance tools to manage new development to minimize increased storm intensities and limit the effect of this new development on local flooding issues.

Local flooding problems threaten structures and private property at several locations in the watershed. The capital improvement projects identified in this report address the most critical of these structural problems with recommended infrastructure improvement.

This report also recommends several stormwater management projects that can result in better watershed management of high flows and improve water quality. The report describes stream improvement projects that will enhance the waterways capability to manage flows without further stream bank degradation and will help to lessen infrastructure issues related to sediment deposition and improve overall stream quality and habitat.

Project Tasks

There was a sequence of tasks required to accomplish the objectives of the work under this project. The major tasks included the database collection and mapping, hydrologic and hydraulic modeling and analysis as well as the capital improvement plan recommendations. A description of those tasks is provided below.

1.1 Stormwater Infrastructure & Outfall Inventory Geodatabase and Mapping

The information collected during the stormwater infrastructure inventory was used to create a GIS compatible geodatabase and digital maps. The maps and geodatabase are presented with this report to Hendersonville so that the city may view the GIS data, collect new data to be stored in the geodatabase, and update and maintain the geodatabase in the future. The inventory identified many problem areas including primarily bank erosion and sediment deposition but also failing pipes, headwalls and undermined pipes. Some of the major findings are listed below.

Along Britton Creek:

- Downstream of Asheville Highway there is very heavy sediment deposition.
- Upstream of Orleans Avenue there is a lack of vegetative buffer.
- There are two ditches contributing to the Creek that are severely incised. They are within 700 feet on either side of Greenwood Drive.
- The CMP that crossed under Long John Drive has been severely undermined causing large sink holes in residential property.
- The road is partially undermined at a smaller (24" CMP) pipe crossing on Long John Drive.
- Failure of the RCP, headwall and asphalt swale at Hendersonville Elementary School

Along Tributary 2:

- Meadowbrook Terrace culvert is partially clogged with sediment.
- Retaining walls and stream bank just downstream of Meadowbrook Terrace are degrading.
- Downstream of Asheville Highway there is heavy sediment deposition.
- There is both sediment deposition and bank erosion in the immediate area around Meadowbrook Terrace.
- Upstream of Chelsea Street there is a lack of vegetative buffer and bank erosion.
- Between Comet Drive and North Harper Drive there are several areas of bank erosion and sediment deposition.

In addition to these particular items, each stream had degrading structures such as crushed or rusted out CMP pipes, pipes clogged with sediment, or cracked headwalls. Although there are several specific areas mentioned above that have particular erosion or sediment deposition problems, these issues were present along the majority of the two streams. Section 5 goes into greater detail about the stream and infrastructure assessment.

1.2 Hydrologic and Hydraulic Modeling

Capital improvements and policy decisions are made through the collection of stormwater infrastructure inventory and the engineering analysis using quantity-based and quality-based models. Hydrologic and hydraulic models were created to assess the capacity of the culvert crossings as well as estimate the water surface elevations for flood events including the 10, 25, 50 and 100 year storm events (10%, 4%, 2% and 1% annual chance respectively). The results indicated that both Britton Creek and Tributary 2 had culverts fail to carry the designated storm frequency (overtop) during each of the assessed storm events. Table 1 shows the number of failures for each event. These are hydraulic, not structural, failures. Section 4 gives more detail about culvert failures.

Table 1: Number of Culvert Failures by Stream and Storm Event

		BRITTON CREEK	BRITTON CREEK TRIBUTARY 2
NUMBER OF CULVERTS THAT ARE EXPECTED TO FAIL DURING STORM	10 YEAR STORM	1	1
	25 YEAR STORM	1	3
	50 YEAR STORM	4	5
	100 YEAR STORM	9	6

*Note: A failure during the 10 year storm will also be counted for the 25, 50 and 100 year storm, etc.

1.3 Capital Improvements Plan

In Section 7 the report describes a recommended Capital Improvements Plan for the City of Hendersonville that includes general stormwater management recommendations along with specific stormwater projects.

1.3.1 General Stormwater System Improvements

Water Quality Treatment Structures

In highly urbanized locations where there often is insufficient area and private property issues, installation of natural treatment systems such as bioretention and treatment wetlands are not realistic, it is often necessary to consider underground water quality treatment structures. These, however, can be very expensive and will still require significant property for their construction, access and maintenance. In most areas of new development, the treatment of runoff from a 1-inch rainfall event is the minimum required by State regulations. On April 7th 2011, the City's stormwater ordinance was revised to state that "all stormwater treatment measures shall treat either: the runoff volume calculated utilizing the 1-year, 1-hour design storm rainfall depth; or the difference in stormwater runoff volume between the pre- and post-development conditions for the 1-year, 24-hour storm; whichever is greater." Devices, both natural and structural, in these applications are required to be sized to remove at least 85% of the Total Suspended Solids (TSS) from the treated stormwater. The agency also recommends that efforts be made to address other pollutants such as bacteria, oils and greases, nitrogen, phosphorous, other nutrients, and heavy metals wherever possible. In the case of existing development and impact within a watershed, it generally isn't possible to accomplish these levels of treatment or performance. The agency supports the use of the technologies "to the extent possible" within existing watersheds. This means that any new structures would have to "fit" the property available and get as much water quality benefit as possible.

Riparian Buffers

As noted, the City already has a program to provide protection of riparian areas under its local ordnance for new development. The City's ordnance can be found at http://www.cityofhendersonville.org/Modules/ShowDocument.aspx?documentid=283. Article XV addresses buffering and Article XVII natural resource protection. Additionally, the City is a Phase II community and on April 7, 2011City Council was presented an ordinance, see Appendix Item 9.16, that replaced the existing stormwater ordinance with one incorporating Phase II requirements. A riparian buffer, or vegetated buffer zone along a stream or water body, is used to describe vegetated areas that help protect the streams from adjacent land uses. Riparian buffers if oriented properly and with appropriate vegetation are important for enhancing water quality. They are most effective at improving water quality when they include native grass or herbaceous filter strips and native deep rooted trees and shrubs along the stream. Additionally, riparian vegetation slows floodwaters, thereby helping to maintain stable stream banks and protect downstream property. By reducing the velocity of floodwaters and stormwater runoff, the riparian vegetation allows water to soak into the ground and recharge groundwater. It is sometimes possible in already developed areas to identify stream segments or lakes and ponds where vegetated riparian areas already exist that may be purchased or an easement secured for leaving them in as natural a state as possible. These areas can even be enhanced by modifying their hydrology to reduce water pollution potential or to remove invasive plant species and do plantings of acceptable species to improve function and habitat. There are several specific stretches of stream where buffer zones would be beneficial. These areas include:

- Along Britton Creek upstream of Orleans Avenue.
- Along Tributary 2 upstream of Chelsea Street.

In both areas, the banks have been mowed and evidence of stream bank failure is apparent. Since these areas are not within City or County property, one option may be to seek easements from the property owners by offering some tax incentives.

1.3.2 Stormwater Capital Improvement Projects

This project has helped to assess the condition of the stormwater infrastructure in the basin as well as identify sites where projects may be undertaken to improve the quality of Britton Creek. The two major streams in this watershed, Britton Creek and Britton Creek Tributary 2 both contain sections with a high degree of erosion and sediment deposition. The watershed also contains structures that are undersized, degraded, undermined or completely ineffective, as noted above in Sections 1.1 and 1.2.

It is the recommendation of this report that several categories of stormwater management practices be implemented at specific locations to address issues of water quality, water quantity and infrastructure degradation. In addition, the City should continue to identify sites in the watershed where it may pursue projects in the future. The main categories of improvements include

- Infrastructure upgrade/replacement (rusted CMPs cross Haywood Road between Browning and Longview
- Bank stabilization,
- Stream enhancement,
- Vegetative buffer zones,
- Wetlands,
- Underground detention,
- Rain gardens,
- Rain barrels/ cisterns, and
- Replacement of vented sewer lids.

Section 5 goes into more detail about specific problem spots or areas that may require attention. Section 7 discusses specific recommendations that may improve the overall quality of the streams and watershed.

1.3.3 Mud Creek Watershed Restoration Project

The Mud Creek Watershed Restoration Project is the direct result of the 2003 report entitled **Watershed Restoration Plan for the Mud Creek Watershed**. This is an ongoing program to address degradation problems in Mud Creek and to move the watershed toward compliance with all of North Carloina's water quality standards. In 2000, Land of Sky Regional Council of Governments convened local stakeholders in the Mud Creek watershed to develop a plan for addressing water quality problems in the watershed. At that same time, the Division of Water Quality initiated an independent study to identify causes and sources of impairment in Mud Creek and two of its tributaries, Bat Fork and Clear Creek. The Britton Creek watershed is tributary to the section of Mud Creek on the degraded steam list.

The work documented in this report and its associated conclusions and recommendations in large part address the same objectives as the Mud Creek Project. As a result, this section links the results of this project to the Mud Creek effort. Because components of the Restoration Project are funded under Section 319 of the Federal Clean Water Act, EPA has established a list of nine key components that the Mud Creek effort should address. The following is a listing of the nine points and references to the Britton Creek project and how it addresses these points:

The nine 'Key Elements' of stormwater plan structure:

1) Identify causes and sources of pollution,
2) Informational/ educational component – public awareness participation,
3) Management practices needed to achieve load reductions,
4) Estimate load reductions from practices,
5) Estimate technical and financial resources needed,
6) Implementation schedule ("reasonably expeditious"),
7) Interim milestones,
8) Criteria: determining load reductions/ progress, and
9) Monitoring: evaluate effectiveness

Item #1 - Sediment is the primary pollutant. However, the area is developed and there would be some organic pollution and nutrients, but the primary impact is from sediment, both carried in sheetflow from runoff and from streambank erosion. Environmental and Conservation Organization (ECO) of Hendersonville (http://eco-wnc.org/) have taken many water samples from streams in the watershed.

Item #2 – There will be public meetings to discuss the project objectives and collect public input. In addition, a questionnaire has been posted on the city website and advertized to watershed residents. The questionnaire discusses the objectives of the project and solicited public input. It is discussed further in Section 1.0.

Item #3 – Effective management practices include wetlands, stream enhancement, bank stabilization, rain gardens, rain barrels/ cisterns, underground detention, vegetative buffer zones and wherever possible, the disconnection of roof leader outfalls from the stream. Management practices are discussed further in Section 7. The City's Phase II stormwater program requires stormwater management for new development and redevelopment of existing sites. This program helps to prevent load increases. Stormwater requirements on redevelopment will actually reduce existing loads.

Item #4 – The 319 program uses EPA's Spreadsheet Tool for Estimating Pollutant Load (STEPL) to estimate sediment load reductions and the urban BMP tool component built into it.

Item #5 – Preliminary cost estimates have been provided in Section 7 for projects such as constructed wetlands, stream rehabilitation, stream bank stabilization and culvert replacement.

Item #6 – The implementation schedule will depend on funding sources. A preliminary schedule may be produced by the City of Hendersonville upon completion of the review of the current Britton Creek Stormwater Master Plan.

Item #7 – Interim milestones that currently exist for this project include the presentation of this report to the City of Hendersonville Engineering Department and also the City Council. Both which are anticipated before August 31, 2011.

Item #8 – Any Capital Improvement Projects that are implemented will be tracked both during the construction phase and afterward. Documentation will be made of stream improvements through habitat and structure stability. For wetlands the health and function will be assessed by documenting vegetation health and survival, water quality sampling, bug counts and hydraulic integrity. ECO and the volunteer monitoring program will be a valuable resource.

Item #9 – After construction the physical integrity of the systems will be monitored and documented. The Army Corps of Engineers provides guidelines on how monitoring can be accomplished. Citizen volunteers may be available to help in the monitoring process by taking samples in the Britton Creek watershed. ECO has been a primary proponent of volunteer monitoring and will certainly be an asset in this process.

2.0 BACKGROUND

The City of Hendersonville, North Carolina is located in Henderson County in the southwest portion of the state and is part of the Asheville Metropolitan Statistical Area. The city was officially recognized as the seat of Henderson County on January 7, 1847. The county and city were named after Leonard Henderson, who served as Chief Justice of the North Carolina Supreme Court from 1829 to1833.

The City of Hendersonville is located in the Blue Ridge Mountains, but is situated in an intermontane basin formed by the French Broad River and its tributaries. According to the United States Census Bureau, the city has a total area of 6.0 square miles comprised mostly of land and including about 7 acres of water.

According to the State Climate Office of North Carolina, the average high temperature in The City of Hendersonville is 84 degrees Fahrenheit and the average low is 25 degrees Fahrenheit. The average annual precipitation is approximately 57 inches. Due to its higher elevation and therefore cooler climate, Henderson County is about the southernmost limit for commercial apple growing (apples require extensive winter chilling and do not tolerate summer heat and humidity well). Apples have been the traditional agricultural crop in Henderson County, especially since World War II, but are today being superseded by land development (for housing and light industrial development). However, the tradition of honoring the local apple industry persists in the annual Apple Festival, held in Hendersonville each year around Labor Day.

As previously noted, the Britton Creek watershed is certainly an example of development growth within the City. The attached figures illustrate development changes from 1993 to 2007 within the watershed.

This project was conducted under the direction of the City of Hendersonville with funding assistance and technical coordination from the North Carolina Clean Water Management Trust Fund (CWMTF). We coordinated the project with and incorporated some of the components of the Mud Creek Restoration Project into the report.

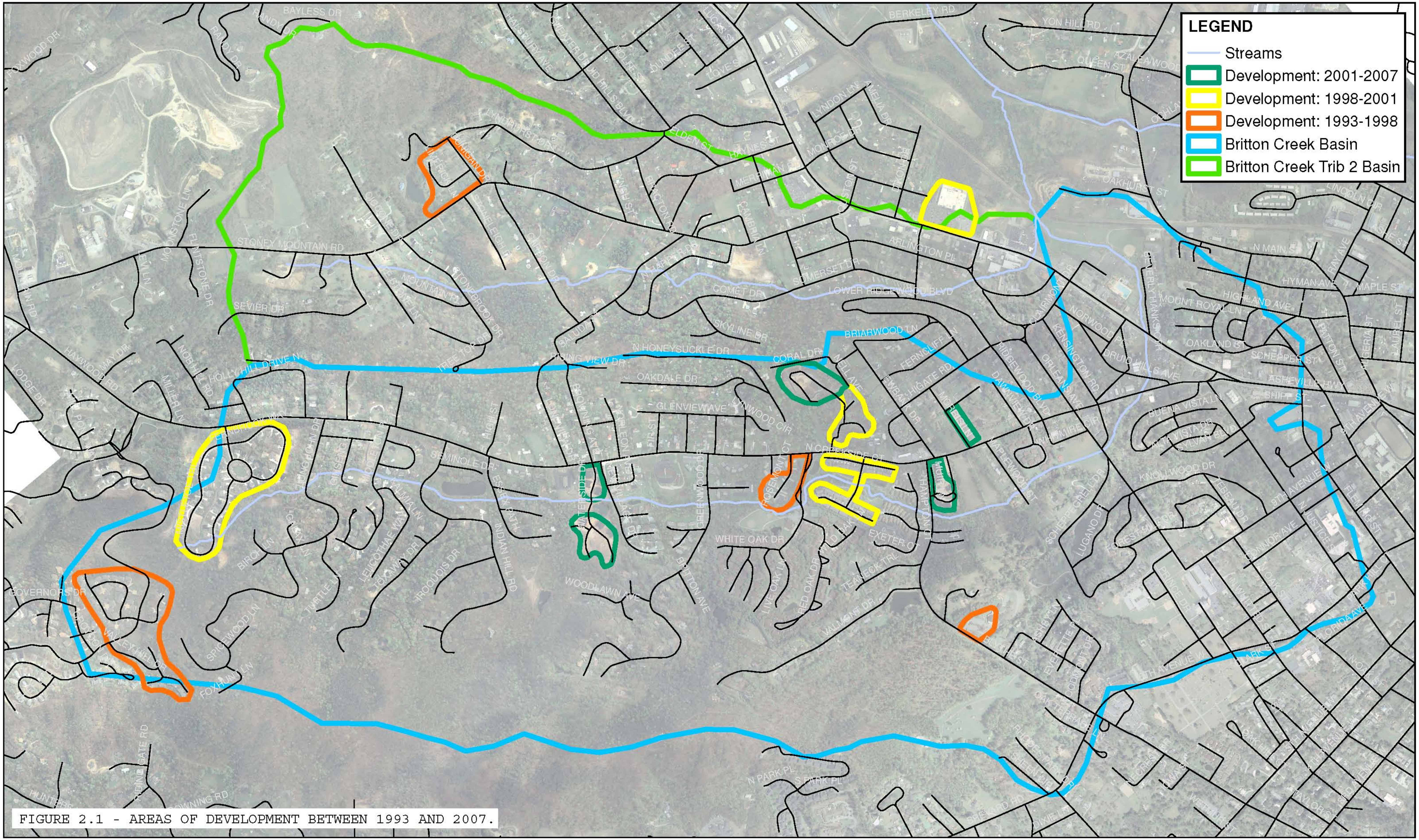

FIGURE 2.1 - AREAS OF DEVELOPMENT BETWEEN 1993 AND 2007.

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF DEVELOPMENT FROM 1993 THROUGH 2007

0 500 1,000 2,000 3,000 4,000 Feet

1 INCH = 1,000 FEET

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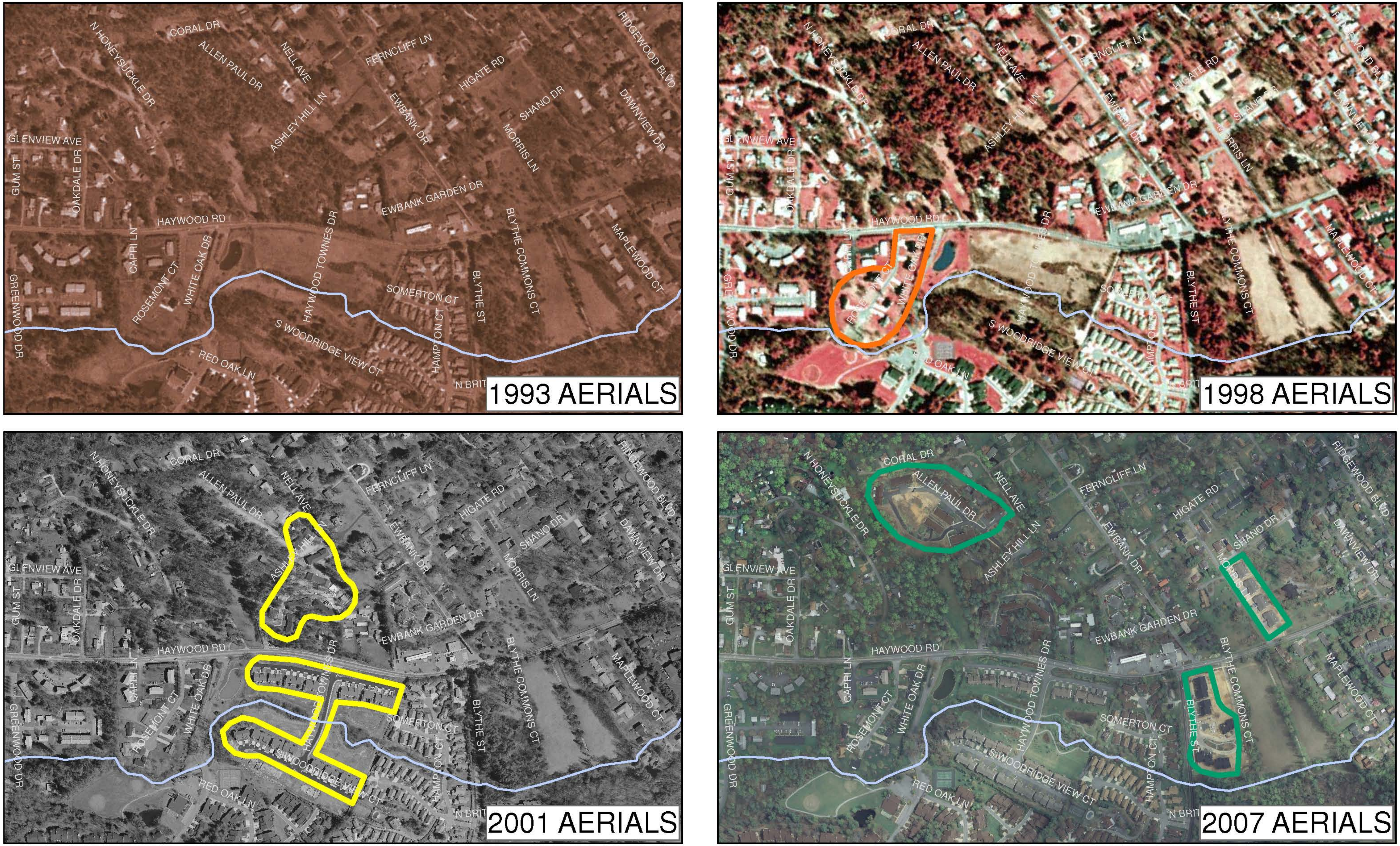

FIGURE 2.2 - EXAMPLE AREA SHOWING DEVELOPMENT OVER THE PERIOD FROM 1993 TO 2007.

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
EXAMPLE OF DEVELOPMENT OVER THE PERIOD FROM 1993 TO 2007

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

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3.0 DATA COLLECTION AND DATABASE ANALYSIS

Survey field crews utilized Geographic Information System (GIS) and surveying technologies offered by Leica Geosystems Mobile Matrix and ESRI ArcView. The technology allows the collection of survey quality data using a mobile GPS antenna, while placing the data points directly into a Geographic Information System (GIS) database.

3.1 Geographic Information System (GIS)

ArcInfo is an advanced GIS software product from Environmental Systems Research Institute, Inc. (ESRI). ArcInfo provides everything needed to build and manage a complete GIS system from start to finish. ArcInfo has all the functionality of ArcEditor and ArcView, plus advanced analysis, extensive data manipulation, and high-end cartography tools for the creation of maps. This includes the creation of geodatabases and feature datasets needed for an accurate and complete data collection in the field with the Leica Mobile Matrix. With ArcInfo, the geodatabases can be managed by adding, removing, and calculating fields to personalize the database. Once data collection is complete, data can be removed, checked for accuracy, and data analysis can be performed. Final maps can be professionally produced to represent and symbolize the collected data for reports or presentations.

Using ESRI GIS software ArcGIS 9.3, a geodatabase was created for the collected inventory data. The geodatabase, a native data format for ArcGIS, is a data storage container. The included data is represented as a feature class (such as point, line, or polygon) with the corresponding attributes and spatial reference. The spatial reference refers to the coordinate system information used to store the geometry. The coordinate system used for this data collection was North American Datum 1983, North Carolina State Plane FIPS 3,200 Feet. Additionally, orthographic photos were used to correct stream locations in order to provide a more accurate blue line database than what is provided by the State of North Carolina.

3.2 Leica Mobile Matrix

Leica Geosystems enables environmental data inventory to be fast and efficient, giving field personnel the ability to collect data at survey grade in true geodatabase format. When operating the Leica Geosystems equipment, Total Station and Real Time Kinematic (RTK) Global Positioning System (GPS) is used to map features and build and populate geodatabases in the field on a tablet PC. Survey data is not processed in external software; rather, it is integrated within the GIS. Essentially, complete maps are created in the field and can be easily edited by the same personnel that collected the data. This process ensures that stormwater system connectivity and spatial positioning are at the highest degree of accuracy.

Leica Mobile Matrix is a GIS application that enables a multisensory GIS. Generally, it combines and controls surveying sensors with GIS software to efficiently capture and maintain spatial data. Benefits of this software include:

- Incorporating a variety of sensor types in a mobile GIS platform,
- Surveying real-time data collection in the GIS environment,

- Integrating and graphically rendering quality control management in real-time,
- Conducting real-time GIS analyses in the field, and
- Eliminates the historical bottlenecks of GIS data collection and migration.

Multiple feature editing is a beneficial tool for GIS data collection. Multiple feature editing is a process that ensures economical field practices and preserves topological relationships. With this process, a single measurement, whether GPS or Total Station is used to create or extend several feature classes at the same time. For example, a stormwater pipe system where several catch basins are connected by underground piping can be edited using this tool. The catch basin point features are selected and the line features of the underground piping are automatically snapped to the vertices of the catch basin to complete the system connectivity.

The native file format used by Mobile Matrix is the ESRI Geodatabase feature class; no file conversion is necessary for ArcGIS. All measurements from survey instruments (GPS or Total Station) are stored in a survey dataset inside the geodatabase. The survey dataset is a sub-set of tables within the geodatabase that dynamically links survey features to their corresponding feature classes. The Leica software Survey Explorer is used for managing survey measurements. The user can import and export survey measurement data, manage multiple sets of coordinates, edit coordinate values, create survey reports, and use SQL queries to quickly find specific survey data.

The biggest advantage the Mobile Matrix system offers is real-time visualization (i.e. the user sees everything in the map display that has been surveyed). The end-user knows from the map display whether or not everything has been collected and connected properly. The need for costly site revisits to collect missed features is greatly reduced. Mobile Matrix provides a graphical representation of both feature classes and survey measurements. Therefore, the data collection methodology is permanently archived in the database and visible in the map document. Since quality control is the most useful when addressed at the time of data collection, Mobile Matrix actively writes the X/Y and Z measurement quality for each position to the survey dataset. This information enables Mobile Matrix to display error ellipses in real-time. In this manner, the end-user can see the quality of each measurement in the map display and the error can be resolved immediately.

The Leica Mobile Matrix equipment is shown in Figures 3.1 and 3.2.

Figure 3.1: Leica Mobile Matrix Equipment

Figure 3.2: Collecting data using Mobile Matrix

3.3 Stormwater Infrastructure Inventory

Due to the size of the watershed and the limits of the project scope, a complete stormwater system inventory for the watershed was not feasible for this project. Because a hydraulic analysis of Britton Creek and Britton Creek Tributary 2 was an integral part of the project, survey data collection focused largely on characterization of the hydraulic features of the streams. Therefore, bridge and culvert crossings were the primary focus though other items were collected. The following is a list of the items that were collected during the field survey phase of this project:

- End of Pipe (136)
- Bridge Deck (99)
- Pipe (75)
- General Observation (71)
- Catch Basin (37)
- Headwall (30)
- Bridge/ Culvert (19)
- Cross Section Point (19)
- Stream (6)
- Engineered Channel (5)
- Weir Box (4)
- Junction Box (3)

Each feature was inventoried with descriptive attributes such as: dimensions, material, condition and photo identification. Field crews evaluated and recorded a general assessment of the existing infrastructure. The data was collected for use in accurately modeling and analyzing how water is conveyed through stream and its culvert crossings. Characterized as a hydraulic study, this analysis provides estimates of expected flood levels and extents, helping engineers to design and develop improvements.

National Pollutant Discharge Elimination System (NPDES) Phase II requirements call for the detection and elimination of illicit discharges found in communities with a population less than 100,000 persons. An MS4, or municipal separate storm sewer system, is defined by the Environmental Protection Agency (EPA) as “any pipe, ditch, or gully, or system of pipes, ditches, or gullies, that is owned or operated by a governmental entity and used for collecting and conveying storm water”. Illicit discharges, noted in Minimum Measure Three, are defined as “any discharge into an MS4 that is not composed entirely of stormwater”. Discharges from permitted industrial sources are an exception to this rule. Locating potential illicit discharges along the streams was also an objective of this project. One observation of potentially illicit discharge was made and is discussed in greater detail in Section 5. Illicit discharges are unlawful because MS4's are not designed to collect or discharge anything other than stormwater. It is important to collect a complete a closed system inventory in order to trace potential pollutants to their source.

In addition to the potential illicit discharges, field personnel identified several areas that could be negatively impacting the health of the streams. In general stream bank erosion was a significant problem along both streams. Sediment is the primary pollutant in the streams. Areas of stream bank erosion or heavy sediment deposition were identified in the 'Observation' feature and also noted in the comments field of other connected features. For example, if sediment deposition was heavy at the inlet of a pipe, it would be noted in the comment field of 'Endpipe' or 'Pipe.'

There are generally five types of pipe found in storm sewers, including reinforced concrete pipe (RCP), corrugated metal pipe (CMP), ductile iron pipe (DIP), polyvinyl chloride (PVC), vitrified clay pipe (VCP), and high density polyethylene (HDPE). Although they are no longer widely used for new construction, vitrified clay pipes are the most commonly seen pipes in the United States due to their use in sanitary sewers and stormwater conveyance systems. Modern pipe designs fall under two categories: *rigid* and *flexible*.

Rigid pipes can bare loads other than their own weight. When installed, these pipes can be laid and surrounded to their spring line with gravel and then backfilled with any compactable material. RCP and DIP both fall in this category.

Flexible pipe is used to create a passage for stormwater runoff to flow in a closed system. These pipes cannot bear loads other than their own weight and must be backfilled with stone or gravel to distribute weight around the pipe rather than through it. Pipes in this category include CMP, VCP, HDPE, and PVC). Table 3.1 shows the life expectancy and resistance to flow for each type of pipe observed.

Table 3.1: Life Expectancy and Resistance to Flow based on Pipe Material

Pipe Material	***Life Expectancy (years)***	***Resistance To Flow (N Value)***
Corrugated Metal (CMP)	25	0.024-0.026
Vitrified Clay (VCP)	45-60	0.011-0.013
Reinforced Concrete (RCP)	50-75	0.012-0.015
High Density Polyethylene (HDPE)	50-75	0.009-0.012
Ductile Iron (DIP)	75-100	0.0101-0.0103

High density polyethylene pipes are becoming more widely used. Although similar to reinforced concrete piping in both life expectancy and resistance to flow, HDPE is a much lighter and safer product to work with.

3.4 City of Hendersonville Inventory Verification

The City of Hendersonville has a significant database of stormwater structures throughout the city limits. The database consists of 117 culverts, 821 catch basins, 963 drop inlets, 1599 pipes and several other categories of structures. As part of the scope of this project, the existing database was to be verified during the field survey. A survey of each structure within the existing database was neither feasible nor necessary. It was not necessary because the database is not obsolete and would not be significantly more useful for planning purposes if the data points were given a higher degree of precision. However, by surveying a representative group of structures within the City's database, a verification of the coordinates can be made and an average deviation can be calculated. The average deviation will provide planners and city officials with a sense of the degree of accuracy in all of the structures that were collected in a similar manner, with the same locating equipment.

Table 3.2: Variation Measured in Feet Between the Previous and Current Stormwater Infrastructure Survey.

STRUCTURE LABEL	VARIATION IN POSITION (FEET)
A	6.6
B	4.4
C	3.9
D	8.7
E	7.7
F	9.9
G	4.8
H	--
I	--
J	--
K	8.3
L	3.9
M	6.8
N	9.2
O	--
P	--
Q	4.7
R	9.4
S	10.1
T	3.5
U	6.8
V	7.3
W	--
X	18.6
Y	3.1
Z	8.8

The stormwater drainage system that runs between Hendersonville Middle and Elementary Schools was used in this verification process (Figure 3.3). This system collects runoff along Valley Street down toward the middle school and from Orleans Avenue down Prince Drive. It also collects runoff from the parking lot of the elementary school and routs it underneath the baseball field and into an open system that drains to Britton Creek.

Twenty-six catch basis and twenty six pipes were collected using the same survey equipment described in Section 3.2. The catch basins are labeled from A-Z on Figure 3.3. The system of catch basins and pipes shown in white was previously collected as part of City's stormwater database. The system shown in black lines and points was collected as part of the current survey. Table 3.2 shows the variation measured in feet between the previous and current survey. Six structures that were collected in the current survey were not part of the previous survey. Those are indicated in the table by a dash mark. The average deviation in position is 7.3 feet for the area surveyed.

It should also be noted that the pipe routing differed in two areas. Just east of the baseball field, the pipe network was surveyed to have a junction within the middle school field rather than across Prince Drive near the sidewalk. Also, next to the wing of the middle school closest to the basketball court there are inconsistencies between the mapped networks. Some of this may be due to improvements that have been made since the previous survey was conducted.

FIGURE 3.3 - STORMWATER INVENTORY DATABASE VERIFICATION.

HENDERSONVILLE ELEMENTARY/MIDDLE SCHOOLS: HENDERSONVILLE, NC
STORMWATER INVENTORY DATABASE VERIFICATION

McGill ASSOCIATES

4.0 WATERSHED ANALYSIS

4.1 Background

The City of Hendersonville is located in Henderson County, North Carolina. Hendersonville lies within the French Broad River basin. The Britton Creek watershed, drains to Mud Creek. The Britton Creek watershed has two main waterways: Britton Creek and Britton Creek Tributary 2.

According to the Natural Resources Conservation Service (NRCS), the underlying soils in Hendersonville are generally classified as Hydrologic Soil Group Type "B". Hydrologic Soil Groups (HSG) are based on estimates of runoff potential; soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storm events. The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D).

HSG Type "B" soils have a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. HSG Type "B" soils have a moderate rate of water transmission. HSG Type "C" soils have slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. HSG Type "C" soils have a slow rate of water transmission. HSG Type "D" soils have a high runoff potential and have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan at or near the surface, and shallow soils over nearly impervious materials. HSG Type "D" soils have a very low rate of water transmission.

4.2 Hydrologic Analysis Method

The hydrologic analysis is designed to produce estimates of discharge rates in the streams. Several factors are taken into consideration for this analysis including:

- Drainage area,
- Ground cover and degree of vegetation,
- Slope of ground, and
- Precipitation depth.

The US Army Corps of Engineers' HEC-HMS Hydrologic modeling computer program version 3.4 (US Army Corps of Engineers - Hydrologic Engineering Center, April 2006) was utilized to complete the Hydrologic modeling (Figure 4.1). The following models were created solely for the purpose of stormwater analysis in the Britton Creek watershed. It is not intended to supersede or replace effective data published by the Federal Emergency Management Agency (FEMA).

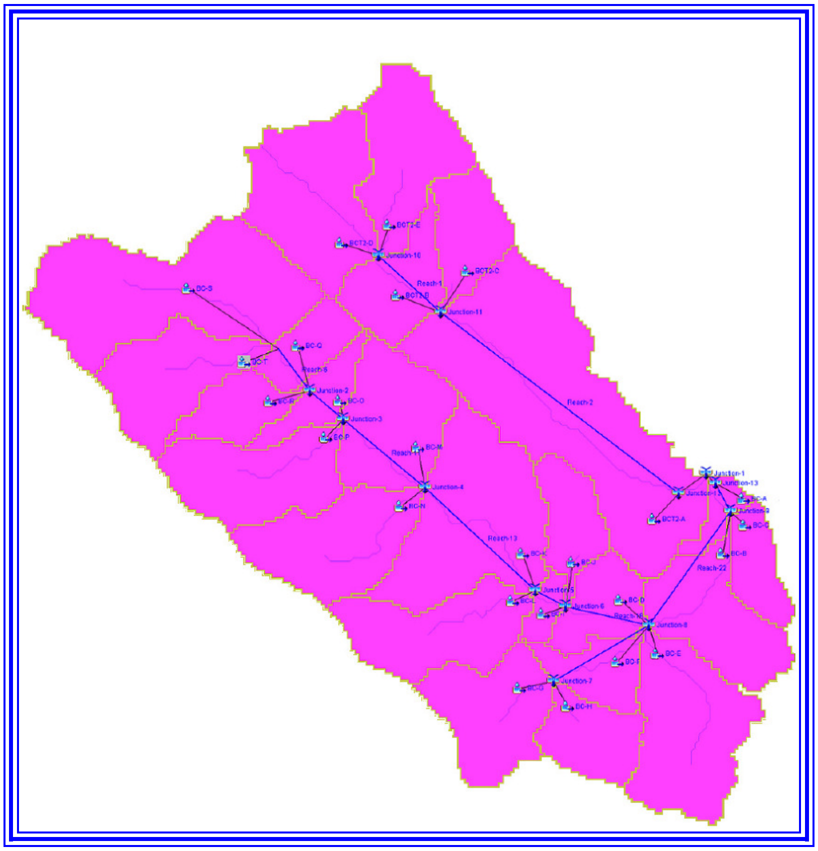

Figure 4.1: Schematic of Britton Creek watershed as modeled in HEC-HMS.

Sub-Basins

The Britton Creek watershed was divided into twenty sub-basins and the Britton Creek Tributary 2 watershed was divided into five sub-basins (Figure 4.2). Since the theoretical discharge rate changes continuously along the stream, having more sub-basins is useful because it allows estimates of discharge rate to be made in more places along the length of the stream.

Rainfall

The rainfall data found in the *Precipitation-Frequency Atlas of the United States* - NOAA Atlas 14, Volume 2, published by the National Oceanic and Atmospheric Administration (NOAA) was utilized for this project (Table 4.1). The 24-hour storm events were analyzed using the SCS Type II rainfall distribution to characterize the storm pattern.

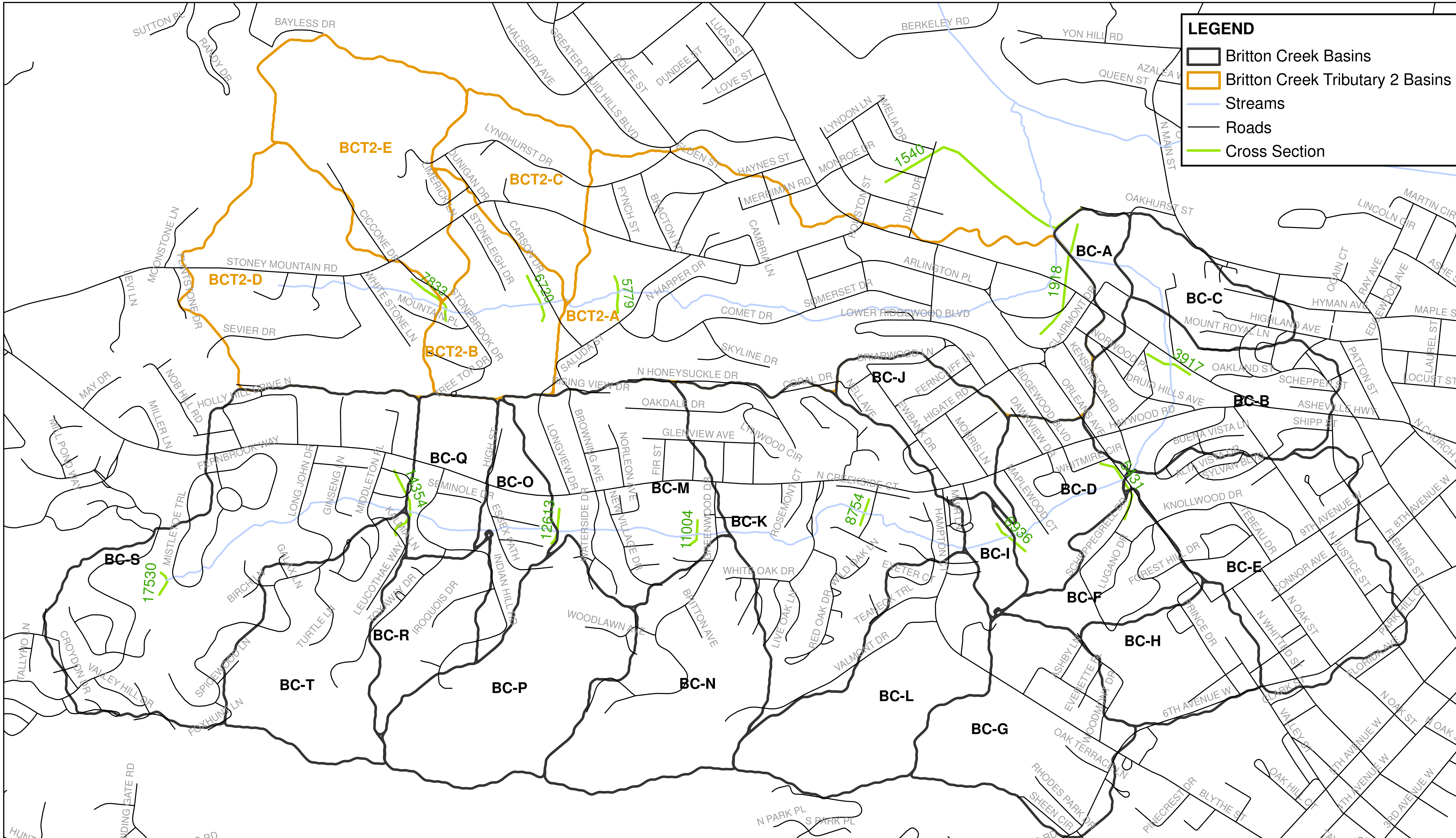

FIGURE 4.2 - HYDROLOGIC AND HYDRAULIC BASIN MAP.

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
BASIN MAP USED FOR HYDROLOGIC AND HYDRAULIC ANALYSIS

0 500 1,000 2,000 3,000 4,000 Feet

1 INCH = 1,000 FEET

McGill ASSOCIATES

Table 4.1: NOAA Precipitation Depth Estimates for Hendersonville.
http://hdsc.nws.noaa.gov/hdsc/pfds/index.html.

Precipitation Frequency Estimates (inches)																		
ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.38	0.60	0.75	1.03	1.28	1.51	1.63	2.13	2.69	3.25	3.87	4.39	5.12	5.87	7.94	9.71	12.35	14.75
2	0.45	0.72	0.90	1.24	1.56	1.83	1.96	2.54	3.23	3.90	4.62	5.22	6.08	6.94	9.34	11.38	14.42	17.18
5	0.54	0.86	1.08	1.54	1.98	2.31	2.46	3.13	3.96	4.79	5.62	6.25	7.28	8.23	10.84	13.03	16.26	19.20
10	0.60	0.96	1.22	1.76	2.30	2.69	2.87	3.64	4.55	5.50	6.42	7.06	8.24	9.25	11.99	14.27	17.59	20.64
25	0.69	1.10	1.39	2.06	2.74	3.22	3.47	4.38	5.39	6.48	7.53	8.16	9.54	10.64	13.50	15.83	19.20	22.36
50	0.76	1.20	1.52	2.29	3.11	3.66	3.97	5.01	6.08	7.28	8.41	9.02	10.57	11.74	14.64	16.98	20.34	23.55
100	0.82	1.30	1.65	2.53	3.48	4.12	4.50	5.71	6.80	8.11	9.33	9.88	11.63	12.85	15.76	18.06	21.37	24.62
200	0.89	1.41	1.77	2.76	3.88	4.62	5.09	6.46	7.57	8.96	10.28	10.76	12.71	13.98	16.85	19.09	22.32	25.58
500	0.97	1.54	1.94	3.09	4.43	5.32	5.93	7.58	8.67	10.16	11.59	11.97	14.19	15.51	18.25	20.37	23.43	26.69
1000	1.04	1.64	2.06	3.34	4.88	5.89	6.65	8.54	9.57	11.12	12.64	12.93	15.36	16.70	19.30	21.29	24.21	27.44

Methodology

The Soil Conservation Service (SCS) Methodology was used to determine the peak discharge rates. This methodology was selected because of its general acceptance in the engineering community and because it is the most commonly used methodology for this type of analysis. The SCS Methodology uses Curve Numbers to relate rainfall to runoff and the time of concentration to determine the response of each sub-basin.

Curve Numbers

Curve Numbers (CN) are determined by analyzing the infiltration capacity of the underlying soils and reviewing the type and extent of development within a basin. The Natural Resources Conservation Service (NRSC) provides soil surveys for the United States and classifies soils into Hydrologic Soil Groups based on the soil's infiltration ability. An analysis of the NRCS soil survey determined that both watersheds, collectively, contain approximately 1% A-type soils, 87% B-type soils, 11% C-type soils, and 1% D-type soils. A detailed soils report is contained in Appendix 9.5. Review of the aerial photographs of the region indicated that the watersheds are primarily residential development with a smaller portion of forested areas. Using the table in Appendix 9.6, "Table of Runoff Curve Numbers", the appropriate Curve Number, based on soil type and development intensity, for each sub-basin was selected. These numbers ranged from 58 to 81.

Time of Concentration

The time of concentration (t_c) was determined for each sub-basin using the methods outlined in *Technical Release 55 - Urban Hydrology for Small Watersheds* by NRCS dated June 1986. This method breaks the flow path of runoff in the watershed into three parts: sheet flow, shallow concentrated flow, and channel flow. HydroCAD Version 8.50 2007 was used for this analysis. A HydroCAD report summarizing the parameters for each basin of the two streams is included in Appendix 9.7.

Analysis

The 1-, 2-, 5-, 10-, 25-, 50- and 100-year 24-hour storm events were analyzed. The models were calibrated to approximate the discharge rates published (October 2, 2008) in the effective Flood Insurance Study (FIS). You can find relevant pages of the FIS in Appendix 9.8. The discharge rate at the downstream point of each model is the number that was adjusted to approximate the correlating discharge rate reported in the FIS. For Britton Creek, the downstream point is just upstream of the Tributary 2 confluence, approximate river mile 0.29. The FIS reports the 100-year discharge rate in Table 4.2 as 1,185 cfs. The calibrated HEC-HMS model calculated a discharge rate of 1,167 cfs. For, Tributary 2, the downstream point is at the Britton Creek confluence. The FIS reports the 100-year discharge rate in Table 4.2 as 700 cfs. The calibrated HEC-HMS model calculated a discharge rate of 700.5 cfs. The model was calibrated by adjusting the CNs by a factor of 0.63 in the Britton Creek watershed and 0.7 in the Tributary 2 watershed.

Table 4.2: Excerpt from 'Table 8 – Summary of Discharges' in the October 2, 2008 FIS for Henderson County.

Flooding Source	Location	Drainage Area *(square miles)*	Discharges *(cfs)*			
			10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Britton Creek	At the confluence with Mud Creek	3.5	720	1,250	1,530	2,000
	Below tributary, Mile 0.29	3.2	685	1,180	1,475	1,900
	Above tributary, mile 0.29	2.3	540	960	1,185	1,520
	Below tributary, mile 0.96	2.1	500	900	1,100	1,420
Britton Creek	Above tributary, mile 0.96	1.6	430	760	945	1,200
	Approximately 100 feet downstream of Essex Path	0.5	*	*	470	*
Britton Creek Tributary 2	At the confluence with Britton Creek	0.9	*	*	700	*
	Approximately 300 feet upstream of Browning Avenue	0.5	*	*	500	*

Tables 4.3 and 4.4 show a summary of the HEC-HMS calculated discharge rates for Britton Creek and Tributary 2. To find the location by cross section of the estimated discharge refer to Figure 4.2.

Table 4.3: Summary of HEC-HMS Calculated Discharges for Britton Creek.

BRITTON CREEK	RECURRENCE INTERVAL (YR)	CALCULATED DISCHARGE (CFS) AT CROSS SECTION:									
		17530	14354	12613	11004	8754	6936	5431	3917	1918	1540
	1	1	1.5	1.6	2.4	3.8	4.1	6.7	10.3	10.5	15.5
	2	4.6	7	7.5	10.8	17.9	19.5	30.5	42.4	43.6	65.6
	5	23.6	37.5	41.5	58.9	86.2	91.6	127	145.1	146.6	240.1
	10	51.2	84.1	96.9	135.3	187.6	197.4	260.7	287.4	289.8	468.5
	25	104.4	175.5	209.8	289.9	388.2	405.8	517.4	557.7	561.5	895.9
	50	158.4	269.4	328.3	451.9	596.1	621.2	779.8	832.5	837.4	1326.7
	100	222.6	381.6	472	648.4	847.1	880.6	1093.8	1160.8	1167.1	1838.3

Table 4.4: Summary of HEC-HMS Calculated Discharges for Britton Creek Tributary 2.

BRITTON CREEK TRIBUTARY 2	RECURRENCE INTERVAL (YR)	CALCULATED DISCHARGE (CFS) AT CROSS SECTION:		
		7833	6720	5779
	1	1.1	1.8	6.1
	2	5.2	9.2	26.2
	5	26.3	42.3	93.7
	10	57.1	91.2	181.3
	25	117.8	186.1	344.6
	50	180.1	283.2	508.2
	100	254.6	398.8	700.5

As part of the project scope an additional hydrologic analysis was performed assuming ‘built-out’ conditions of the watershed. This condition was defined as the maximum possible development based on zoning. Since the watershed is partially located in Henderson County, both the Hendersonville Zoning Map and the Henderson County Zoning maps were referenced to determine the built-out condition of the watershed (Figure 4.3). The curve number table referenced above was used to calculate the curve numbers (CNs) for built out conditions. Table 4.5 shows the comparison of between the CNs used for the existing condition analysis and the built-out CNs. There is a dramatic difference between the two CNs for each basin. This difference should be interpreted in light of the CN calibration described above. As stated above, the ‘raw’ existing conditions CNs were higher than those used in the analysis because the calibration reduced the CN by a specific factor. The calibration allows data comparison with an analogous model. However, in the case of the built-out conditions, there is no analogous model. Furthermore, the built-out conditions model is meant to be conservative. Tables 4.6 and 4.7 show a summary of the HEC-HMS calculated discharge rates for the built-out conditions of Britton Creek and Tributary 2.

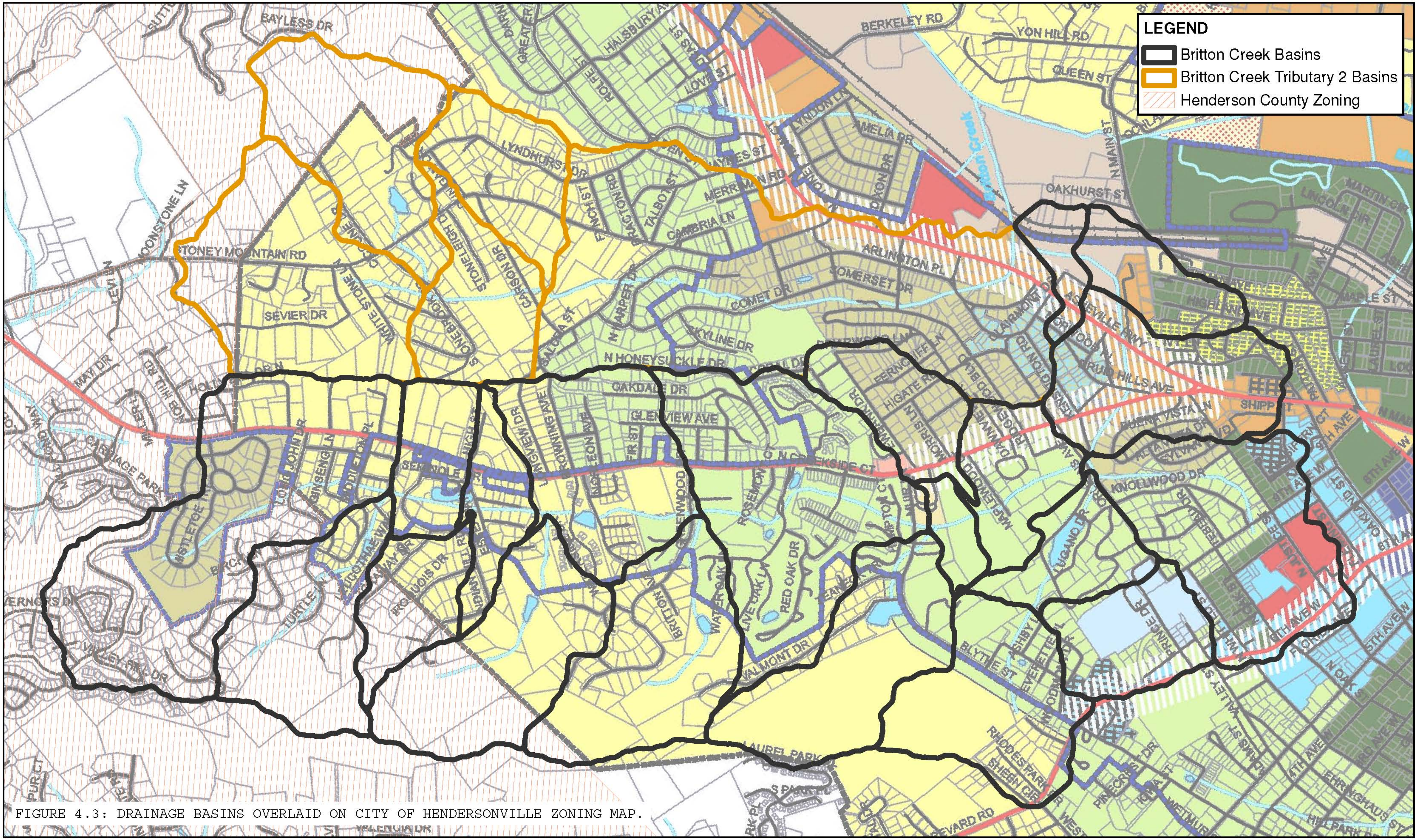

FIGURE 4.3: DRAINAGE BASINS OVERLAID ON CITY OF HENDERSONVILLE ZONING MAP.

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
DRAINAGE BASINS OVERLAID ON CITY OF HENDERSONVILLE ZONING MAP

1 INCH = 1,000 FEET

Table 4.5: Calculated CNs based on Existing and Built-Out Conditions.

Subbasin Name	Curve Number	
	Existing	Built-Out
BC-A	45.4	88
BC-B	51	85.8
BC-C	45.4	87.5
BC-D	42.3	75
BC-E	46.8	84
BC-F	42.9	76.6
BC-G	40.6	73
BC-H	43.9	85.5
BC-I	38.3	78.4
BC-J	44.1	76.6
BC-K	44.9	75.7
BC-L	38.5	71.5
BC-M	43.4	72
BC-N	38.8	71
BC-O	41.1	70
BC-P	36.5	76.5
BC-Q	42.3	70
BC-R	40.9	77.6
BC-S	42.2	78.1
BC-T	40.5	82.7
BCT2-A	49.2	77
BCT2-B	44.9	70
BCT2-C	47.6	70
BCT2-D	47	71.2
BCT2-E	42	72.7

Table 4.3: Summary of HEC-HMS Calculated Built-Out Discharges for Britton Creek.

	RECURRENCE INTERVAL (YR)	BUILT-OUT DISCHARGE (CFS) AT CROSS SECTION:									
		17530	**14354**	**12613**	**11004**	**8754**	**6936**	**5431**	**3917**	**1918**	**1540**
BRITTON CREEK	**1**	4.2	6.6	7	9	13.6	14.8	25.8	48.1	49.6	55.7
	2	19.7	30.1	31.7	41.7	64.6	69.7	114.4	180.9	187.8	220.2
	5	91.4	149.9	163.6	215.1	297.4	314.7	436.8	507.1	522.1	736.9
	10	182.4	309.8	356.7	465.5	614.2	643.7	839.2	908.6	916.5	1352.7
	25	335.5	582.6	702	916	1175.4	1222.8	1530.2	1623.4	1633.7	2395.9
	50	472.6	829.4	1023.4	1337.3	1697.5	1760.3	2166.1	2278.7	2291	3352.6
	100	619.2	1094.4	1374.8	1801.6	2272.3	2352.4	2863.7	2995.3	3009.8	4400.9

Table 4.4: Summary of HEC-HMS Calculated Built-Out Discharges for Britton Creek Tributary 2.

	RECURRENCE INTERVAL (YR)	BUILT-OUT DISCHARGE (CFS) AT CROSS SECTION:		
		7833	**6720**	**5779**
BRITTON CREEK TRIBUTARY 2	**1**	2.7	4.6	17.6
	2	13.2	23	72.8
	5	67.3	104.6	241.8
	10	142.3	218.4	444.9
	25	278.7	423.4	792.3
	50	407.7	617.6	1112.8
	100	551.4	834.4	1465.4

4.3 Hydraulic Analysis Method

The U.S. Army Corps of Engineers' HEC-RAS step-backwater computer program version 4.1.0 (U.S. Army Corps of Engineers, Hydrologic Engineering Center, January 2010) was used to complete the hydraulic modeling. HEC-RAS employs the output of the HEC-HMS model (described in Section 4.2) by routing the estimated discharges through cross sections along the stream. HEC-RAS allows the user to estimate water surface elevation (WSEL) at a given cross section and therefore, the extent of flooding. The 100, 50, 25 and 10 year discharges were assessed.

Both Britton Creek and Britton Creek Tributary 2 have been studied under FEMA. A studied stream will have data such as discharge rates and WSELs recorded in a flood insurance study (FIS) report. Also, the North Carolina Floodplain Mapping Program (NCFMP) provided the most recent hydraulic model of the stream on 14 October 2010. This data included a complete HEC-RAS model for Britton Creek Tributary 2 and a partial HEC-RAS model for Britton Creek. The Britton Creek model included the stream portion from XS 11731 to XS 17335. A HEC-2 model, created in January 1980, was used as reference for the lower portion.

HEC-2 is a precursor to HEC-RAS that was in wide use prior to the first HEC-RAS release in 1995. The HEC-2 model was archived in pdf form (Appendix 9.9). It is important to note that due to significant development in the watershed and technological advances in modeling since the time if the HEC-2 model's creation, it is outdated or inaccurate in several respects. For example, discrepancies of over 100 ft exist between the two models with respect to the stream station of crossings such as at Blythe Street. Therefore, the HEC-2 model was used as a data reference rather than a basis for the revised model. It was used to complement the data collected through field surveys, hydrologic modeling and geospatial analysis. Appendix 9.10 contains an illustration comparing the HEC-2 and revised models with respect to stream cross section alignment.

Because the Britton Creek model was split between the HEC-RAS and HEC-2 formats, several steps were required to integrate the data into a single comprehensive model of the stream.

1) In order to ensure the use of the most recent cross section data the 'Personal Geodatabase (PGDB) file for Henderson County was downloaded on March 16, 2011 from www.ncfloodmaps.com. This file contains the effective cross sections, base flood elevations (BFE), floodplain delineation and much more in a digital format that is compatible with ArcGIS software.
2) The PGDB cross sections were incorporated into the revised model in addition to 21 new cross sections on the upstream and downstream sides of several culvert/ bridge crossings. All cross sections were given a numerical 'name' according to their 'river station' measured in feet from the mouth of the stream.
3) NCFMP 'LIDAR Bare Earth' data was downloaded from http://www.ncfloodmaps.com/ and used to create a terrain surface.
4) HEC-GeoRAS, a river analysis tool for use in ArcGIS, created station and elevation data for each cross section based on the terrain surface. This tool converts the cross sections into a format capable of being imported directly into HEC-RAS.
5) The newly created HEC-RAS model was updated to include the surveyed data as well as the data in the 'upper Britton Creek' HEC-RAS model supplied by NCFMP.

During the field survey, all significant bridge or culvert crossings along Britton Creek and Tributary 2 were surveyed. Elevations were collected on the upstream and downstream inverts as well as the roadway elevation. All relevant parameters of the structures (size, length, material, etc.) were collected so that they could be most accurately modeled in HEC-RAS.

The 'normal depth' option was used to define the reach boundary conditions for both streams. This option allows the program to calculate the WSELs based on the channel slope at the downstream portion of the creek. The HEC-RAS model geometry for Britton Creek and Britton Creek Tributary 2 are shown in Figures 4.4 and 4.5. All of the cross sections are displayed in these figures.

HEC-RAS results provide an estimated WSEL at each cross section for the 100, 50, 25 and 10 year storm events. Figures 4.6-4.10 show the stream profile output of the model. The profiles are labeled with road names at each culvert crossing. Those culverts that were overtopped are color-coded with the minimum storm event that exceeded the culvert capacity. The numerical HEC-RAS output is included in Appendix 9.11.

An analysis of the stream profiles for Britton Creek indicates the overtopping of nine culverts. Haywood Manor Road Connection is overtopped during the 10 year storm. Three more are overtopped during the 50 year storm event: Orleans Avenue, Greenwood Drive and Mistletoe Trail. Five more are overtopped during the 100 year event: Druid Hills Avenue, Haywood Road, Indian Hill Road, Long John Drive and Mistletoe Trail (there are two crossings of this road).

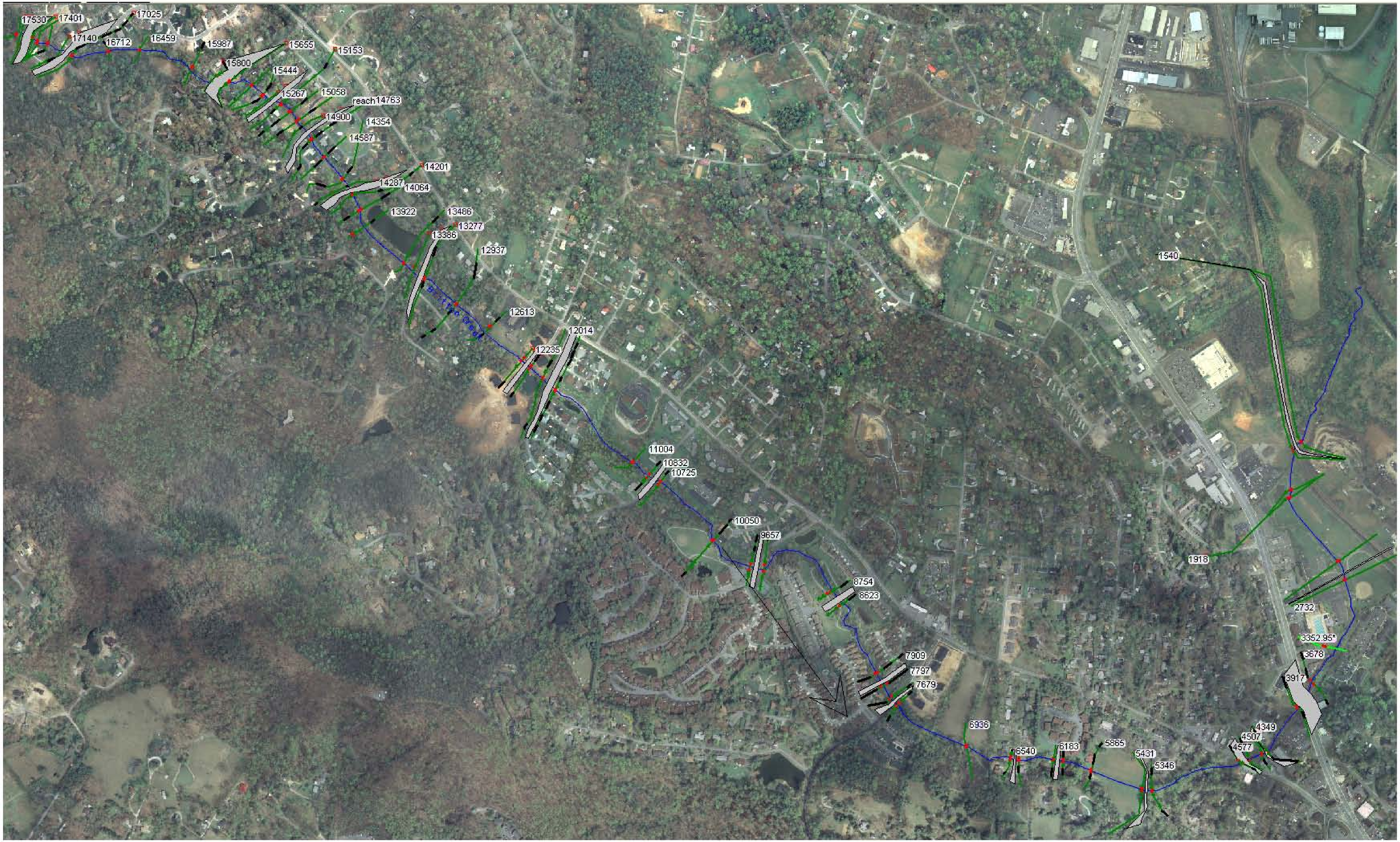

FIGURE 4.4: SCREEN SHOT OF HEC-RAS GEOMETRY FOR BRITTON CREEK. NUMBERED CROSS SECTIONS ARE GREEN. ROAD CROSSINGS ARE GREY. BANK STATIONS ARE RED. STRUCTURES IN CROSS SECTIONS ARE BLACK.

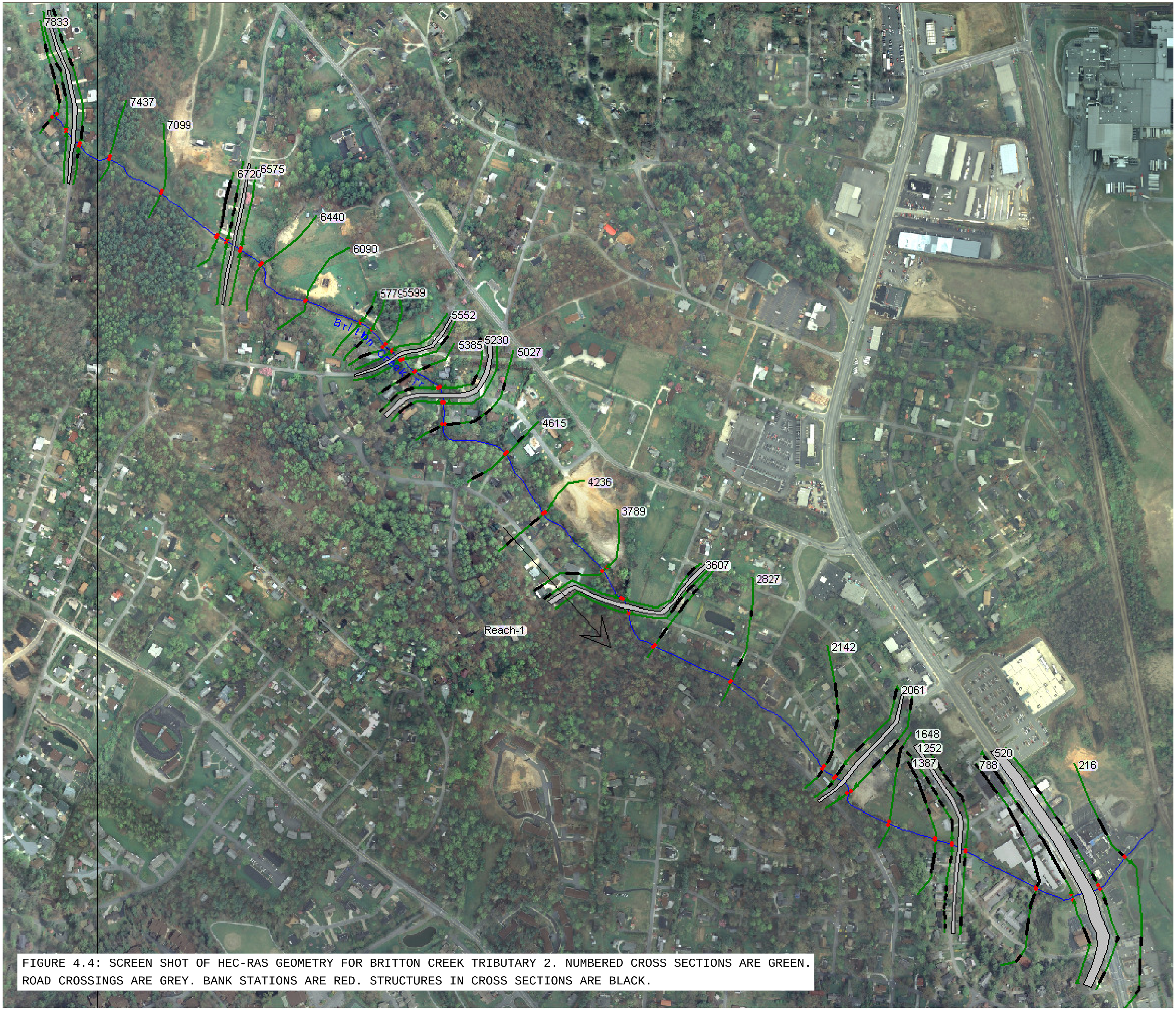

FIGURE 4.4: SCREEN SHOT OF HEC-RAS GEOMETRY FOR BRITTON CREEK TRIBUTARY 2. NUMBERED CROSS SECTIONS ARE GREEN. ROAD CROSSINGS ARE GREY. BANK STATIONS ARE RED. STRUCTURES IN CROSS SECTIONS ARE BLACK.

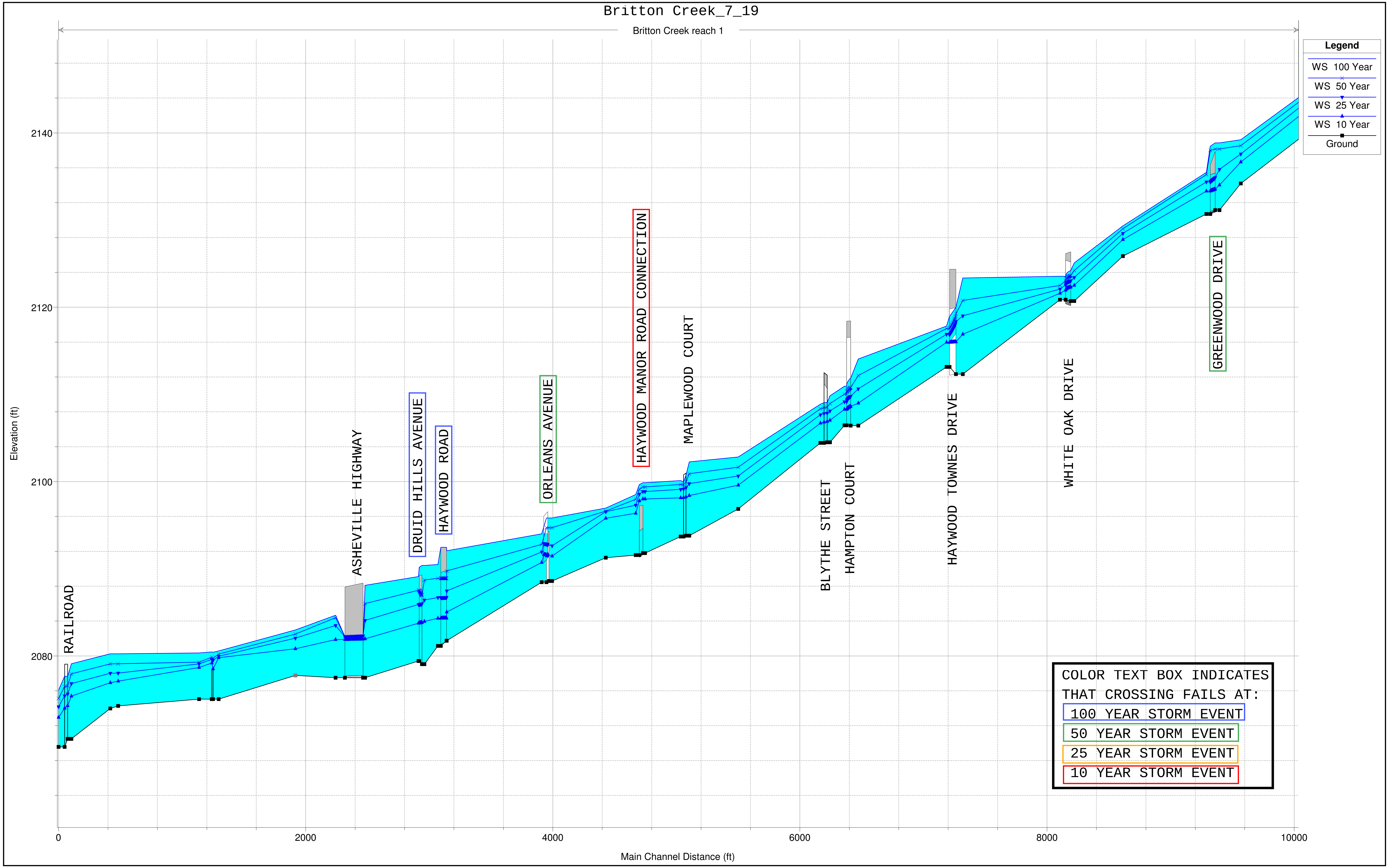

FIGURE 4.6: LOWER BRITTON CREEK PROFILE.

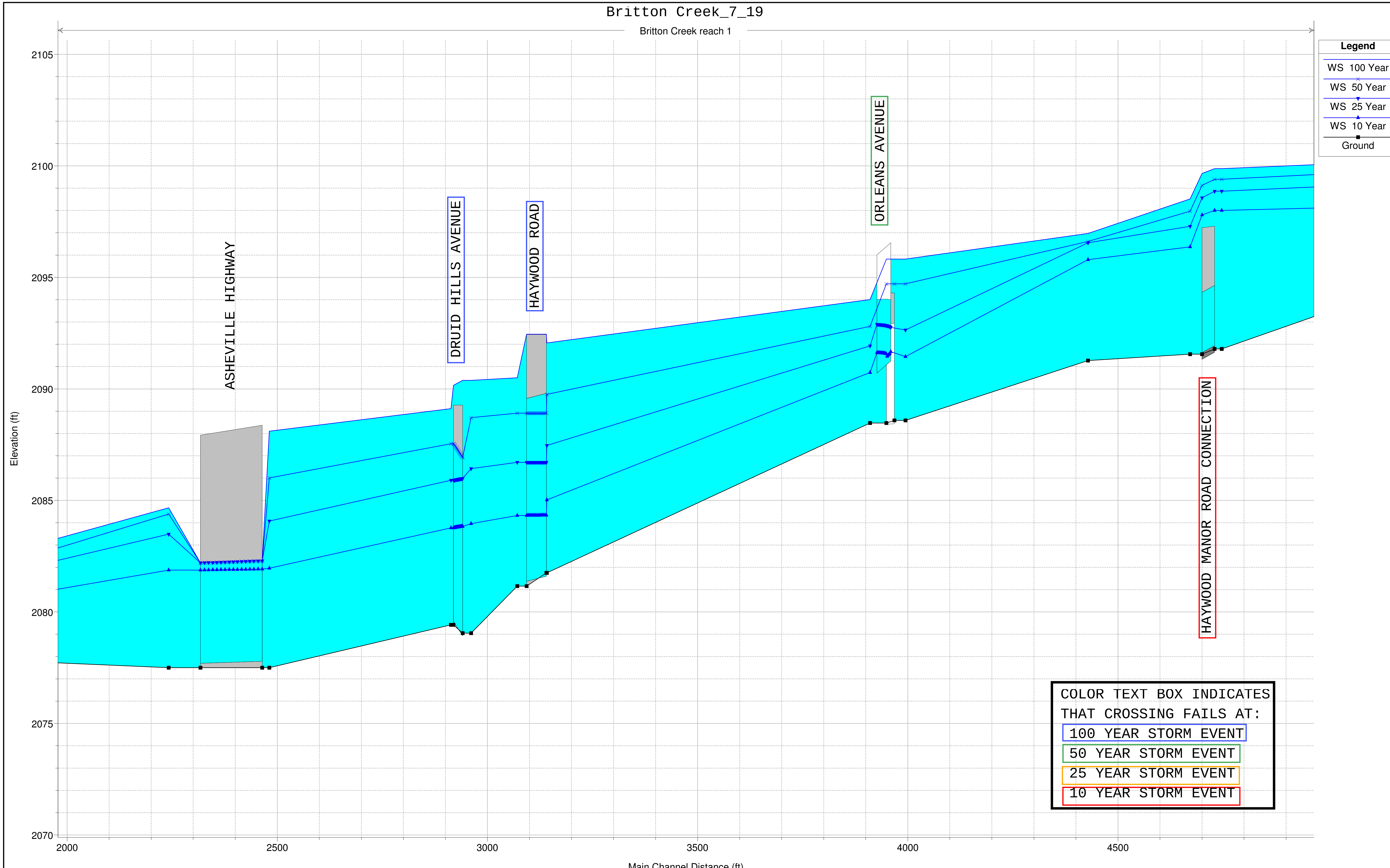

FIGURE 4.7: DETAIL OF LOWER BRITTON CREEK PROFILE FROM ASHEVILLE HIGHWAY TO HAYWOOD MANOR ROAD CONNECTION.

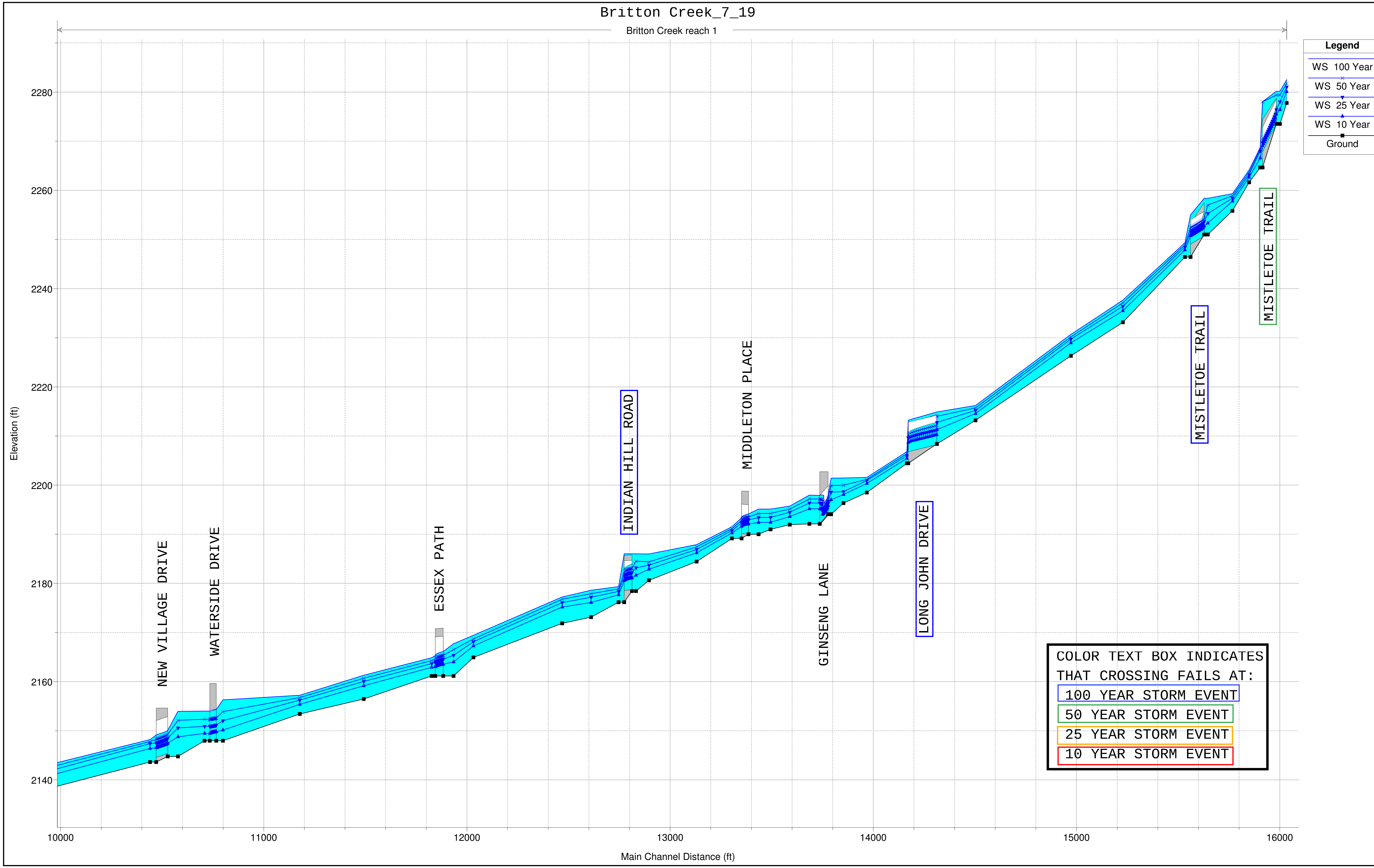

FIGURE 4.8: UPPER BRITTON CREEK PROFILE.

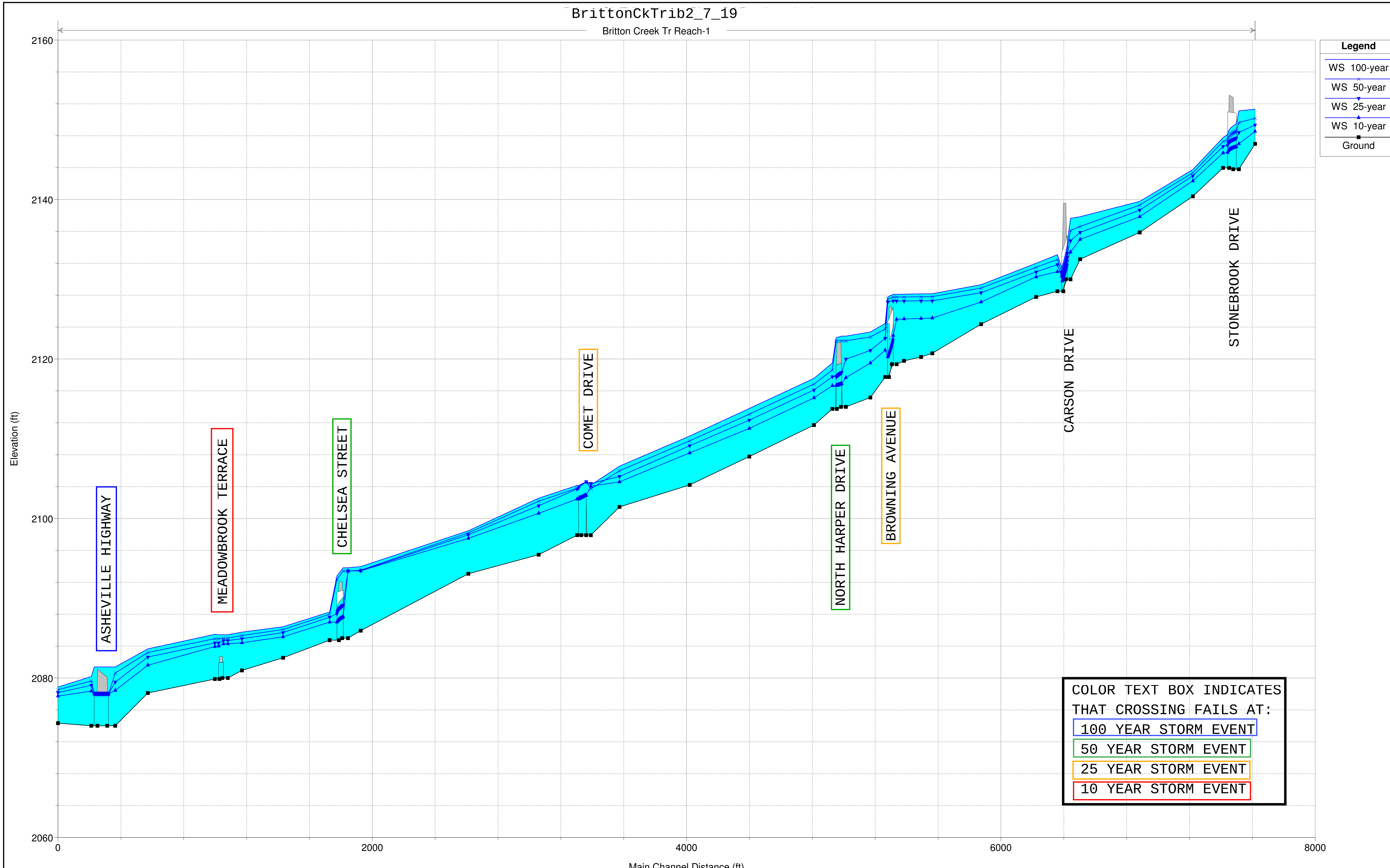

FIGURE 4.9: PROFILE OF BRITTON CREEK TRIBUTARY 2.

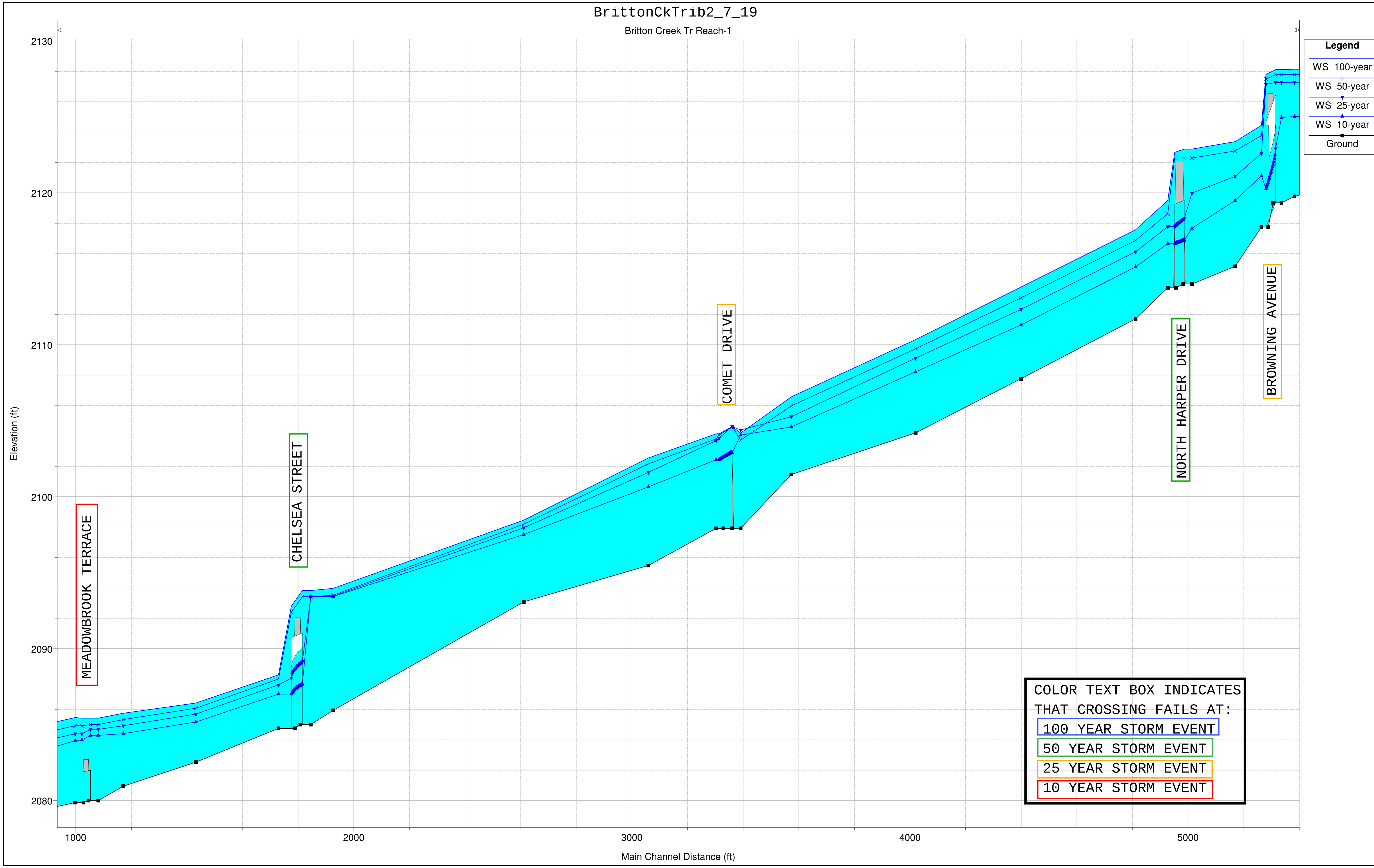

FIGURE 4.10: DETAIL OF BRITTON CREEK TRIBUTARY 2 PROFILE FROM MEADOWBROOK TERRACE TO BROWNING AVENUE.

Table 4.5: NCDOT Design Discharge Standards.

ROADWAY CLASSIFICATION	**FREQUENCY**
Interstate (I)	50 year
Primary (US & NC)	50 year
Secondary (Major, City thoroughfare)	50 year
Secondary	25 year

Based on the NCDOT design standards, shown in Table 4.5, only the Haywood Manor Road Connection culvert does not meet the requirements. However, it is not clear that the culvert needs to meet the requirements because it does not appear to be a public road.

An analysis of the stream profiles for Britton Creek Tributary 2 indicates the overtopping of six culverts. Meadowbrook Terrace is overtopped during the 10 year storm. Two more are overtopped during the 25 year storm event: Comet Drive and Browning Avenue. Two more are overtopped during the 50 year storm event: Chelsea Street and North Harper Drive. Asheville Highway is overtopped during the 100 year event.

The HEC-RAS output tables for Britton Creek and Tributary 2 showing water surface elevations and other data for each cross section and all modeled storm events are shown in Appendix 9.11. All cross sections for each stream are included in digital format. They include WSELs for the 100, 50, 25 and 10 year storm events.

A HEC-RAS analysis was also run to estimate the WSELs at all of the cross sections for Britton Creek and Tributary 2 for future, built-out conditions. The HEC-RAS output tables showing water surface elevations and other data for each cross section and all modeled storm events are shown in the Appendix 9.12.

4.4 Hydraflow Culvert/ Bridge Analysis

The Britton Creek model includes twenty-one culvert/ bridge crossings. The Britton Creek Tributary 2 model includes eight culvert/ bridge crossings. Incorporated into the HEC-RAS program is an analysis of culvert and bridge crossings. The program assesses the capacity of the crossing to convey the specified discharge. As shown in the previous section, the stream profile views can be used to determine whether culverts and bridges are overtopped or convey the specified discharge.

Additionally, a separate culvert/ bridge analysis was performed using Hydraflow Express 2006 (Version 1.0.0.1) by Intelisolve. Each culvert/ bridge crossings along both Britton Creek and Tributary 2 was analyzed individually. Each crossing was characterized with parameters collected during the field survey. A table showing the related parameters for each of the culverts and how they performed during selected storm events is included in Appendix 9.13 along with the model output. Output discharges of the HEC-HMS model (described in Section II) were used in the analysis and included the 1, 2, 5, 10, 25, 50 and 100-year 24-hour event storms.

The two analysis methods yielded similar results although HEC-RAS was more conservative in some cases, showing overtopping at a lower discharge rate than Hydraflow Express. One cause for a difference may be that HEC-RAS incorporates the entire cross-section into the analysis whereas Hydraflow analyzes only the immediate area of the crossing.

4.5 Floodplain Mapping

The subsequent step in the analysis utilized the WSELs that were generated in HEC-RAS and described in Section 4.3 to generate a floodplain. From a modeling standpoint a floodplain is formed by delineating along the contour of the specified flood elevation between each cross section. Since the HEC-RAS model provided flood elevations (WSEL) for the 100, 50, 25 and 10 year storm events, a floodplain can be created for each. However, the 100-year storm, which has a 1% chance of occurring in any given year, is special in the sense that it is the national standard for floodplain mapping. The area inundated during the peak of the 100-year storm, called the 'base floodplain,' is used to help determine flood insurance rates and it appears on flood insurance rate maps (FIRMs). The FIRMs for the Britton Creek watershed are included in Appendix 9.14.

As part of this mapping effort, the North Carolina Floodplain Mapping Program (NCFMP) provides a wealth of flood mapping data to the public free-of-charge on their website: http://www.ncfloodmaps.com/. Included in the databank is digital LiDAR topographic data. This data was used to create a terrain surface for the watershed which is shown in Figure 4.11.

HEC-GeoRAS is a powerful extension tool for ArcGIS. It is published by the Army Corps of Engineers and provides the capability to integrate several of the Army Corps other programs with ArcGIS. It allows the transfer of watershed modeling data to and from HEC-RAS. With this tool the HEC-RAS output is introduced geospatially referenced into ArcGIS. Using the HEC-GeoRAS tool, ArcGIS is able to read the WSELs that are calculated at each cross section and interpolate the WSEL between cross sections. This data is then overlaid on the terrain surface creating a floodplain based directly on HEC-RAS output. The floodplain generated for the watershed is shown on an 800 foot scale in Figure 4.12. Appendix 9.15 includes illustrations of the generated floodplains on a more detailed 200 foot scale. The appendix also includes the floodplains for the 50, 25 and 10-year flood estimates.

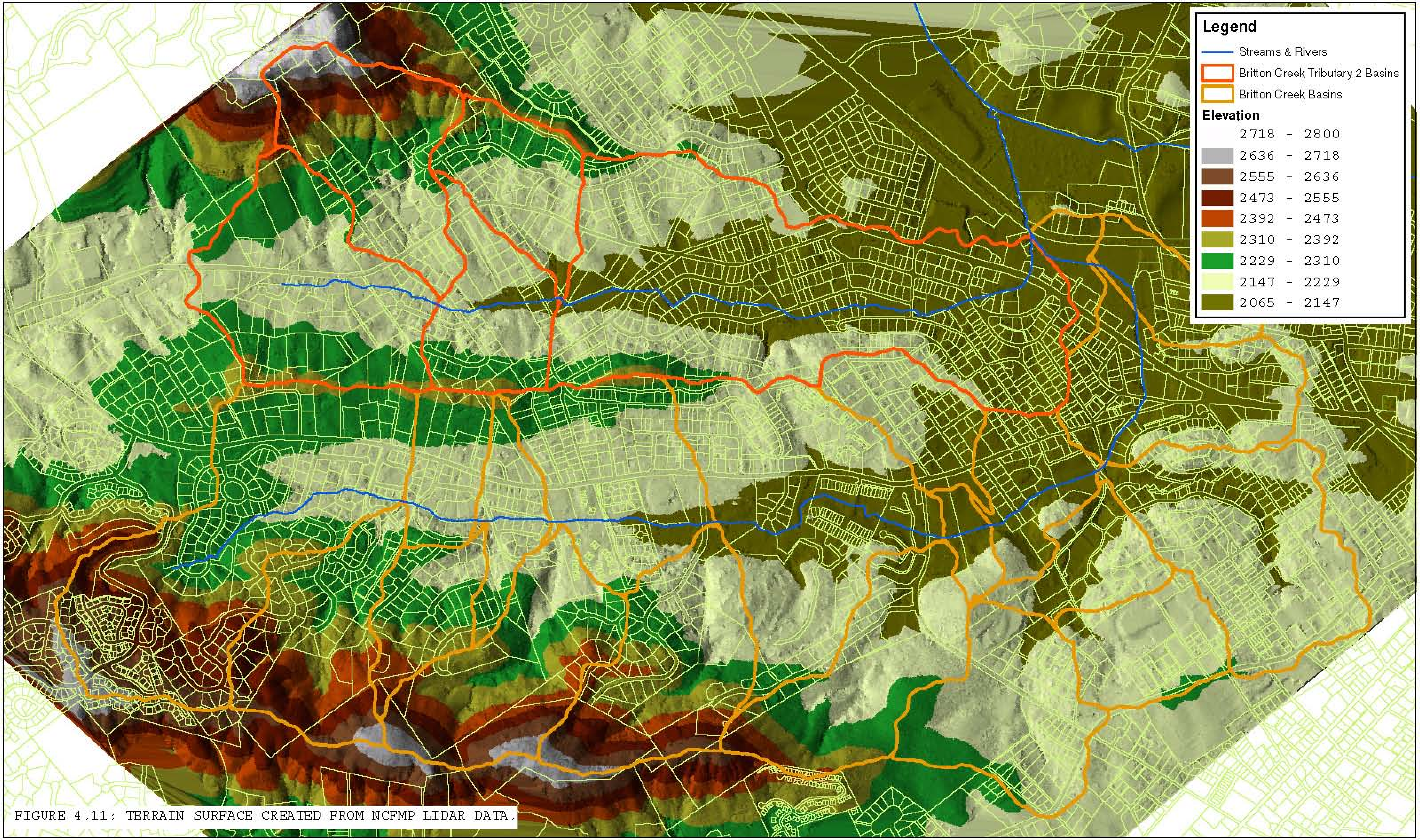

FIGURE 4.11: TERRAIN SURFACE CREATED FROM NCFMP LIDAR DATA.

BRITTON CREEK WATERSHED
CITY OF HENDERSONVILLE, NC

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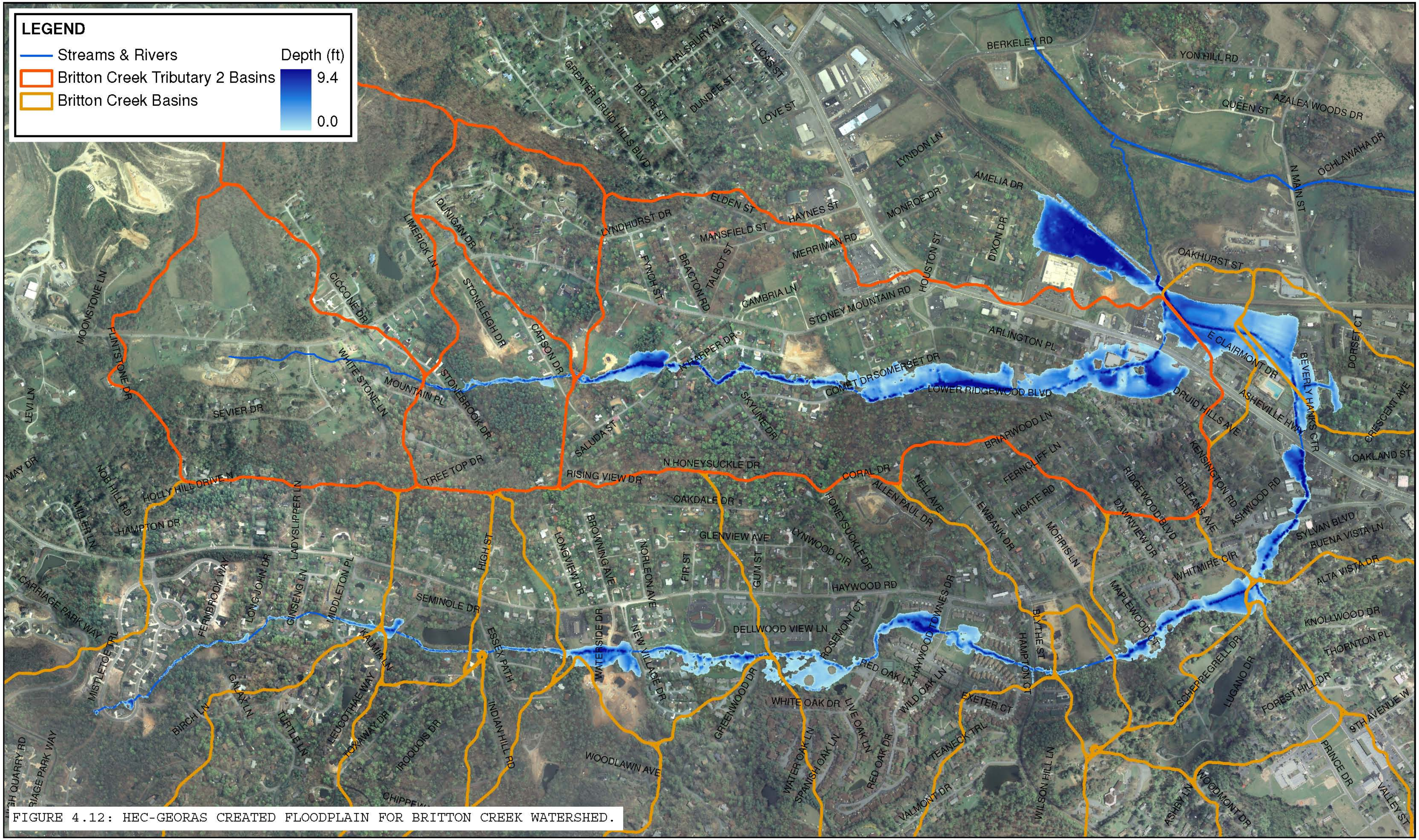

FIGURE 4.12: HEC-GEORAS CREATED FLOODPLAIN FOR BRITTON CREEK WATERSHED.

100 YEAR FLOOD EXTENTS
CITY OF HENDERSONVILLE, NC

0 400 800 1,600 2,400 3,200 Feet

1 INCH = 800 FEET

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5.0 Stream and Infrastructure Assessment

5.1 Introduction

Britton Creek and Britton Creek Tributary 2 were evaluated by field personnel over a period of six days: 11/10/2010, 11/18/2010, 11/23/2010, 12/09/2010, 2/22/2011 and 03/09/2011. The evaluation was performed in order to discover point sources of pollution assess the overall stream health and identify failing infrastructure. The evaluation considered the following elements:

1) Presence of a vegetative stream buffer zone,
2) Stream bank erosion,
3) Severe undercutting/loss of stream bank,
4) Deposition of sediment on stream channel bottom,
5) Resident complaints/concerns,
6) Unsecured grate inlets,
7) Rusted/crushed corrugated metal pipe (CMP),
8) Cracked reinforced concrete pipe (RCP) or headwall,
9) Discoloration of water or sediment,
10) Presence of standing water,
11) Inordinate amounts of rubbish or debris,
12) Possible illicit discharges and
13) Vented sanitary sewer lids.

Britton Creek was visually inspected from its confluence with Tributary 2, which occurs along the northern edge of Patton Park, up to Mistletoe Trail. Tributary 2 was inspected from the confluence upstream to North Springs Drive. This is consistent with the stream extents that have been modeled by the North Carolina Floodplain Mapping Program or that you may see on the associated Flood Insurance Rate Map (FIRM – Appendix 9.14).

5.2 Evaluation Methods

The evaluation was performed either by a team of two or a single person. The equipment that was utilized by field personnel included a camera, 25 foot measuring tape and surveying equipment, which is described in detail in Section 3.

In cases where access to the stream was limited due to thick growth or trespass issues, the stream evaluation was completed to the greatest extent possible. In general, tributaries or drainage systems to the streams, were not included in the assessment as it was beyond the scope of this study. However, some connected drainage systems were included because they were thought to significantly impact the stream health or provide possible opportunities for improvement projects.

During the stream walk, attention was paid to drainage outfall locations such as pipe outfalls, ditches or sheet flow from directly connected impervious surfaces. Any discoloration of water or sediment was noted and apparent illicit discharges were photographed and mapped. Where possible the source of any impacted water was identified.

Sediment, although a significant source of pollution in both streams, was not traceable directly to its source. During the days of field visits, the stream flow was moderate and suspended sediment was not generally visible in the stream (the exception is shown in Figure 5.1).

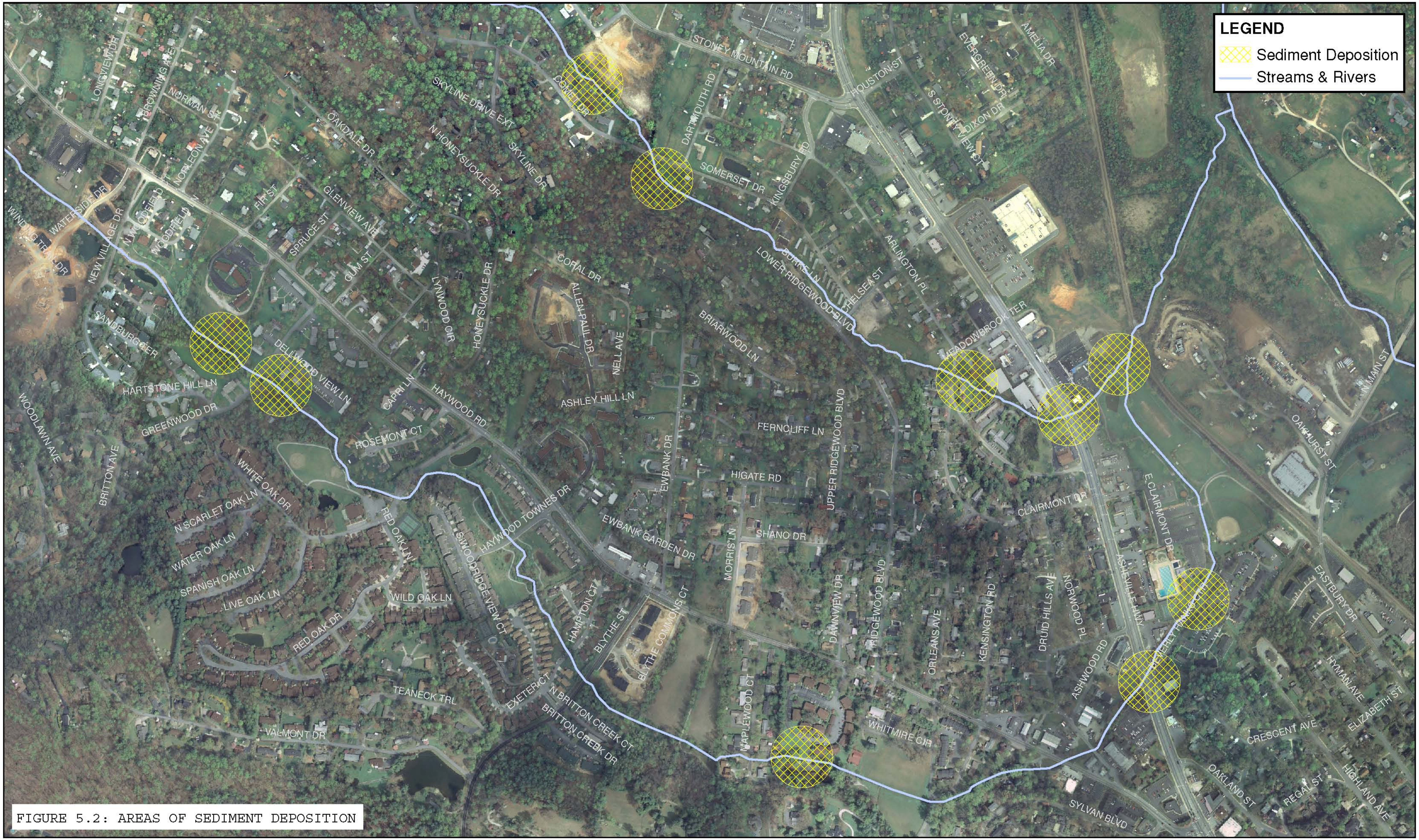
Figure 5.1: Sediment Discharge at Hendersonville Elementary.

However, deposited sediment was readily visible throughout both streams. Figures 5.2-5.3 illustrate ten locations of particularly heavy sediment deposition. Several sources of the sediment loads were identified through inference because of obvious stream bank undercutting and sediment loss. Figures 5.4-5.5 illustrate the areas where major erosion problems were identified.

Infrastructure degradation, in some cases caused by erosion, was identified in several places along both streams. The types of problems encountered include:

1) Sinking asphalt roadway,
2) Unsecured grate inlet,
3) Cracked RCP or headwall, and
4) Rusted out or crushed CMP pipe.

Figure 5.6 shows the locations in the watershed of each of these problems. In addition, off of the map shown in the figure, at Hendersonville Elementary School, there is serious RCP and headwall failure. This is illustrated along with others in the photos below.



BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF SEDIMENT DEPOSITION IN STREAM CHANNEL

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

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BRITTON CREEK JUST DOWNSTREAM OF GREENWOOD DRIVE

BRITTON CREEK JUST DOWNSTREAM OF ASHEVILLE HIGHWAY

BRITTON CREEK JUST DOWNSTREAM OF ASHEVILLE HIGHWAY

BRITTON CREEK JUST DOWNSTREAM OF ASHEVILLE HIGHWAY

BRITTON CREEK JUST UPSTREAM OF MAPLEWOOD COURT

FIGURE 5.3: PHOTOS OF SEDIMENT DEPOSITION

FIGURE 5.4: AREAS OF STREAM BANK EROSION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF STREAM BANK EROSION

0 300 600 1,200 1,800 2,400 Feet

1 INCH = 600 FEET

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BRITTON CREEK UPSTREAM OF GREENWOOD DRIVE

TRIBUTARY 2 DOWNSTREAM OF NORTH HARPER DRIVE

SMALL TRIBUTARY TO BRITTON CREEK NEAR 'THE OAKS'

BRITTON CREEK UPSTREAM OF GREENWOOD DRIVE

BRITTON CREEK UPSTREAM OF ORLEANS AVENUE

FIGURE 5.5: PHOTOS OF STREAM BANK EROSION

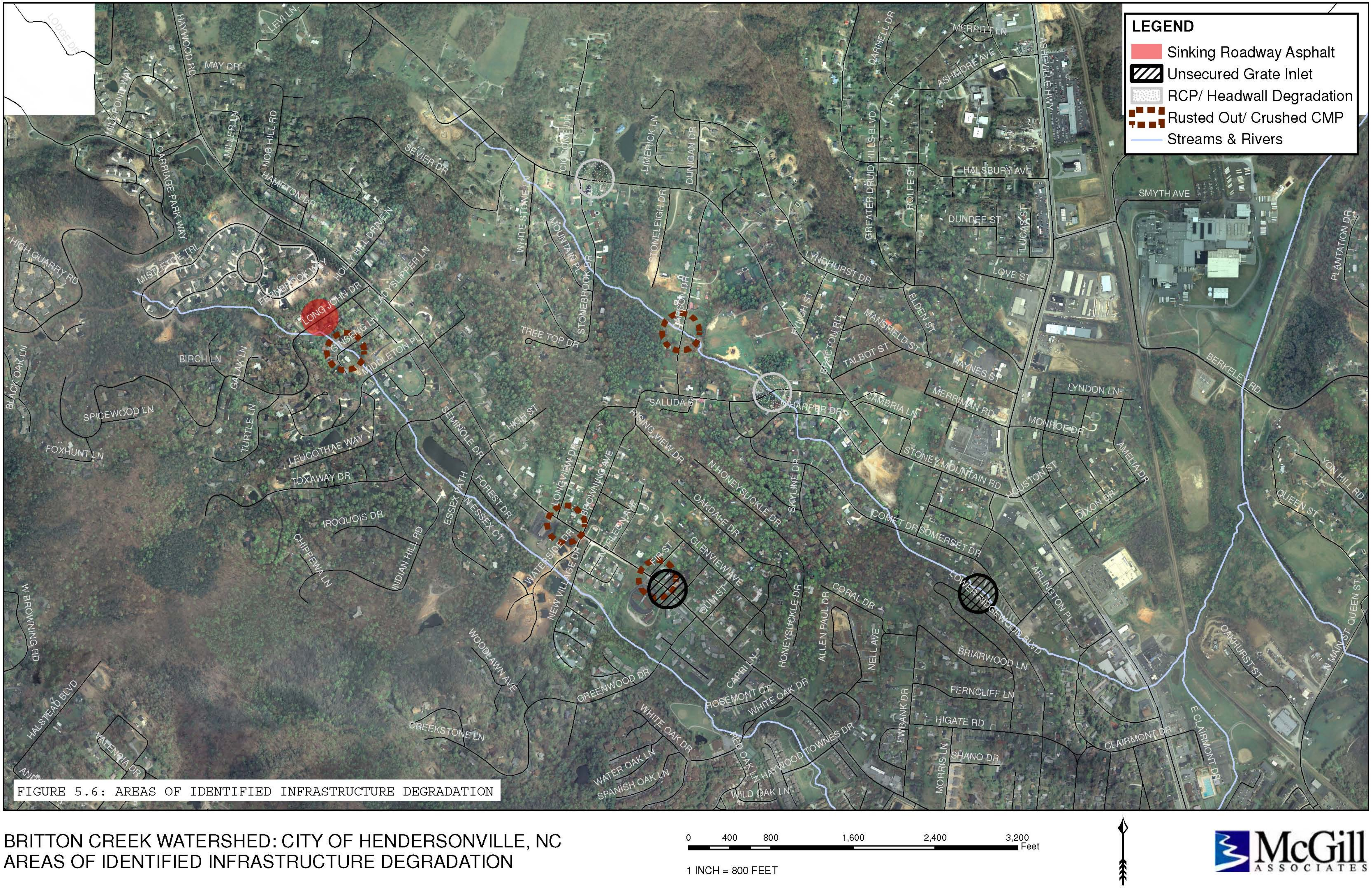

FIGURE 5.6: AREAS OF IDENTIFIED INFRASTRUCTURE DEGRADATION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF IDENTIFIED INFRASTRUCTURE DEGRADATION

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Figure 5.7: Headwall at Hendersonville Elementary.

Figure 5.8: Asphalt Swale at Hendersonville Elementary.

Figure 5.9: Headwall Browning Avenue.

Figure 5.10: Sinking Asphalt on Long John Drive.

Figure 5.11: Open Grate Inlet Burke Lane.

Naturally occurring in particularly low-lying areas is standing water. There were two locations that were identified to have standing water (Figure 5.12). One is on the right hand side (with a downstream orientation) of Britton Creek just upstream of Waterside Drive in the wooded area. Another is in a more prominent location just upstream of Asheville highway on the right hand side of Tributary 2.

An item that may or may not be naturally occurring is the discoloration of water or sediment around outfalls into the streams. This may be due to natural chemical reactions taking place among minerals in the environment. It could also be due to an illicit discharge. Two locations with discoloration of water were identified during the evaluation and one location of potential illicit discharge was also identified. Figure 5.13 identifies the three locations as potential point sources of pollution.

Additionally, two incidents of pollutant discharges occurred during the time the field personnel were present. One involved an underground water line repair near the Hendersonville Elementary School. The dug up sediment combined with the water being discharged and washed into the system. The photo of the discharge is shown in Figure 5.1. The other discharge occurred when a landscaping crew in the Haywood Manor Road development dumped grass clippings directly into the stream.

Waste and debris were observed in the channels, on stream banks or in drainage ditches in four places in the watershed. In some areas the debris was chunks of concrete intended to help stabilize the bank. Other areas were littered with trash. Figure 5.14 shows their locations and includes photos.

The City of Hendersonville is actively replacing vented sanitary sewer lids within their jurisdiction. This action is important because vented lids allow additional stormwater to enter the wastewater system. During wet weather infiltration into the wastewater system can overload the capacity of the treatment plant, which can result in Sanitary Sewer Overflows (SSOs). During a SSO wastewater is discharged directly into the stream diminishing water quality and potentially harming the health of wildlife and humans. Two vented sanitary sewer lids were located during the field survey. Keith Fogo of the City of Hendersonville was one of the survey crew members and, upon discovering the vented lids; he immediately reported them to the City and requested that they be sealed with a replacement lid. The two locations of the vented sewer lids are shown in Figure 5.15.

During the evaluation, field personnel encountered residents several times each day. Some were curious about the work, some offered input and some were not interested. Each time a resident was engaged in conversation about the work, the opportunity to give feedback directly to the City was presented verbally and in the form of the prepared letter, provided by the City of Hendersonville. There were two instances where residents offered feedback that was related to stormwater issues. On November 10, 2010, field personnel were surveying in The Oaks development (White Oak Drive) and engaging residents about their stormwater-related concerns. One resident, Ms. Jacek (of lot #106 building 69), showed the areas around her property that she noticed standing water or wet ground after rain events. Also, adjacent to her property is a

FIGURE 5.12: AREAS OF STANDING WATER

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF STANDING WATER

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

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FIGURE 5.13: POTENTIAL POINT SOURCES OF POLLUTION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
POTENTIAL POINT SOURCES OF POLLUTION

0 260 520 1,040 1,560 2,080 Feet

1 INCH = 500 FEET

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FIGURE 5.14: AREAS OF DEBRIS IN CHANNEL

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF DEBRIS IN CHANNEL

0 200 400 800 1,200 1,600 Feet

1 INCH = 400 FEET

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FIGURE 5.15: VENTED SANITARY SEWER LIDS

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
VENTED SANITARY SEWER LIDS

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

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drainage ditch which feeds into a drainage pipe. The ditch and pipe are so obstructed with leaves that field personnel were unable to locate the pipe. On February 22, 2011, field personnel surveying on Long John Drive were addressed by a driver of a passing car. He stated that he had observed that the asphalt roadway directly above the 2 foot CMP culvert had sunk. A photo of the road is shown in Figure 5.16.

Figure 5.16: Sinking Asphalt on Long John Drive.

All of the items described in this section are included in the digital GIS files provided to the City. All photographs are also provided with the data package.

6.0 ENVIRONMENTAL REGULATIONS

The Britton Creek Watershed, like other water courses in North Carolina, are covered by a variety of Local, State and Federal regulations and environmental laws. Activities related to the management of wastewater and water resources are covered by provisions of the Federal Clean Water Act passed initially in 1972. The City operates a wastewater collection system within the majority of the watershed serving both residential areas and business activities. The City has specific constraints on what can be discharged to the system and regulates it use through a sewer use ordinance. As noted elsewhere in this report, the City has in place provisions to manage potential impacts to the floodplain and to maintain vegetated streamside buffers related to new development within its jurisdiction. Hendersonville is also an NPDES (National Pollutant Discharge Elimination System) Phase II stormwater municipality under the Federal Clean Water Act and NC law. Erosion and sediment control provisions are included in the Henderson County ordinances and development is managed under its subdivision, planning and building permits programs. Other State and Federal water pollution control programs are managed by the State under its Division of Water Quality and the US Army Corps of Engineers. Some general background on the major drainage and quality characteristics of the River Basin that includes the sub-watershed of Britton Creek follows:

6.1 The French Broad River Basin

Britton Creek is in the portion of the French Broad River watershed that lies within North Carolina. The North Carolina part of the French Broad River Basin drainage area encompasses approximately 2,809 square miles, consists of all or portions of nine counties (including Henderson County), and contains 4,113 miles of streams. Water resources in this river basin support municipal water systems, wildlife, agriculture, irrigation, many types of industry and recreation based businesses such as whitewater rafting, canoeing, and trout fishing. Several streams in the basin are classified as “High Quality Waters” (HWQ) or “Outstanding Resource Waters” (ORW) because of exceptionally high water quality, and in the case of the ORW designation, important ecological habitat or recreational attributes. Significant activities in the basin include agriculture, manufacturing, and mining. The overall quality of the water in the French Broad River Basin is good, although approximately 11% (~400 miles) is impaired by sediment, fecal coliform bacteria, toxic substances, and/or turbidity. The sources of these pollutants are agriculture, construction, urban development, point source discharges, septic systems, and forestry activities.

There are four surface waters in The City of Hendersonville listed on the North Carolina 2010 Impaired Waterbodies List (see the 2010 303(d) List in Appendix 9.7), including portions of Bat Fork, Clear Creek, Devils Fork, and Mud Creek. The listings are for Category 5 type impairment, which under the listing criteria for North Carolina indicates that streams in this Category are subject to a Total Maximum Daily Load (TMDL) development process. However, contact with the North Carolina DWQ TMDL program indicates that no plans or schedule are in place for the Mud Creek drainage basin. Because there are significant voluntary efforts to address the impairment, specifically including the Mud Creek Watershed Restoration Project described in this document, the State agency is holding off on any TMDL process. This is particularly important in this area since it is clear that a wide variety of stormwater runoff characteristics are impacting the water quality of Mud Creek and its tributaries. Impairment of Mud Creek and its tributaries actually begins upstream of any City drainage which reflects the role that other parts of the watershed play in affecting stream quality. 303(d) listing is an important component of environmental regulation in this project study area, but specific regulatory actions by State and Federal agencies are pending since local actions to improve water quality are ongoing.

A complete listing of the North Carolina 2010 303(d) List as well as information describing the list and how it is used can found online at http://portal.ncdenr.org/web/wq/ps/mtu/assessment.

A major objective of State and Federal regulatory agencies is to promote effective watershed and pollution control management across the country. This certainly applies to the Britton Creek watershed and all drainage systems downstream of Britton Creek. A crucial component of this effort is to keep all of its streams, creeks, and rivers off of the 303(d) list by promoting effective principles for the use of construction and post-construction erosion control and water quality Best Management Practices (BMPs). Through existing programs; the watershed management requirements under Phase II; and the existing local programs implemented by the City, Hendersonville is an effective partner in managing new development. The City's ongoing efforts to effectively address existing stormwater impacts, as illustrated by its cooperation with voluntary efforts by the Mud Creek Watershed Restoration Program and the Britton Creek watershed effort documented in this report, points to Hendersonville's commitment to mitigate the effects of watershed modification from development. Although some portion of four surface waters in Hendersonville are already listed on the 303(d) List, the City is making good effort to address these issues and prevent other streams from becoming listed.

Table 6.1 shows the classifications for the 2010 303(d) listed streams of the French Broad River Basin located in Hendersonville.

Table 6.1: Classification of the 2006 303(d) List Streams in Hendersonville

Name of Stream	Current Classification	Reason for 303(d) Listing	Impaired Use
Bat Fork *from source to County Route 1779*	C	Impaired Biological Integrity	Aquatic Life
Clear Creek *from source to Laurel Creek*	B, Tr	Impaired Biological Integrity	Aquatic Life
Devils Fork *from first UT west of State Route 1006 to Johnson Drainage Ditch*	C	Impaired Biological Integrity	Aquatic Life
Mud Creek *from Little Mud Creek*	C	Impaired Biological Integrity	Aquatic Life

B = Waters protected for all Class C uses in addition to primary recreation. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis.

C = Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, aquatic life including propagation, survival, and maintenance of biological integrity, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner.

Tr = Trout Waters. Supplemental classification intended to protect freshwaters which have conditions which shall sustain and allow for trout propagation and survival of stocked trout on a year-round basis.

Table 6.2: Identification of the 2010 303(d) Streams in Hendersonville

NC 2010 Integrated Report Categories 4 and 5 Impaired Waters

All 13,123 Waters in NC are in Category 5-303(d) List for Mercury due to statewide fish consumption advice for several fish species

AU_Number / Category	AU_Name / Parameter	AU_Description / Reason for Rating	Use Category	LengthArea AU_Units / Collection Year	Classification / 303(d)year
French Broad River Basin			**Mud Creek Watershed**	**0601010503**	
6-55-8-1a	**Bat Fork**	From source to State Route 1779		**4.8 FW Miles**	C
5	**Ecological/biological Integrity Benthos**	Poor Bioclassification	Aquatic Life	1989	1998
6-55-8-1b	**Bat Fork**	From State Route 1779 to Johnson Drainage Ditch		**1.5 FW Miles**	C
5	**Ecological/biological Integrity FishCom**	Poor Bioclassification	Aquatic Life	2002	1998
6-55-11-(1)a	**Clear Creek**	From source to Laurel Creek		**2.7 FW Miles**	B;Tr
5	**Ecological/biological Integrity Benthos**	Poor Bioclassification	Aquatic Life	2001	2000
6-55-11-(1)c	**Clear Creek**	From Puncheon Camp Creek to Lewis Creek		**2.1 FW Miles**	B;Tr
5	**Ecological/biological Integrity Benthos**	Poor Bioclassification	Aquatic Life	2001	2000
5	**Ecological/biological Integrity FishCom**	Fair Bioclassification	Aquatic Life	2001	2000
6-55-8-2b	**Devils Fork**	From first unnamed tributary west of State Route 1006 to Johnson Drainage Ditch		**2.7 FW Miles**	C
5	**Ecological/biological Integrity Benthos**	Poor Bioclassification	Aquatic Life	2000	2006
6-55c	**Mud Creek**	From Little Mud Creek to Byers Creek		**11.0 FW Miles**	C
5	**Ecological/biological Integrity Benthos**	Fair Bioclassification	Aquatic Life	2000	2006
5	**Ecological/biological Integrity FishCom**	Fair Bioclassification	Aquatic Life	2002	2006
6-55d	**Mud Creek**	From Byers Creek to French Broad River		**2.2 FW Miles**	C
5	**Ecological/biological Integrity Benthos**	Fair Bioclassification	Aquatic Life	2007	2006

B = Waters protected for all Class C uses in addition to primary recreation. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis.

C = Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, aquatic life including propagation, survival, and maintenance of biological integrity, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner.

Tr = Trout Waters. Supplemental classification intended to protect freshwaters which have conditions which shall sustain and allow for trout propagation and survival of stocked trout on a year-round basis.

6.2 Background: Federal Clean Water Act (CWA)

In order to give some point of reference to the above discussion, this report is providing a general description of the regulatory development process in this country.

Prior to 1970, United States environmental policy was focused on managing the environment as a natural resource. Regulations focused very little on the *quality* of environmental resources such as air and water. Environmental policy encountered a major shift in the early 1970's, and the state of environmental quality was the basis for this change. A citizen outcry for cleaner air and water pushed the federal government to initiate policy changes. One of the most important regulations implemented was setting minimum standards on which pollutants and how much of each pollutant could be discharged into the nations' natural resources.

The Environmental Protection Agency (EPA) was created to be the gate keeper of the environment in the United States. Much of the federal law was written in general terms and established broad goals, but gave the EPA the power to set and enforce standards. More significantly, early legal challenges of the law resulted in the EPA gaining huge levels of power from the courts to use their own discretion in protecting the environment. It can be said that the EPA is the foundation for the states' environmental protection, subsidizing the creation of state environmental agencies. Federal Law helped to strengthen the states' leadership by reinforcing the states' power to deal with industrial and municipal sources of wastewater. The water pollution management functions under the Federal Clean Water Act (CWA) of 1972 was delegated to NC in 1976.The CWA established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave the EPA the authority to implement pollution control programs, such as setting wastewater standards for industry. The CWA also continued to set requirements for water quality standards for all contaminants in surface waters. The CWA made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It also funded the construction of publically owned wastewater treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by nonpoint source pollution. Most states, including NC, adopted versions of the CWA at the State level and the regulatory systems in place today derive their authority and focus from this legislation.

6.2.1 CWA Section 303 Requirements and the Move Toward the Control of Non-Point Sources

The 1972 amendments to the Clean Water Act included Section 303. The regulations implementing Section 303 require states to develop water quality standards, establish water quality management systems and list waterbodies that do not meet water quality standards and to submit list to the EPA every two years for approval. The first part of this section of the report addresses the specific 303(d) issues for the Mud Creek watershed. Water quality standards protect beneficial uses, water quality objectives, and antidegradation requirements. The EPA is required to review impaired water body lists submitted by each state and approve or disapprove all or part of the list.

For water bodies on the 303(d) list, the CWA requires that a pollutant load reduction plan or a total maximum daily load (TMDL) be developed for each situation to correct each impairment. TMDLs must document the nature of the water quality impairment, determine the maximum amount of a pollutant which can be discharged and still meet standards, and identify allowable loads from the contributing sources.

6.2.2 CWA Section 305(b) Requirements

The 1972 Federal Act also includes Section 305(b). The regulations implementing Section 305(b) required states to develop an inventory of the water quality of all water bodies in the state and to submit an updated report to the EPA every two years. This process was established as a means to determine the status of the nation's waters.

The 305(b) Report also includes:

- An analysis of the extent to which water bodies comply with the “fishable/swimmable” goal of the CWA;
- An analysis of the extent to which the elimination of the discharge of pollutants and a level of water quality achieving the “fishable/swimmable” goal have been or will be attained, with recommendations of additional actions necessary to achieve this goal;
- An estimate of the environmental impact, the economic and social costs, the economic and social benefits, and the estimated date of such achievement; and
- A description of the nature and extent of nonpoint sources of pollutants and recommendations of programs needed to control them, including an estimate of the costs of implementing such programs.

6.2.3 Integrated Water Quality Monitoring and Assessment Report

The EPA issued guidance for the development of an Integrated Water Quality Monitoring and Assessment Report (Integrated Report). This guidance recommends that states integrate their Water Quality Inventory Report (Section 305(b) of the CWA) and their Impaired Waterbodies List (Section 303(d) of the CWA). The Integrated Report is intended to provide an effective tool for maintaining high quality waters and improving the quality of waters that do not attain water quality standards. NC has responded to this directive by developing an Integrated Water Quality Monitoring and Assessment Report for the State.

In 2002, North Carolina prepared the first North Carolina Water Quality Assessment and Impaired Waters List, also referred as the 2002 Integrated Report. This report is based on US EPA guidance issued during the latter portion of 2001 and met requirements under 305(b) and 303(d). lists of impaired waters.

6.3 National Pollutant Discharge Elimination System (NPDES)

The primary mechanism for implementing the objectives of the CWA is the point source control program under NPDES. This program is a stepwise effort to address pollutants discharged by wastewater treatment systems. Phases I and II of the stormwater component of NPDES as noted below expands the program significantly and moves much of the responsibility for controlling stormwater to the local government for implementation.

6.3.1 Phase I

In response to the 1987 amendments to the Clean Water Act, the EPA developed Phase I of the NPDES Stormwater Program in 1990. The Phase I program addresses sources of stormwater runoff that have the greatest potential to negatively impact water quality. Under Phase I, EPA requires NPDES permit coverage for stormwater discharges from medium and large municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 persons or more. The program also includes requirements for specific industrial and construction activities. These permits are issued in NC by the DWQ.

6.3.2 Phase II

Phase II of the NPDES Stormwater Program requires operators of regulated small municipal separate storm sewer systems (MS4s) to obtain a NPDES permit and develop a stormwater management program. The stormwater management program is designed to prevent harmful pollutants from being washed by stormwater runoff into the MS4 (or from being dumped directly into the MS4) and discharged from the MS4 into local waterbodies.

A small MS4 is any MS4 not already covered by the Phase I program as a medium or large MS4. On a nationwide basis, the Phase II rule automatically covers all small MS4s located in urbanized areas (UAs) as defined by the Bureau of the Census (unless waived by the NPDES permitting authority) and, on a case-by-case basis, those small MS4s located outside of urbanized areas that the NPDES permitting authority designates.

Goals of the NPDES Phase II program are to reduce the discharge of pollutants, to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act. In the State of North Carolina, it is required that a Phase II community develop, implement, and enforce the following ‘Six Minimum Measures’ to stay in compliance:

1. Public education and outreach on stormwater impacts.
2. Public involvement participation.
3. Illicit discharge detection and elimination.
4. Construction site stormwater runoff and control.
5. Post-construction stormwater management in new developments and redevelopments.
6. Pollution prevention for municipal operations.

These steps not only keep the municipality in compliance with their Phase II permit, they help to reduce the amount of polluted runoff entering the local waterways.

The illicit discharges, noted in *Minimum Measure Three*, are defined as “any discharge into an MS4 that is not composed entirely of stormwater”. Discharges from permitted industrial sources are an exception to this rule. Illicit discharges are considered to be illicit because MS4’s are not designed to collect or discharge anything other than stormwater.

It is important that, at a minimum, an outfall inventory be performed; however, a full MS4 inventory is preferred to enable municipalities to seek out the source of any potential discharges. Discharges can then be classified as unintentional, intentional, or accidental due to a spill/leak of a given pollutant. These pollutants have been shown to have detrimental effects on water bodies and rivers, damaging water quality and threatening ecosystems. Pollutants include, but are not limited to, heavy metals, toxics, oil/grease, solvents, nutrients, viruses, and bacteria.

6.4 Britton Creek and the Existing Regulatory Framework

In many respects as noted and documented in this report, the Britton Creek Stormwater management program has addressed important components of this program in the watershed. The CIP for Britton Creek identifies some important projects that can actually address impacts from existing development. The expansion of the Federal and State regulatory programs will continue to place additional pressure on local governments for the management of stormwater from both new and existing sources. With current programs and the work of the Britton Creek project, the City has positioned itself well for taking a lead role to address existing impacts of water quality from stormwater and identified infrastructure management objectives for the future.

7.0 PROPOSED CAPITAL IMPROVEMENT PLAN

7.1 General Stormwater System Improvements

This proposed Capital Improvement Plan (CIP) for the City of Hendersonville provides recommendations for improvements to the existing stormwater and stream system.

7.1.1 Water Quality Treatment Structures

Natural systems such as wetlands, infiltration swales, and bioretention cells should be used where possible to effectively treat stormwater runoff. However, in highly urbanized areas, it is uncommon to find sufficient pervious area to allow natural systems to treat discharges from large impervious areas. For these situations, it is recommended that underground water quality treatment structures be installed. The City's ordinance requires the treatment of the greater of: the 1-year 1-hour runoff volume or the difference between the pre and post development runoff volumes for the 1-year 24-hour storm. The treatment devices, both natural and structural, should be sized to remove at least 85% of the Total Suspended Solids (TSS) from the way-stream. Efforts should also be made to address other pollutants, such as bacteria, oils and greases, nitrogen, phosphorous, other nutrients, and heavy metals.

Several water quality treatment structure options are available. Manufacturers of Hydrodynamic Stormwater Quality Structures include CrystalStream Technologies, Stormceptor, and Contech. Makers of catch basin inserts include Filterra, Kristar, Inceptor, and Ultratech.

Smaller scale BMPs implemented basin-wide can have as much impact as a larger BMP. Examples of small scale BMPs are rain gardens, rain barrels, cisterns and underground or aboveground detention. This type of management also puts some responsibility for watershed care and maintenance on the residents, providing a mechanism for grassroots action.

7.1.2 Stormwater Collection and Conveyance System

In order for treatment structures to work effectively, a modern stormwater collection and conveyance system must be installed to convey untreated runoff to the water quality device. Either reinforced concrete pipe (RCP) or high density polyethylene pipe (HDPE) with a minimum inside diameter of 15 inches should be used. Metal pipes should be avoided due to their shorter lifespan and higher flow resistance values.

Standard North Carolina Department of Transportation (NCDOT) hood and grated curb inlets, marked with a statement such as "DUMP NO WASTE - DRAINS TO WATERWAY" and heavy duty manhole covers and castings marked with a statement such as "STORM SEWER" and "DUMP NO WASTE - DRAINS TO WATERWAY" should be used.

7.1.3 Riparian Buffer

All blue line streams in the City of Hendersonville should have a minimum of a 30-foot riparian buffer. The term riparian buffer, or vegetated buffer zone, is used to describe vegetated areas along streams that help protect the streams from adjacent land uses. The vegetation is strongly influenced by the presence of water and usually contains native grasses, flowers, shrubs, and trees. A healthy riparian buffer can be a key part of good watershed protection.

Riparian buffers are important for good water quality. Riparian zones help to prevent sediment, nitrogen, phosphorus, pesticides, and other pollutants from reaching a stream. Riparian buffers are most effective at improving water quality when they include native grass or herbaceous filter strips and deep rooted native trees and shrubs along the stream. Overhanging riparian vegetation helps to reduce the stream's temperature, which is especially important for North Carolina's mountain trout populations.

Additionally, riparian vegetation slows floodwaters, thereby helping to maintain stable stream banks and protect downstream property. By reducing the velocity of floodwaters and stormwater runoff, the riparian vegetation allows water to soak into the ground and recharge groundwater. Slowing floodwaters also allows the riparian zone to reduce erosion by trapping sediments that would otherwise degrade our streams and rivers.

The City should encourage the maintaining of existing riparian buffers by the residents in not only this watershed, but along all of the City's waterways. One avenue to facilitate this would be the establishment of buffer easements. In exchange for the easement, property owners could receive tax incentives or compensation from the City. The City could then, with the cooperation of the owners, enhance the existing buffers or create new ones to increase their effectiveness in treating stormwater runoff. Areas, such as the 400 ft of Britton Creek upstream of Orleans Avenue, where banks are poorly vegetated should be considered for this type of solution. Acquisition costs are variable depending on the value of the land and impacts on future land use.

7.1.4 Incorporation of Other Improvements

Upgrading stormwater conveyance systems involves installing large diameter pipes and culverts that require large cuts into the existing streets and sidewalks of an urban center. This often conflicts with existing underground utilities (UGU). Therefore, it is beneficial to plan additional improvements, as needed, when completing stormwater projects. Pre-planning provides one comprehensive strategy combining stormwater system upgrades with replacing existing UGU, such as water and gas mains, and burying existing overhead utilities, such as electric power, cable, and telephone lines.

Coordinating improvement plans has an extra benefit when replacing or upgrading wastewater lines. Inflow and Infiltration (I/I) is a problem with many wastewater systems caused by natural groundwater or runoff entering the wastewater system through holes and cracks in the pipes during rainfall events. The additional rainwater places a strain on the system, which is typically not designed to handle these flows, resulting in either sanitary sewer overflows (SSOs) or superfluous water being treated or bypassed at the wastewater treatment plant. Consequently, I/I works both ways; on dry days, wastewater systems can leach sewage into the ground, which regularly finds its way into the lower stormwater system, while wet weather infiltration that would otherwise recharge groundwater is taken into the sanitary system.

The final improvements to consider when planning projects are the streets, sidewalks, and other amenities. Consideration should be given to replacing paved surfaces with landscaping or semi-pervious areas, where possible, to help maintain the water balance within the basin and reduce the rate and amount of runoff. Also, large canopy trees should be utilized to help intercept rainfall and provide shade, reducing the effects of urban heating. These trees should be placed in parking areas and along roadways.

7.1.5 Geographic Information System (GIS)

A geodatabase was created for the purposes of this stormwater master plan. It includes all of the data that was collected during field surveys. The field data collection is described in more detail in Section 3. The City of Hendersonville has comprehensive GIS software capability.

Pre-planning is required in order to keep the geodatabase up-to-date using as-built computer-aided design (CAD) drawings. CAD Standards need to be implemented to ensure the data can be imported correctly. Once CAD files are received, the data can be loaded into the geodatabase. In ArcCatalog, the data is loaded by selecting only the layer file that corresponds with the feature class being updated. This demonstrates the importance of CAD Standards because the GIS uses points, lines, and polygons as separate feature classes. For example, manholes, which are points, cannot be in the same layer as sewer lines, which are line features, in the CAD drawing. Each feature class must be separated accordingly.

7.2 Capital Improvement Projects

The repair options given in this section of the Capital Improvement Plan (CIP) are intended to be cost effective solutions for the existing stormwater conveyance systems and critical stream reaches in the City of Hendersonville. The actual cost of implementing these repair options will depend on the date of actual installation and the contractor chosen. Although efforts were made to provide realistic cost estimates, they are preliminary in nature and should be viewed as such. Cost estimates are based on the most recent pricing data and the final design will determine the true and current cost of each project at the time of construction.

7.2.1 Stream Reach Projects

The analysis considered Patton Park for locations of stormwater improvements because of its public exposure and central location at the confluence of the two streams. However, after consideration it was determined that the Park, with its low lying floodplains, pond and recreational importance is already providing a significant stormwater benefit.

As described in Section 5, there were several sections along both Britton Creek and Britton Creek Tributary 2 that exhibited moderate to severe impairment. Types of impairment most commonly seen are stream bank erosion, undercutting of banks, mowed/ non-vegetated banks and sediment deposition. Maps showing the areas of greatest concern are attached in Figures 5.2 and 5.4.

As the preliminary step for addressing the impairments, a more in depth analysis should be performed over the reaches identified. It would be useful to collect the data necessary to estimate the flow velocity and shear stresses associated with various storm recurrences. The calculated velocity and shear stress are useful measures because they provide an indication of where problems may arise more quickly. Relatively high velocity or shear stress can cause severe erosion and bank failure. Velocities above (or near) 5 ft/sec and shear stresses higher than 2 lb/ft^2 are indicators of high velocity or shear stress.

Capital improvement recommendations for these reaches include culvert upgrades, bank stabilization, stream rehabilitation and enhancement, and wetlands. The following paragraphs briefly describe these stream management practices.

Culvert Upgrades

Culvert replacements are recommended to be single-span, reinforced concrete structures with a natural bottom. These three sided structures are not only more hydraulically efficient than multiple pipes at each crossing, but also more environmentally friendly and require less maintenance. Figures 7.1 and 7.2 illustrate the difference in the streams' general health and condition when an enclosed culvert is used compared to when a bottomless culvert used.

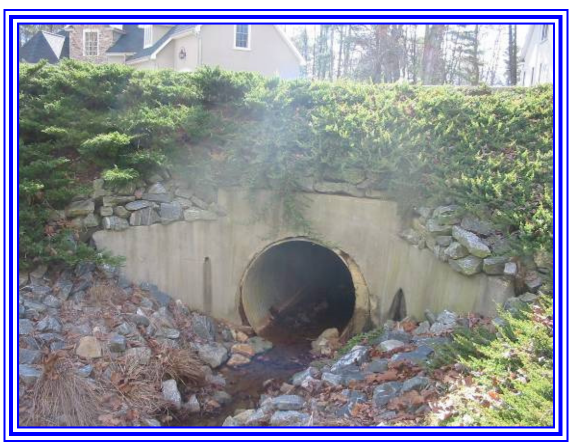

Figure 7.1: Enclosed Culvert (Mistletoe Trail)

Figure 7.2: Bottomless Culvert (Maplewood Court)

There are four culvert replacements recommended (Figure 7.3). In order of priority they are:

1) Long John Drive (2 ft culvert) – Small Tributary to Britton Creek
2) Browning Avenue – Britton Creek Tributary 2
3) Meadowbrook Terrace – Britton Creek Tributary 2
4) Carson Drive – Britton Creek Tributary 2

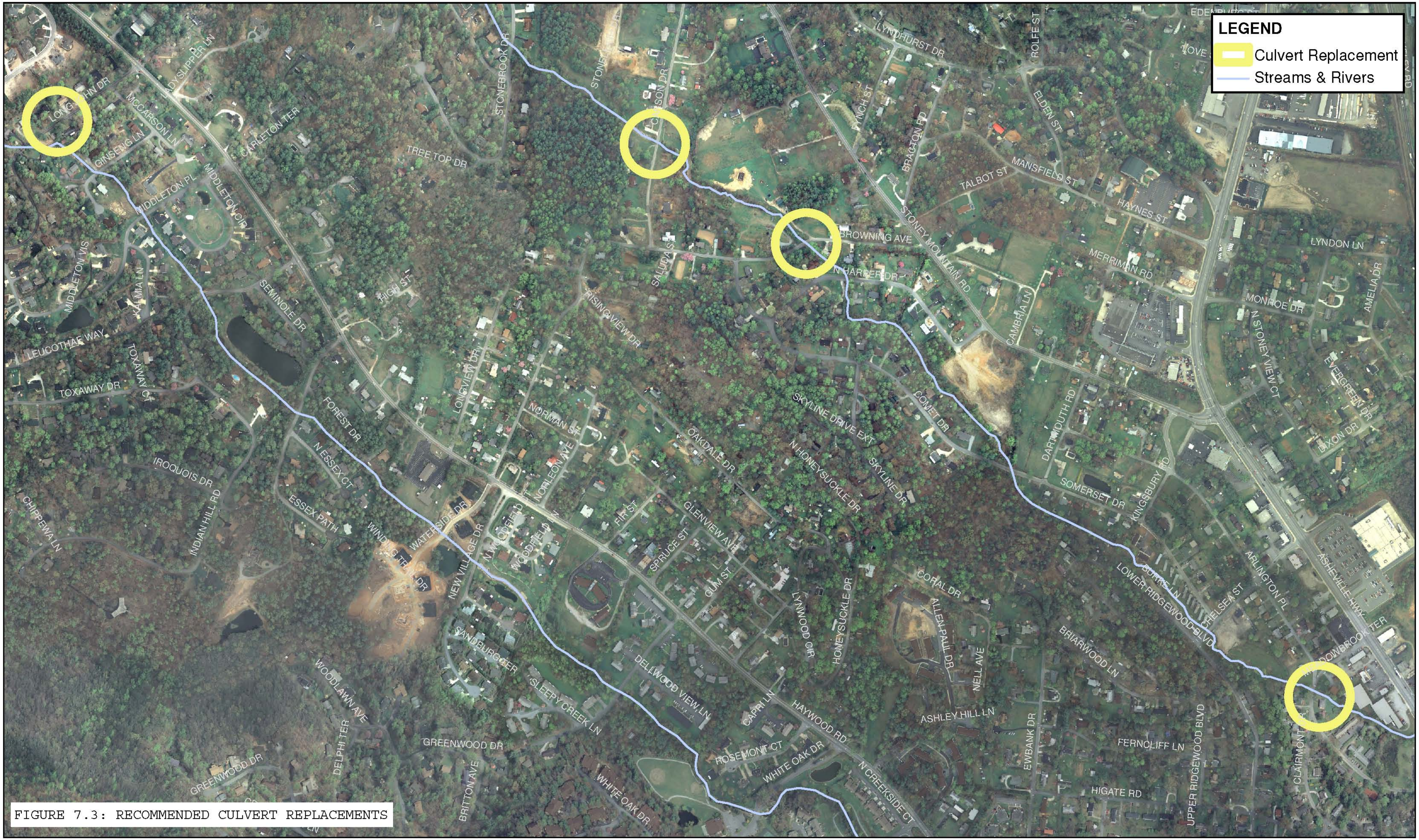

FIGURE 7.3: RECOMMENDED CULVERT REPLACEMENTS

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
RECOMMENDED CULVERT REPLACEMENTS

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

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The recommendations for culvert replacement were made based on two factors. The first is the integrity of the structure. The culverts on Long John Drive, Browning Avenue and Carson Street are damaged to various extents. The second consideration is hydraulic capacity. As described in more detail in Section 4, the Browning Avenue and Meadowbrook Terrace culverts are undersized. The recommended culvert replacements are described in more detail in section 7.2.2.

Stream Bank Stabilization

Stream bank stabilization provides toe stabilization and grade control structures through the stream reach. Stream bank stabilization techniques mainly include spot fixes and not complete stabilization of an entire reach. Based on the observed and measured conditions of the failed banks and the amount of disturbance that has occurred, bank repairs are accompanied by supplemental in-stream structure reinforcement. The failed bank areas are stabilized with brush mattresses and in-stream structures, comprised of boulder vanes and root wads.

Brush mattresses provide a living wall of vegetation and are comprised mostly of black willow and silky dogwood, which in time would create a thick mat of vegetation that anchors surrounding soil in place.

Boulder vane structures are made of quarried rock and are placed pointing upstream approximately 15-20 degrees off the bank. Boulder vanes are also oriented as flat to the water surface as possible on a 1-2% slope upward, creating a shallow pool on top of the structure. The shallow pool helps protect adjacent banks by slowing and turning water away towards the center of the channel. The result is a deep pool on the back side of the structure that provides excellent habitat for macro-invertebrates and fish.

Root wads provide bank stabilization by placing a hard structure below the water surface up to mid-bank in front of vulnerable soil. Root wads are made from trees by pushing them over so that the subsequent root mass is left intact on the tree. The trunk of the tree is trimmed to approximately 10 to 15 feet in length and buried at or below the water's surface and anchored with boulders to prevent the structure from floating.

Figure 7.4 shows ten areas including both stream sections and drainage ditches that should be considered for stream bank stabilization. These areas have been selected because of their erosion issues. The erosion problem is discussed in Section 5. The project is described in more detail in section 7.2.2.

Stream Rehabilitation and Enhancement

Stream rehabilitation and enhancement provides the establishment of natural vegetation and the creation of a floodplain bench to safely pass flood flows through the stream corridor. Stream bank enhancement measures consist of rock/log vanes to center flood flows in the channel and alleviate shear bank stresses through channel bends. The rock/log vanes provide valuable in-stream habitat for fish and macro-invertebrates otherwise not found in an urban stream setting. Brush mattresses are used to help with the bank and overbank stabilization with the use of native

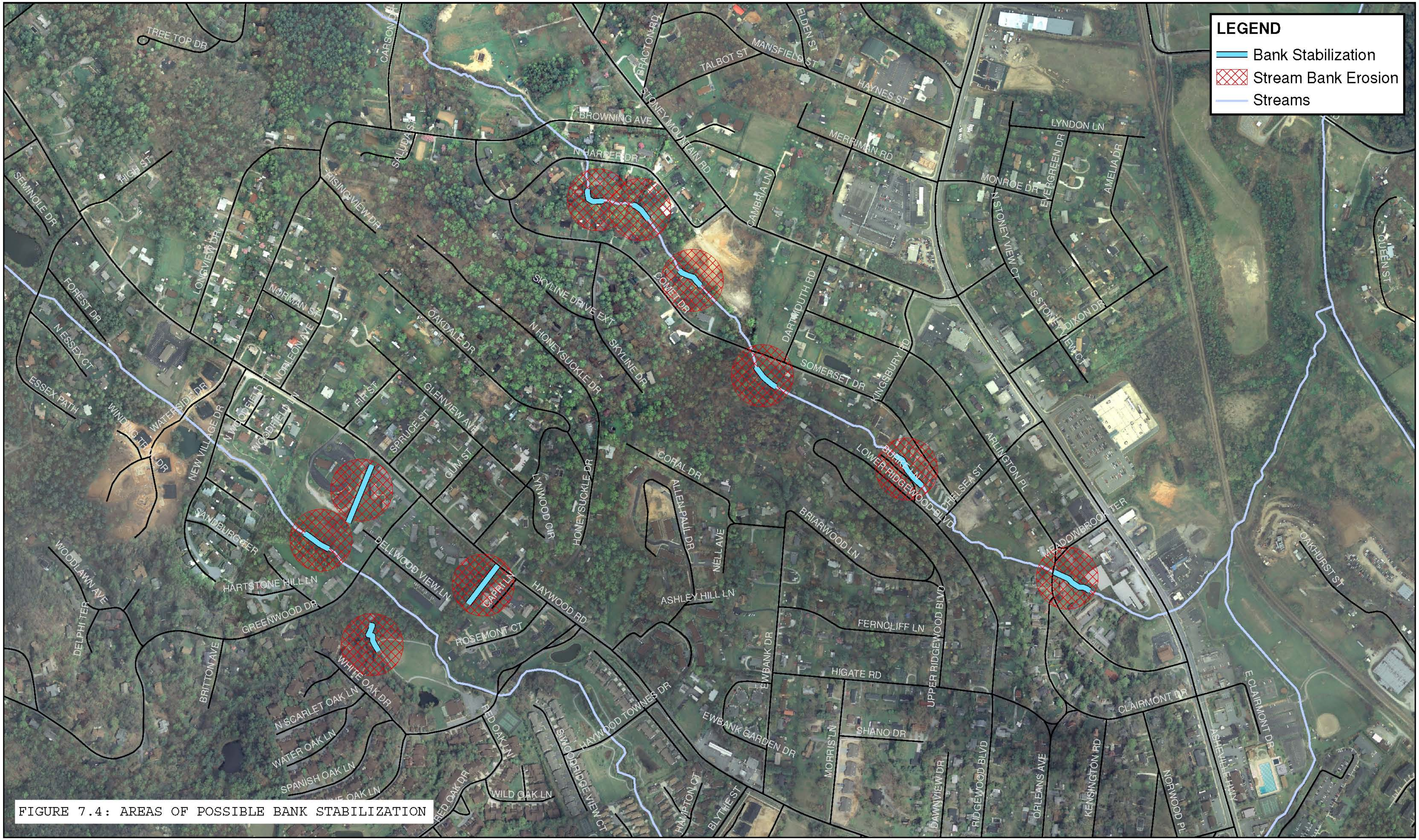

FIGURE 7.4: AREAS OF POSSIBLE BANK STABILIZATION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF POSSIBLE BANK STABILIZATION

0 250 500 1,000 1,500 2,000 Feet

1 INCH = 500 FEET

McGill ASSOCIATES

vegetation. Root wads are used in channel meander bends to provide hard toe stabilization and cover for fish and macro-invertebrates.

A new stream alignment and floodplain bench provides a more stable stream profile along the reach while providing the much needed riffle/pool/run sequence found in a natural stream setting. Also, by creating a meandering stream profile, shear forces are slowed along stream banks and allow for consistent bed load transport. A meandering stream with a recreated floodplain bench allows the stream channel to flood during the 2-year and greater storm events while alleviating pressure on the stream channel. It allows flood flows to spread out and dissipate energy in the flood plain, creating a natural and stable stream corridor. The flood plain bench would be cut low enough to capture frequent flood flows while keeping surrounding building structures out of harm's way during significant events. It should be noted that the newly created floodplain bench does not eliminate risk to persons or property in severe flooding events as associated with the 100-year storm event.

Brush mattresses provide a living wall of vegetation and comprise mostly of black willow and silky dogwood, which in time creates a thick mat of vegetation that anchors surrounding soil in place.

Rock/log vane structures are made of quarried boulders or trees harvested on site and are placed pointing upstream approximately 15 to 20 degrees off the bank. Rock/log vanes are also oriented as flat to the water surface as possible, creating a shallow pool on top of the structure. The shallow pools help protect adjacent stream banks by slowing and turning water away towards the center of the stream channel. The result is a deep pool directly behind the structure, on the downstream side, with an overhanging rock or log structure that provides excellent habitat for macro-invertebrates and fish.

Root wads provide bank stabilization by placing a hard structure below the water surface up to mid-bank in front of otherwise vulnerable soil. Root wads are made from trees harvested on site by pushing them over so that the root mass is left intact on the tree. The trunk of the tree is trimmed to approximately 10 to 15 feet in length and buried at or below the water's surface and anchored with boulders to prevent the structure from floating during high flow storm events.

This approach to stream corridor/bank repair improves the overall potential for the success of the repair and improve water quality. The installation of structures protects channel banks with significantly smaller rock volume (when compared to bank armoring), thereby reducing overall repair costs. One additional benefit to this type of repair is the placement of natural (less structural) repairs appropriate for the reach, which generally are more aesthetically desirable and provide Hendersonville residents with an esthetic asset instead of a reoccurring nuisance.

A no-disturbance vegetated buffer should also be included once all stream work is complete. The buffer should be seeded and planted with the appropriate native riparian vegetation. This provides channel and overbank stability and treat surface waters traveling laterally through the buffer area. Species should consist primarily of native shrubs and trees. The repaired bank should be planted with the appropriate channel bank species in the form of bare-root seedlings (and/or container plants) and transplants where available. Native shrubs that are available elsewhere on-site should be removed with as much of the root ball intact and transplanted adjacent to the restored channel. The majority of planting efforts (with the exception of site transplants) should be conducted by locally identified plant sources or purchased from local, reputable nurseries. Sources outside of the local area could be used depending on the availability of plant materials.

One particular stream section may be suitable for stream rehabilitation/ enhancement. It is a 2,000 foot section of stream shown in Figure 7.5. It runs from about 750 feet upstream of Chelsea Street to about 400 feet downstream of Meadowbrook Terrace. The section has several areas of severely eroded banks and also runs through a city-owned parcel. The project is described in more detail in section 7.2.2.

Wetlands

An extended detention stormwater wetland helps retain large volumes of water and provides significant water quality benefits. Wetlands can be an effective method of removing pollutants from urban runoff. The implementation of additional Best Management Practices (BMPs) in conjunction with wetlands or shallow marshes can maximize pollutant removal. The use of wetlands in conjunction with wet pond sites is generally applicable provided that the runoff does not dislodge the aquatic vegetation. Vegetation systems may not be effective where the water's edge is extremely unstable or where there is heavy use of the water's edge. Some types of marsh vegetation are not effective in flood-prone areas due to the alteration of the hydraulic characteristics of the watercourse.

A diversion device, such as a weir, diverts water into a turf reinforcement mat (TRM) lined vegetated swale and to the stormwater wetland. The vegetated swale conveys a large portion of inflow, bypassing the wetland and transporting normally occurring base flow and sediment downstream. The other portion of base flow is diverted into the off-channel storage area to provide a constant water supply for the wetland area. The main channel running through the stormwater wetland is designed to maximize the linear distance from the point of diversion to the point where it enters back into the culvert. This would take full advantage of the water quality benefits that can be achieved in a stormwater wetland.

The entire extended detention stormwater wetland is graded to create a large pool area. The wetland channel meanders along the perimeter of the stormwater management facility. This allows for small storm events to move through the channel. Once this channel reaches capacity, the detention area fills like a large pond.

There are two locations that should be considered for potential wetland sites. These are shown in Figure 7.6. The locations include the City property that is located just downstream of Chelsea Street along Tributary 2. The other location is along Britton Creek in The Oaks development where the walking trail is located. These projects are described in more detail in Section 7.2.2.

FIGURE 7.5: AREAS OF POSSIBLE STREAM REHABILITATION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF POSSIBLE STREAM REHABILITATION

0 100 200 400 600 800 Feet

1 INCH = 200 FEET

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FIGURE 7.6: AREAS OF POSSIBLE CONSTRUCTED WETLANDS

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF POSSIBLE CONSTRUCTED WETLANDS

0 200 400 800 1,200 1,600 Feet

1 INCH = 400 FEET

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7.2.2 Specific Improvement Projects

Long John Drive Culvert Replacement

The smaller CMP culvert about 575 feet down Long John Drive (from Haywood Road) is somewhat deformed on the upstream side, but the size was estimated to be two feet in diameter. It has been a concern, not only because its inlet side is deformed, but also the asphalt road directly above is sinking due, presumably to erosion or undermining of the roadbed (Figure 5.10). Since it is a culvert for a small tributary to Britton Creek and not in the creek itself, discharge rates for this culvert are unknown. However, it is notable that the next culvert upstream is a 4 foot by 3 foot elliptical CMP. Therefore, for cost estimate purposes, a 48” RCP pipe is recommended. The culvert is approximately 25 feet long. Preliminary cost estimates based on other 48” RCP installations indicate approximately $260 per linear foot.

Browning Avenue Culvert Replacement

The Browning Avenue Culvert, as indicated in Section 4, was estimated to overtop during the 25 year storm. With the large crack across the headwall (Figure 5.9), it cannot be considered structurally sound and should be replaced. It is recommended that a 12 ft span bottomless culvert be installed in its place. Preliminary cost estimates based on bottomless culvert installations indicate a cost of approximately $300,000.

Meadowbrook Terrace Culvert Replacement

The Meadowbrook Terrace culvert is considerably obstructed by deposited sediment (Figure 7.7) and its hydraulic capacity is greatly reduced. It cannot function as designed and should be replaced. However, as shown in Section 4, the culvert is overtopped during even the 5 and 10 year storms. Because the road and the immediate area are at elevations below the flood levels, a culvert replacement will not necessarily attenuate flooding.

Figure 7.7: Meadowbrook Terrace Culvert.

Carson Drive Culvert Replacement

The Carson Drive culvert replacement is not imperative in the short term. The overall condition of the culvert is good and it performs very well hydraulically. However, the pipe material is CMP, and it has shown indications of beginning to corrode. Once this process begins, it is irreversible and the CMP will be completely rusted out. This culvert replacement should be listed as part of the long term stormwater plan.

Stream Bank Stabilization Projects

The section of Tributary 2 between North Harper and Somerset Drive show evidence of massive loss of sediment. This area should be immediately considered for bank stabilization. The banks will continue to erode until the stream has cut a more natural channel. It appears that in this area, residents have attempted to slow the erosion process by reinforcing the banks with cinderblock and other heavy material.

There are four areas in the vicinity of Greenwood Drive that have contributed a great deal of sediment to Britton Creek (Figure 7.8). The largest mass of sediment likely comes from the section of Britton Creek that is between 200 and 500 feet upstream of Greenwood Drive. The stream has carved out a large part of the left bank.

There is a residential development on either side of Greenwood Drive at its intersection with Haywood Road. For each development on the side opposite Greenwood Drive, there is a drainage ditch that runs into Britton Creek. In the case of both drainage ditches there is very severe bank loss. The banks of the ditches are near vertical in some points. This is also a significant source of sediment for Britton Creek.

In the same vicinity, there is a small tributary stream (as described above in ‘The Oaks Wetland’) to Britton Creek that runs along the walking path at The Oaks development. It has also been a source of sediment; however, considering that the stream runs first through the pond, the sediment is likely to be trapped within the pond.

Photographs of all of these locations can be found in Figure 5.5. The total length of all of the stream bank stabilization sections is about 2,000 feet. Because they are disjointed it is convenient to implement this project only in part or in stages. Preliminary cost estimates based on other stream rehabilitations indicate approximately $250 per linear foot.

Tributary 2 Stream Rehabilitation and Enhancement

The lower section of Britton Creek Tributary 2 shows evidence of urban impacts. The amount of woody vegetation on its banks is greatly decreased as it approached Chelsea Street. From that area downstream to the Druid Hills Assisted Living center is in poor condition. The retaining wall just downstream of Meadowbrook Terrace is cracking, and erosion is occurring from behind the wall.

FIGURE 7.8: AREAS OF POSSIBLE BANK STABILIZATION

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
AREAS OF POSSIBLE BANK STABILIZATION

0 100 200 400 600 800 Feet

1 INCH = 200 FEET

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The area is increasingly urbanized and yet there is still room for further development. Therefore, to establish a rehabilitated stream corridor would be an attractive feature for the still growing neighborhood.

The length of stream shown on Figure 7.5 is about 2,000 feet; however, the rehabilitation and enhancements could be implemented in stages. Preliminary cost estimates based on other stream rehabilitations indicate approximately $300 per linear foot.

The City of Hendersonville Wetland

The City of Hendersonville owns two parcels of land along Britton Creek Tributary 2 just downstream of Chelsea Street (Figure 7.9). Coming into this area, the stream becomes increasingly urbanized, banks are mowed and there is a lack of woody vegetation and permanent stability, and erosion problems are obvious. The problems only increase in magnitude as the stream continues on through Meadowbrook Terrace and into Patton Park. Therefore, a constructed wetland in this area may provide an important opportunity for the stream to slow down and reduce pollutant loading. It may also relieve some flooding downstream.

The available area for stormwater wetlands is about one acre. Preliminary cost estimates based on other constructed stormwater wetlands indicate approximately $110,000 per acre. It is not necessary to use the entire area as a wetland. Using a combination of wetland area and higher ground will result in lower cost.

The Oaks Wetland

The open area in the Oaks development contains a small stream that is tributary to Britton Creek and has a drainage area of about 30 acres and receives runoff from the Greenwood Drive development (Figure 7.10). The stream runs along the southwest edge of the walking trail and enters a small pond near the pool house, where it eventually flows out and into Britton Creek. The banks of the stream as it flows along the walking path have become severely incised transferring much sediment to the pond. Although the pond does facilitate the removal of suspended solids and other pollutants, it is not able to provide much storage to help mitigate problems in Britton Creek related to the quantity of stormwater runoff. For this reason, a wetland may be an option which would provide a natural wildlife habitat as well as a beautiful area for the community to enjoy. If a boardwalk is included through the wetland the residents would not lose their walking trail and the beauty and stream health would be augmented.

The total area of the open space is about two acres. There can be a combination of smaller wetlands or one larger wetland. Preliminary cost estimates based on other constructed stormwater wetlands indicate approximately $110,000 per acre.

7.3 Example Projects, Structural and Natural Approaches

The proposed stormwater CIP for the Britton Creek watershed includes several projects related to stormwater management and attenuation. Because the watershed is significantly developed, particularly as the streams approach Asheville Highway, finding sites is a challenge. For City or

FIGURE 7.9: PROPOSED WETLAND ON CITY OF HENDERSONVILLE OWNED PROPERTY

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
THE CITY OF HENDERSONVILLE STORMWATER WETLAND

McGill ASSOCIATES

FIGURE 7.10: STORMWATER WETLAND AT THE OAKS DEVELOPMENT

BRITTON CREEK WATERSHED: CITY OF HENDERSONVILLE, NC
THE OAKS STORMWATER WETLAND

0 50 100 200 300 400 Feet

1 INCH = 100 FEET

McGill ASSOCIATES

County owned areas identified it may be possible to allocate a portion of the property for the installation of structural or "natural" stormwater management projects. For privately owned areas identified it will be necessary to reach agreement with the owner to allow the City to use the property for a project either through purchase or easement.

Another important factor is "fitting" the project to the site. For highly urbanized areas the use of structures and treatment units are often the most effective and provide a way of "retro-fitting" the facility to existing land or allowing other uses to occur on the property. For more natural system approaches it is necessary to have larger open areas where wetland and surface storage/treatment areas can be interspersed with areas that are above the water table and available for other uses. Both of these type projects can provide stormwater management and still function as important components of urban park or natural areas. An example of a natural wetland/stormwater storage system is the Dingle Creek wetland project in the City of Asheville that included enhancement of the stream segment, a storm flow diversion structure and a wetland area with pooling and channel characteristics that both treats the stormwater and provides some storage. Both of these projects are described below.

City of Asheville - Dingle Creek Wetland

The Dingle Creek watershed in Asheville drains a highly urbanized area along US 25 South (Hendersonville Road) in southern part of the City limits. The stream has consistently exhibited degraded biological integrity and is dramatically impacted by urban runoff pollution, sedimentation and streambank erosion. Stormwater management evaluations of the City consistently identified Dingle Creek as a high priority for installation of water quality improvement best management practices (BMPs).

In 2009, the City of Asheville contracted with McGill Associates to provide the professional services to help implement the Dingle Creek Stormwater Master Plan which included the design, permitting, and construction administration for a 1-acre stormwater wetland and 800 lf of stream restoration and enhancement along Dingle Creek. This project was a key component of the City's initiative for improving water quality and decreasing stream erosion within the Dingle Creek watershed. The project was partially paid for by grant funding through the American Recovery and Reinvestment Act, and matching funds will be paid over the next 20 years by the Clean Water Management Trust Fund and the City of Asheville.

The City partnered with Biltmore Farms during project development. This public/private initiative allowed the City to achieve important watershed improvement objectives for the drainage and provided significant stability and enhancement to an open space area within the company's development, The Ramble. Biltmore Farms donated approximately three acres of land within the development for construction. McGill Associates' design included stream restoration and enhancement of Dingle Creek in a long section of Dingle Creek and the riparian zone along the stream. The design utilized natural channel design techniques to stabilize and improve the channel and also called for the use of several j-hooks and cross-vanes. Bank stabilization components included the use of root wads and other natural materials to minimize erosion potential and improve the condition of existing stream banks. Disturbed areas were stabilized with biodegradable erosion control matting and re-planted with native vegetation consisting of one- and five-gallon container plants and a riparian seed mix.

The stormwater wetland portion of the Dingle Creek project utilized the natural topography and hydrology of the area to provide year-round flow and appropriate soil moisture to the wetland zones by installing a small series of streams running through the wetland. Due to the tremendous energy of storm flows within this section of Dingle Creek, the design included hardened inlet and outlet structures designed to withstand the estimated flood flows produced by the urban watershed. The structures were configured and installed to manage both the one-inch water quality storm event and up to the 25-year flooding events.

The primary pollutants targeted by the stormwater wetland are Total Suspended Solids, Nitrogen and Phosphorus. The wetland utilizes deep pools and areas of shallow lands planted with wetland vegetation designated by research performed by NC State University for the mountainous regions of North Carolina to aid in pollutant removal.

The one-acre stormwater wetland has been designed to provide mountainous bog habitat, with areas of ponded water, higher areas with large trees and in-stream structural habitat ideal for native fish, aquatic insects and amphibians. The project received 401 Certification issued by the NC Division of Water Quality. The system will be maintained by the City under a maintenance plan developed as part of the project design.

Figure 7.11 Dingle Creek during construction

Figure 7.12 Dingle Creek after the enhancement project

8.0 FUNDING OPTIONS

The process of identifying possible capital improvement projects to improve infrastructure and stormwater management in the Britton Creek watershed is a necessary first step in planning. However, without the necessary financial resources the projects are just possibilities. The next two steps are critical: 1) establishing priorities within the list of possible projects and 2) finding the funds to do the project. Because funding is in fact the most critical of these steps, this report includes the following discussion of ways to fund stormwater projects for the City within the Britton Creek watershed and really within the entire City.

8.1 Clean Water Management Trust Fund (CWMTF)

North Carolina's Clean Water Management Trust Fund (CWMTF) was established by the General Assembly in 1996 (Article 18; Chapter 113A of the North Carolina General Statutes). CWMTF receives a direct appropriation from the General Assembly in order to issue grants to local governments, state agencies, and non-profit conservation organizations to help finance projects that specifically address water pollution problems. The 21-member, independent CWMTF Board of Trustees has full responsibility over the allocation of moneys from the Fund. CWMTF will fund projects that (1) enhance or restore degraded waters, (2) protect unpolluted waters, and/or (3) contribute toward a network of riparian buffers and greenways for environmental, educational, and recreational benefits. More information about the CWMTF can be found at http://www.cwmtf.net/index.html.

Based on previous guidance grant monies from CWMTF may be used for any of the following purposes:

- Acquire land for riparian buffers for the purposes of environmental protection of surface waters or urban drinking water supplies and for establishing a network of greenways for environmental, educational, or recreational uses.
- Acquire conservation easements or other interests in real property in order to protect and conserve surface waters or urban drinking water supplies.
- Coordinate with other public programs involved with lands adjoining water bodies to gain the most public benefit while protecting and improving water quality, and restore degraded lands to reestablish their ability to protect water quality.
- Repair failing wastewater collection systems and wastewater treatment works, if repair is a reasonable remedy for resolving an existing waste treatment problem and the repair is not for the purpose of expanding the system to accommodate future anticipated growth of a community.
- Repair and eliminate failing septic tank systems to eliminate illegal drainage connections and expand a wastewater collection system or wastewater treatment works, if the expansion eliminates failing septic tank systems or illegal drainage connections.
- Finance stormwater quality projects.
- Facilitate planning that targets reductions in surface water pollution.
- Stormwater mini-grants (this program has been discontinued).

It is important to note that at the time of this report's preparation, the CWMTF will receive approximately 10 % of the funds that the original legislation authorized ($ 100 million) to allocate during the State fiscal year 2011-2012. Because of backlogged project applications and increased demand for these funds, the program is very limited in its ability to fund new projects. However, it is possible that future budget conditions in NC will allow for additional funds to support this program.

8.2 319 Grants

The Section 319 (the Section of the CWA authorizing this funding) Grant program was established in 1987 by Congress amending the Clean Water Act. Its purpose is to provide funding for efforts to curb non-point source (NPS) pollution, occurring due to stormwater runoff. The Act authorizes the United States Environmental Protection Agency (EPA) to provide 319 funds to state and tribal agencies, which are then allocated via a competitive grant process to organizations to address current or potential NPS concerns. Funds may be used to demonstrate best management practices (BMPs), establish total maximum daily load (TMDL) for a watershed, or restore impaired streams or other water resources. In North Carolina, the 319 Grant Program is administered by the Division of Water Quality of the Department of Environment and Natural Resources. Additional information can be obtained from the state at http://portal.ncdenr.org/web/wq/ps/nps/319program .

Based on the program summary provided on the DWQ Web site, each Federal fiscal year, North Carolina is awarded nearly five million dollars to address non-point source pollution through its 319 Grant program. The initial 30% of the funding supports ongoing state non-point source programs. The remaining 70% is made available through a competitive grants process. At the beginning of each year (normally by mid-February), the NC 319 Program issues a request for proposals with an open response period of three months. Grants are divided into two categories: *base* and *incremental*. Base projects concern research-oriented, demonstrative, or educational purposes for identifying and preventing potential NPS areas in the state where waters may be at risk of becoming impaired. Incremental projects seek to restore streams or other portions of watersheds that are already impaired and not presently satisfying their intended uses. State and local governments, interstate and intrastate agencies, public and private nonprofit organizations, and educational institutions are eligible to apply for Section 319 monies.

As described here, this program is mainly focused on the funding of demonstration BMP projects and ongoing efforts of local non profit groups to address streams and waters on the 303(d) list. However, the money source could be looked at for some part of the projects identified in the CIP section. In the Summary section of this report the Mud Creek Project was linked to the Britton Creek effort because the work on the Britton Creek drainage has direct applicability to efforts to improve the quality of Mud Creek.

8.3 State Revolving Funds

The 1987 amendments to the CWA replaced the Construction Grants Program with the Clean Water State Revolving Fund Program (CWSRF). Under the CWSRF, congress provides the states with grant funds to establish revolving loan programs to assist in the funding of wastewater treatment facilities and projects associated with estuary and non-point source programs. The states are required to provide 20% matching funds. In North Carolina, these funds are made available to units of local government at one-half (½) of the market rate for a period of up to 20 years. The actual term of the loan is determined by the State Treasurer's Office.

Traditionally, loans have been made available for the construction of publicly owned wastewater treatment works that appear on the state's priority list and as they are defined in Section 212 of the federal Clean Water Act. However, loans may be available for implementation of a non-point source pollution control management program developed under Section 319 of the federal Clean Water Act and for the development and implementation of an estuary conservation and management plan under Section 320 of the federal Clean Water Act.

In the ARRA funding provided by the US Government in response to the severe economic conditions experienced recently, the SRF management program in each state was given responsibility to administer a good protion of these funds. The use of these funds for "green" projects has been expanded and there is a greater emphasis being placed on more innovative ways to improve water quality by controlling and treating stormwater runoff. As a result, these monies have become more available to stormwater projects. These are loan funds, however, and competition for the money is significant.

8.4 FEMA Buyout Program

The Federal Emergency Management Agency (FEMA) has regulatory oversight of the Hazard Mitigation Grant Program (HMGP), which is the federal program that provides cost sharing to state and local buyout programs. HMGP funding is used for planning grants to develop or update flood mitigation plans, for project grants to implement mitigation measures such as elevating or dry flood-proofing structures, and for acquisition of property for relocation or demolition of flood prone structures.

It is important to understand that FEMA does not buy houses directly from the property owners. Acquisition or buyout projects are administered by the state and local communities while FEMA funds up to 75% of the costs. The state and local communities work together to identify areas where buyouts make the most sense and prioritize the mitigation programs. Individuals may not apply directly to the state, but the community may sponsor an application on their behalf. Buyouts are an important way to reduce the risk of future disasters. Money is limited and in most cases the amount of money set aside for mitigation generally cannot meet all the mitigation needs following a disaster. Buyouts are an important way to reduce the risk of future disasters.

Property acquisition is one of many forms of hazard mitigation, but it is the most permanent form. It removes people from harm's way forever. In a property acquisition project, the community buys private property, acquires title to it, and then clears it. By law, that property, which is now public property, must forever remain open space land. The community can use it to create public parks, wildlife refuges, etc., but it cannot sell it to private individuals nor develop it. Property acquisitions work the same way as any other real estate transaction. Property owners who want to sell their properties will be given fair prices for them. It is a terrific opportunity for people who live on or near hazard areas to get to safer ground.

Individual property owners will want to weigh the advantages and disadvantages of property acquisition. The advantages of property acquisition include:

- Peace of mind because it reduces, if not eliminates, most of the future risk.
- Fair compensation generally based on the pre-flood market value of your home.
- A chance for a new start.
- A means of recovery that is more advantageous than repair grants or loans.
- An opportunity to recoup at least partially your financial investment in a property that has lost value.

On the other hand, property acquisition has its disadvantages, including:

- Loss of community/neighborhood/family roots.
- Despite efforts to compensate you fairly, property acquisition may not make you "whole" again.

The process can be lengthy and complex. Property acquisition is not an overnight solution. Applying for funds, waiting for approval, transferring funds, conducting appraisals and closings, etc. take time, especially if the project involves many properties. Each proposal is also in a competitive process that limits the likelihood of success.

8.5 Interlocal Agreements and Public/Private Partnerships

With the proximity of the neighboring communities, the City could develop interlocal agreements that provide mutual benefits for all parties involved. Since stormwater runoff rarely follows political boundaries, it is advisable to establish interlocal agreements with neighboring counties and municipalities and look for ways to foster a relationship with state agencies such as the Department of Transportation (DOT) when addressing stormwater issues in the municipality.

Finally, the City may be interested in investigating the feasibility of establishing relationships with developers, property owners associations, and individual private property owners in order to develop solutions to and accomplish some of its stormwater goals..

It is understood that local government resources are limited and these organizations may not be interested in joint development of projects. Under the economic cloud that currently hangs over most of the country, private developers are very hesitant to provide funding for stormwater infrastructure improvement.

8.6 FEMA/NC Division of Emergency Management, Hazard Mitigation Grant Program

The FEMA/NC Division of Emergency Management, Hazard Mitigation Grant Program provided funding to projects that reduce the risk of damage as a result of flood events. While this study has identified several CIP projects, there must be a correlation between the project and hazard mitigation. Significant, additional analysis would be required in an attempt to establish such a correlation for the projects identified within this report.

8.7 Overall Funding Picture

The introduction to this section notes the importance of funding and planning for projects. With the uncertain future of the grant and loan programs that have historically been used for these innovative water quality projects it is important for the City to look at local funding models. Stormwater management for City facilities (including roads) is a real cost to Hendersonville and must be addressed through some funding methodology. Future infrastructure improvements are needed in the Britton Creek and at other locations in the City's drainage system and when they become critical action will become a necessity.