Neuse River Phase II Watershed Assessment

A review of stream and stormwater outfall conditions and potential restoration and BMP retrofit opportunity in portions of the Neuse River Watershed within the Town of Morrisville

Stantec

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Sign-off Sheet

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Glossary

Bankfull Depth – the channel at the top-of bank or point from where water begins to overflow onto a floodplain.

Bankfull Discharge - the stream flow when the height of the water just reaches the top of the banks, is often used as the channel-forming discharge.

Bank Height Ratio - the ratio of maximum depth from top of low bank to maximum depth from bankfull stage measured at a riffle cross-section.

Bed Scour – the removal of material from the bed of the river from streamflow.

BMP – best management practice

Composite Sample – a sample which consists of a mixture of several individual grab samples collected at regular and specified time periods, each sample taken in proportion to the amount of flow at that time.

Confluence – the junction of two streams.

Cross-sectional area – stream width multiplied by average water depth.

Dimension – the two dimensional, cross-sectional profile of a stream channel.

Dry Pond – or detention basin – an excavated area installed to protect against flooding and, in some cases, downstream erosion by storing stormwater for a limited period of time. No permanent pool of water exists. A dry detention basin is used to manage water quantity, but has a limited effectiveness in protecting water quality.

Ecoregion - large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions.

Entrenchment Ratio - the ratio of flood-prone width to bankfull channel width measured at a riffle cross-section. The flood-prone width is measured perpendicular to valley flow direction at the elevation of twice the maximum depth at bankfull in a riffle.

Ephemeral Stream – are features that only carry stormwater in direct response to precipitation. They may have a well-defined channel and they typically lack the biological, hydrological, and physical characteristics commonly associated with intermittent or continuous conveyances of water. These features are typically not regulated by NC DWR or the U.S. Army Corps of Engineers.

Floodplain – an area of low lying ground adjacent to a river, formed mainly of river sediments and subject to flooding.

Floodprone Width – the valley width at the floodprone depth

Floodprone Depth – is equal to two times the bankfull depth

Grab Sample – a single sample or measurement taken at a specific time.

Hydric Soil –soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil profile.

Hydrologic Unit Code (HUC) – a sequence of numbers that identify a drainage basin.

Intermittent Stream - have a well-defined channel that contains water for only part of the year (typically during winter and spring). The flow may be heavily supplemented by stormwater. When dry, they typically lack the biological and hydrological characteristics commonly associated with continuous conveyances of water. These features are regulated by NC DWR and typically regulated by the U.S. Army Corps of Engineers.

Level Spreader – an erosion control device designed to reduce water pollution by mitigating the impact of high-velocity stormwater surface runoff. It usually consists of a poured concrete linear structure constructed perpendicular to surface runoff and has a uniform slope of zero percent.

Nutrient – in terms of water quality, nutrient generally refers to nitrogen and phosphorus. Phosphorus is typically monitored in the form of total phosphorus (TP), while nitrogen can be monitored in many forms including total nitrogen (TN), ammonia (NH4), nitrate/nitrite (NO3/NO2), and total Kjeldahl nitrogen (TKN).

Nutrient Concentration – the amount of nitrogen or phosphorus in a defined volume of water, such as "milligrams of nitrogen per liter of water."

Nutrient Load – the total amount of nitrogen or phosphorus entering the water during a given time, such as "tons of nitrogen per year."

Morphology – the form and structure of stream and river channels.

Outfall – the discharge point of concentrated flow of water into another body of water. In this study an outfall refers to locations where stormwater empties into streams. The outfall may contain an outfall structure which controls the release of flow from a stormwater BMP and an outfall channel which connects the structure to a stream.

Pattern – the sinuosity or meander geometry of a stream.

Perennial Stream - have a well-defined channel that contains water year round during a year with normal rainfall. Groundwater is the primary source of water, but they also carry stormwater.

They exhibit the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. These features are regulated by NC DWR and typically regulated by the U.S. Army Corps of Engineers.

Profile –the longitudinal slope of a channel.

Reach Break – A reach is a length of channel with homogeneous hydrologic and physical characteristics. A reach break marks the boundary between adjoining reaches.

Reference Reach – an undisturbed stream used to develop natural channel design criteria upon which stream restoration parameters are based.

Sediment Basin - a temporary pond built on a construction site to capture eroded or disturbed soil that is washed off during rain storms, and protect the water quality of nearby waterbodies.

Shear Stress – a stress state where the stress is parallel to the surface of the material (i.e. along the stream bank).

Sinuosity – the length of a stream channel from an upstream point to a downstream point divided by the straight line distance between the same two points.

Step-Pool – step pool stream morphology is defined by a regular series of steps and corresponding pools, similar to a staircase in the bed of the stream.

Stream Buffer –or riparian buffer, riparian corridor – a natural or vegetated area measured landward from the top of the defining edge of the stream channel.

Stream Enhancement – may not involve the re-establishment of profile, but may use bank stabilization techniques and stabilization structures to stabilize a stream.

Stream Restoration – the re-establishment of the general structure, function and self-sustaining behavior of a stream system that existed prior to disturbance. Restoration includes a broad range of measures, including installation of structures and planting of vegetation to protect streambanks and provide habitat; and the reshaping or replacement of unstable stream reaches into appropriately designed functional streams and associated floodplains

Substrate – the stream bed material, such as silt, clay, gravel, cobble, or bedrock.

Water Surface Slope – the slope from the elevation of the water surface at the top of a riffle to the top of another riffle at least 20 bankfull widths downstream.

Width to Depth Ratio – dimension of bankfull channel width to bankfull mean depth.

1.0 BACKGROUND

This study involves the assessment of stream and stormwater outfall stability on a number of subbasins (44, 45, and 52) in the Town of Morrisville (Town) (Figures 3 and 4). This is a continuation of an effort by the Town to assess the connection between outfalls and streams throughout the Town's jurisdiction. Most of the land within the Town's boundary, including the assessment study area, drains to Lake Crabtree within the Neuse River watershed). Since 1998, the Neuse River and all other surface waters within the Neuse River Basin have been subject to a set of regulations known as the Neuse Basin Nutrient Strategy or Neuse Rules. The strategy includes an overall nitrogen reduction goal of 30% over baseline conditions (1991-1995) and the implementation of stormwater management measures. It also stipulates a requirement of 50 feet of riparian buffer protection on both sides of a stream or waterbody.

The Neuse Rules focus on nitrogen removal and stormwater treatment. This study examined the connection between outfalls and streams as a source of pollution including nitrogen. Unstable, incising streams can impact stormwater outfalls, leading to erosion and potential undercutting of outfall structures. Also, instability of stormwater outfalls can increase erosion of outfall channels, increasing pollutant loads to receiving streams. In order to reduce pollutants, this study includes a search for potential projects to eliminate the source of pollution or to treat the pollution with stormwater Best Management Practices (BMPs).

1.1 WATERSHED DESCRIPTION

The majority of the Town of Morrisville is located within the Lake Crabtree watershed. Lake Crabtree is a 520-acre flood control reservoir that was constructed in 1989. It is situated south of I-40 between Aviation Parkway and Weston Parkway (Figure 1). The lake's watershed, USGS 14-digit HUC 03020201080010, drains 25,957 acres (40.6 square miles). The watershed includes Raleigh-Durham International Airport (RDU) to the north, along with portions of Durham County and the City of Raleigh. To the south and west, the watershed drains portions of the Towns of Apex, Cary, and Morrisville. Approximately 5,000 acres (7.8 square miles) of the Lake Crabtree watershed fall within the town limits of Morrisville. This is equal to about 19% of the watershed.

The study area for this project focused on a portion of the Town's Lake Crabtree watershed that drains into Crabtree Creek approximately one mile upstream of Lake Crabtree. The 1,081 acre study area is generally bounded by Aviation Parkway to the southeast, Chapel Hill Road to the east, McCrimmon Parkway to the north, and the Town limits to the west (just west of Town Hall Drive) (Figure 1). There are three separate stream systems, all unnamed tributaries to Crabtree Creek.

The study area watershed lies on the edge of the Triassic Basin of the Piedmont ecoregion. Streams in the Triassic Basin typically have low base flows and are low to moderate gradient with mostly sand and clay substrates. Topography in the Triassic Basin consists of low rounded hills and ridges with wide floodplains found along larger streams and Crabtree Creek. According to the

USDA Soil Survey for Wake County (1970), streams in the study area and surrounding floodplains are underlain with Chewacla, Congaree, Creedmoor, Polkton-White Store, and Worsham soils. Of these, only the Worsham soils are hydric, and Congaree and Chewacla soils have minor hydric soil inclusions. Refer to Figure 2 for soils in the study area.

The study area encompasses the oldest parts of the Town of Morrisville, which was established in 1850 after the railroad was built with a train depot near Crabtree Creek. Today, this area is referred to as the Town Center. The earliest historical aerial imagery available for the area is from 1938 (Figure 3). By this time, the main roads crisscrossing the study area were already established including Church Street, NC54/Chapel Hill Road, McKrimmon Parkway, Morrisville-Carpenter Road and Aviation Parkway. The Town Center boasted a number of residences, especially along Church Street. These residential areas seemed to be medium to low density areas. The remainder of the study area was agricultural in nature with areas of forest. Stream channelization and lack of buffers were apparent throughout the agricultural areas.

The next forty years saw little change in the study area. Low density residential development occurred along Scroggins Avenue and Carolina Street beginning in the late 1950s and along Green Drive and Fairview Avenue in the late 1970s. By 1993, a fair number of industrial facilities had been built along NC54/Chapel Hill Road in the northern half of the watershed. One high density apartment complex had been built at Church Street and Treybrooke Drive. Additional industrial areas were present along NC54/Chapel Hill Road by 1998 (Figure 3). The early 2000s saw the beginning of the medium to high residential development on the west side of the project study area (subbasin 52) along with the construction of Town Hall Drive. By 2005 those subdivisions were built out and two new schools were built in the midst of the residential development. Residential development began to also take place off Lake Grove Boulevard in the westernmost portion of the study area in 2005. By 2013, subbasin 52 is at almost completely developed. The central portion of the study area (subbasin 44) still has areas of forest mixed in with industrial and residential land (Figure 3). The majority of the eastern portion of the study area (subbasin 45) appears as it did in 1993 although there has been some development along Chapel Hill Road.

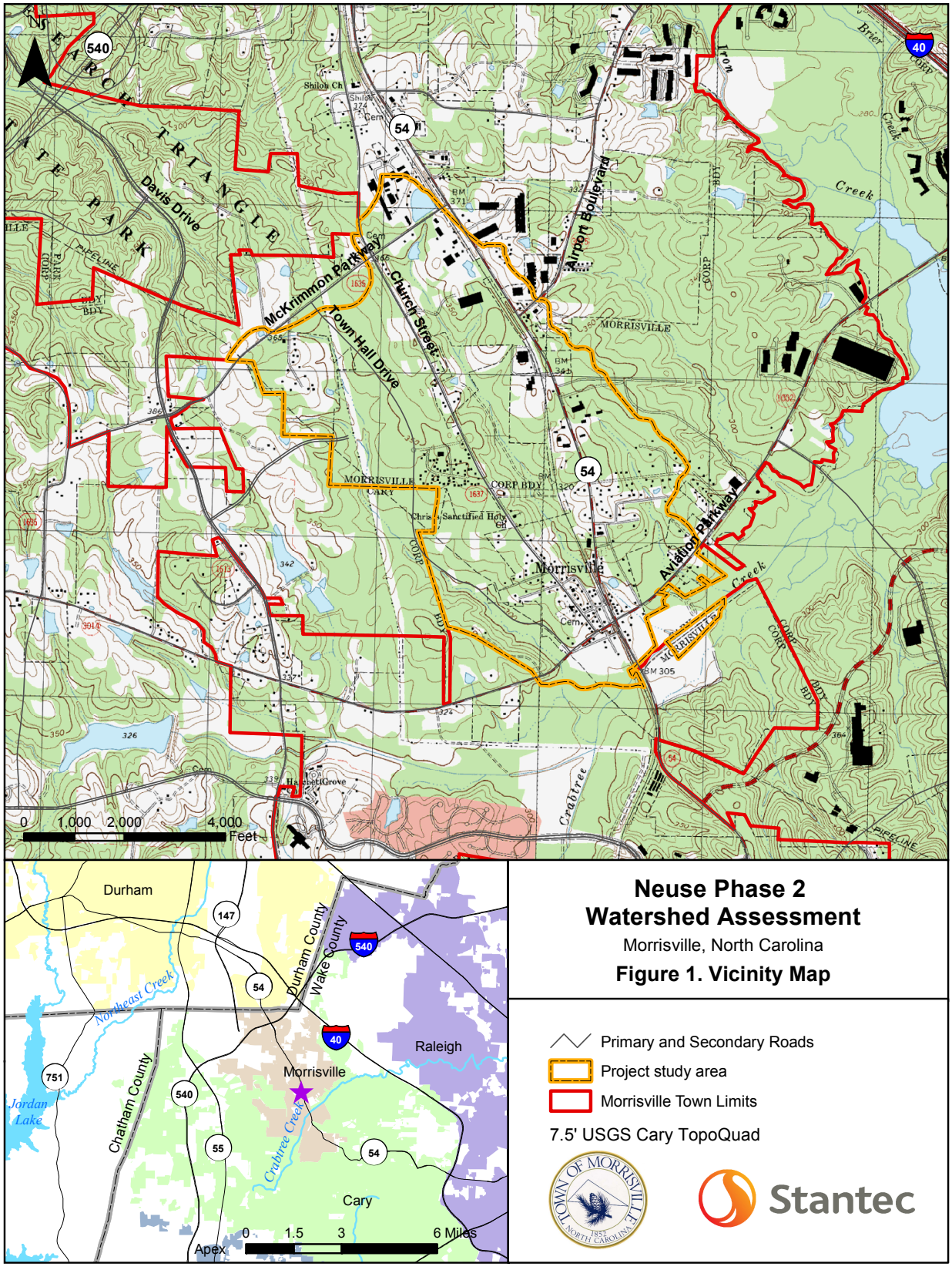
The Town future land use map has designated the northern portion of the study area as medium and high density residential along with commercial and industrial uses along Chapel Hill Road. There is also a Town Center Plan that encompasses the southern half of the study area. In addition to the current uses, that plan depicts an expansion of civic/government/commercial use along Town Center Drive south of Jeremiah Street along with residential land use for much of the remaining undeveloped areas. The low density housing will likely be redeveloped in order to align with the future land use map. The areas surrounding the major streams have been set aside as flood zones or parks. These areas were visited during the fieldwork portion of the watershed assessment to determine how stormwater and stream restoration projects may be incorporated into these long-term plans (Section 3). The only major roadway planned for the study area is the expansion of Airport Boulevard from Chapel Hill Road to a portion that has already been constructed to the east of Davis Drive.

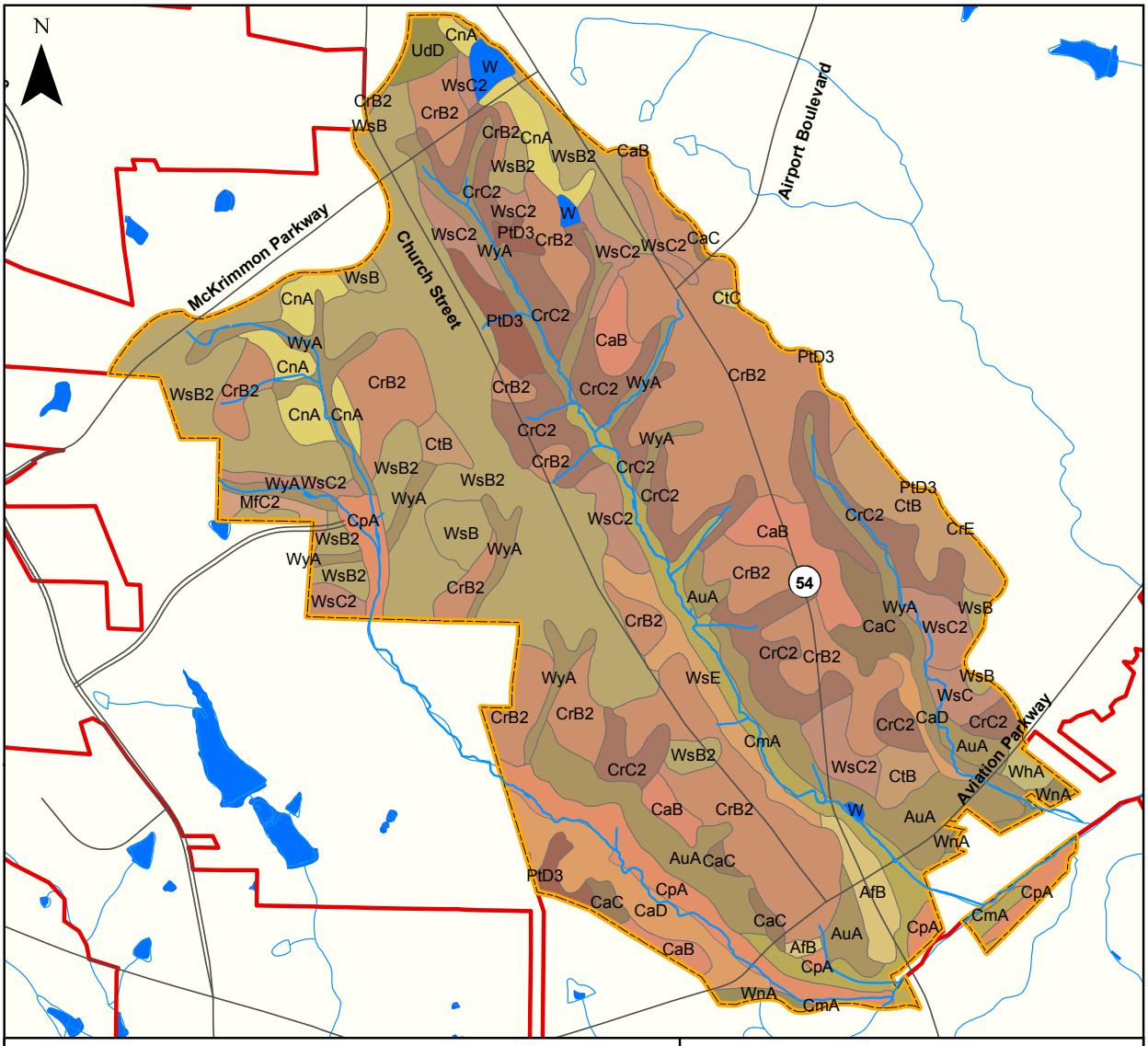
1.2 REGULATIONS AND ORDINANCES

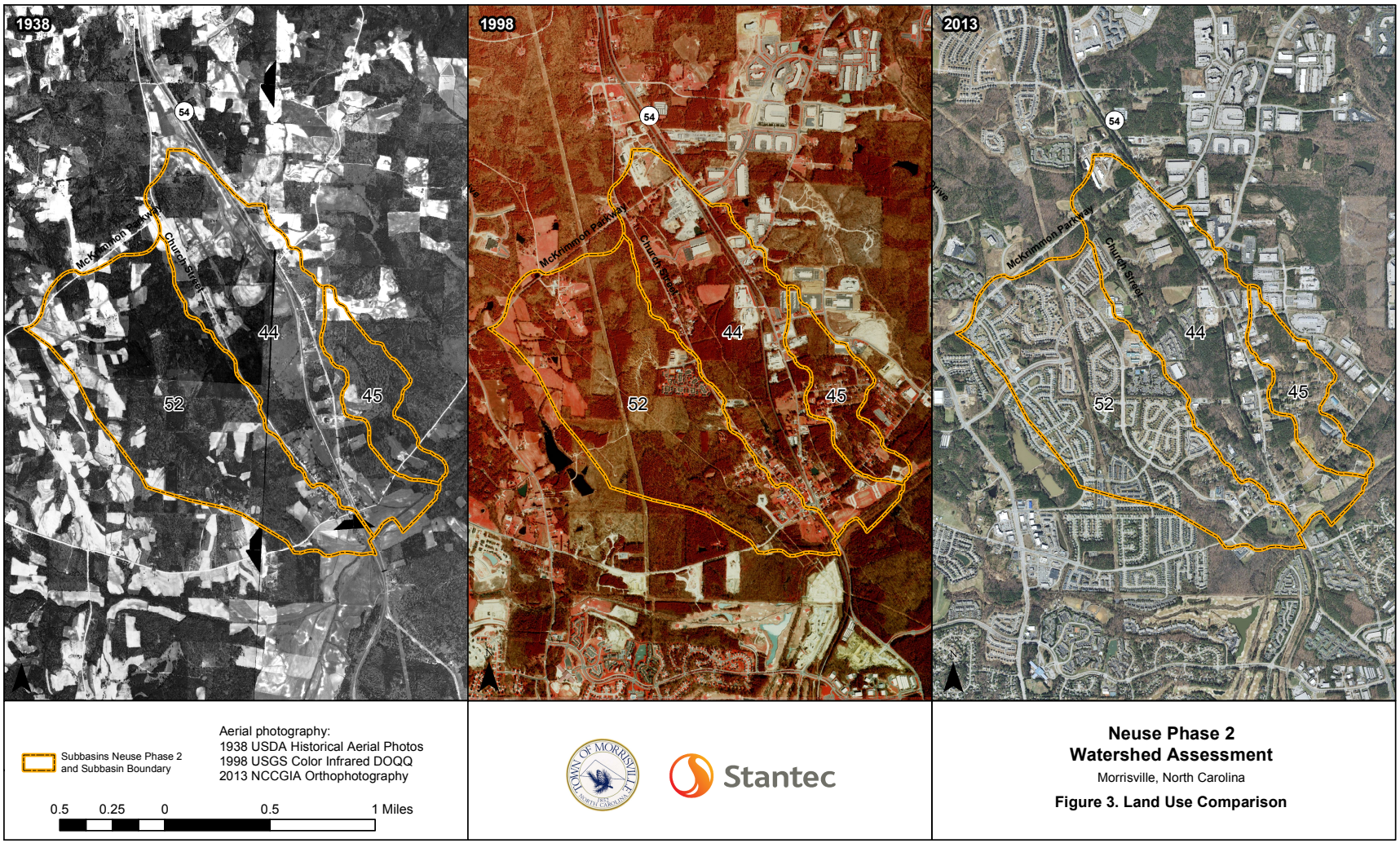
The Town adopted a Unified Development Ordinance (UDO) in 2014 that consolidated many of the existing Town ordinances. Article 7 of the UDO covers stormwater management and aims to manage and minimize the effects of stormwater runoff from development sites, as well as comply with the Town's Phase II stormwater permit. The article establishes a "set of water quality and quantity regulations to meet the requirements of state and federal law regarding control of stormwater runoff and discharge for development and redevelopment" (Morrisville 2015). A Best Management Practices section requires annual operation and maintenance (O&M) reports from BMP owners. Language prohibiting illicit discharges and connections are also contained in this article. The article refers to the use of the Town's Design Manual which contains a chapter focused on stormwater quality management including technical specifications and standards (Morrisville 2014).

As of 2005, the Town began cataloging their stormwater drainage system using GIS. Since 2005, as-built files have been used to update the map. An update to the field inventory was completed in 2013.

Riparian buffer regulations, described in Article 6 of the UDO, aim to protect and preserve existing riparian buffers along intermittent streams, perennial streams, lakes, reservoirs, and ponds within the Neuse River and Jordan Lake watersheds. The article divides the buffers into two zones. Zone One is comprised of the first 30 feet from the stream and is required to consist of undisturbed vegetation. Zone Two is comprised of an additional 20 feet from Zone One. Grading and revegetation is allowed within Zone Two provided that it does not adversely affect the vegetation in Zone One. All concentrated flow must be dispersed (i.e. 'diffuse flow') before entering Zone Two. Riparian buffers within the Lake Crabtree watershed have been regulated since 1998 when the State enacted the Neuse Rules.


RESEARCH TRIANGLE PARK
Davis Drive
McKrimmon Parkway
Town Hall Drive
Church Street
Airport Boulevard
Aviation Parkway
MORRISVILLE
Morrisville
CARY
Crabtree Creek
Iron Creek
Brier Creek
0 1,000 2,000 4,000 Feet
Durham
Wake County
Durham County
Chatham County
Northeast Creek
Jordan Lake
Raleigh
Morrisville
Cary
Apex
0 1.5 3 6 Miles
Neuse Phase 2
Watershed Assessment
Morrisville, North Carolina
Figure 1. Vicinity Map
Primary and Secondary Roads
Project study area
Morrisville Town Limits
7.5' USGS Cary TopoQuad
TOWN OF MORRISVILLE
NORTH CAROLINA
1855
Stantec


N
McKrimmon Parkway
Church Street
Airport Boulevard
Aviation Parkway
54
Soils
AfB - Altavista fine sandy loam 0-6%
AuA - Augusta fine sandy loam 0-2%
CaB - Carbonton-Brickhaven 2-6%
CaC - Carbonton-Brickhaven 6-10%
CaD - Carbonton-Brickhaven 10-15%
CmA - Chewacla sandy loam 0-2%
CnA - Colfax sandy loam 0-6%
CpA - Congaree silt loam 0-2%
CrB2 - Creedmor sandy loam 2-6%
CrC2 - Creedmor sandy loam 6-10%
CrE - Creedmor sandy loam 10-20%
CtB - Creedmor silt loam 2-6%
CtC - Creedmor silt loam 6-10%
MfC2 - Mayodan sandy loam 6-10%
MfD2 - Mayodan sandy loam 10-15%
MfE - Mayodan sandy loam 15-25%
PgF - Pacolet-Gullied 4-25%
PkF - Pinkston sandy loam 10-45%
PtD3 - Polkton-White Store 2-15%
UdD - Udorthents loamy 0-15%
W - Water
WhA - Warne fine sandy loam 0-2%
WnA - Wehadkee silt loam 0-2%
WsB - White Store sandy loam 2-6%
WsC - White Store sandy loam 6-10%
WsE - White Store sandy loam 10-20%
WyA - Worsham sandy loam 0-3%
Neuse Phase 2
Watershed Assessment
Morrisville, North Carolina
Figure 2. Soils Map
Primary and Secondary Roads
Project Study Area
Morrisville Town Limits
Streams
TOWN OF MORRISVILLE
NORTH CAROLINA
Stantec
0
1,000
2,000
4,000
Feet


1938
1998
2013
54
McKnimmon Parkway
Church Street
44
45
52
Subbasins Neuse Phase 2 and Subbasin Boundary
Aerial photography:
1938 USDA Historical Aerial Photos
1998 USGS Color Infrared DOQQ
2013 NCCGIA Orthophotography
0.5 0.25 0 0.5 1 Miles
Stantec
Neuse Phase 2
Watershed Assessment
Morrisville, North Carolina
Figure 3. Land Use Comparison

2.0 EXISTING CONDITIONS

Streams in the study area were likely straightened and channelized for agricultural purposes as seen in some early aerial imagery. Other impacts to streams have occurred with the construction of the railroad, sewer lines, and roadways. Many streams were piped and inlets and outfalls were put in place in order to facilitate development. This includes industrial land in Subbasin 44 (Chapel Hill/Church Street) and almost all of the tributaries in Subbasin 52 (Town Center Drive). Stormwater BMPs were installed in most of the developments constructed since 2000 including residential and commercial developments.

During the spring of 2015, field surveys were conducted to assess streams, stream buffers, and outfall integrity throughout the study area. These three factors were assessed in order to identify areas of degradation along with the degree of degradation and the possibility for improvement or restoration. In addition, as field surveys were conducted, BMP retrofit opportunities were identified.

2.1 STREAM ASSESSMENT

Visual assessments of existing stream conditions were conducted along all streams in the three study area subbasins from the headwaters to Crabtree Creek. Crabtree Creek forms the town limits to the south. In addition, a small section of the western most subbasin is located within the Town of Cary and therefore was not assessed. The visual assessment included investigating parameters such as stream origin, valley type, substrate, slope, Rosgen classification, morphology, bank erosion, stream habitat, and stream stability. Streams were broken into reaches when significant changes in any of these factors were observed. In general, reaches were assigned to a category of stable, moderately stable, or unstable. An example visual assessment form is included in Appendix A.

The jurisdictional stream origin [ephemeral/intermittent (E/I) break] was determined for all streams using the NC Division of Water Quality Methodology for Identification of Intermittent and Perennial Streams and Their Origins (NCDWQ 2010). NCDWQ stream identification forms were completed for all streams encountered during the field investigation and the E/I location (origin) was recorded using a mapping grade (sub-meter) GPS. NCDWQ forms are included in Appendix A. Refer to Figure 4 for the E/I break for all streams. The Town's stormwater inventory GIS data for channels, culvert, culvert barrel, pipes, and pipe barrel layers, were used as a base for the field investigation. The Town's stream layer along with the USGS 7.5' topoquad and NRCS Soil Survey were also used during the field survey to ensure all mapped streams were investigated. Upon completion of the field investigation, streams not accounted for in the channel inventory were added to the channel GIS layer. All entries in the Town's channel layer were classified as ephemeral or as intermittent/perennial. This data can be used to represent the locations and extents of all waterways in the study area as well as streams that are subject to Section 401/404 of the Clean Water Act. This study did not include mapping of other jurisdictional waters including wetlands. Therefore, the data should not be used in lieu of a field visit or as a final

delineation of jurisdictional features. In addition, the USGS 7.5' topoquad and NRCS Soil Survey were examined to see if any or all of the identified intermittent and perennial streams were depicted on them. If a stream appears on either data source, the Neuse Buffer Rules apply. If it does not appear on these sources, the buffer rules do not apply, however they would still be subject to Section 401/404 of the Clean Water Act.

In general, most streams were found to be in stable or moderately stable condition with low to moderate bank erosion. Unstable streams include Reaches 1-5, 1c-1, 1c-2, 2-2, 2-6, 2-8, and 2e. Refer to Table 1 and Figure 4 for the assessment of the current stability of stream reaches in the watershed. Photos of the unstable reaches are included in Section 3.1. The unstable streams are located in developed and undeveloped areas. Those in urban areas (1-5, 1c-1, and 1c-2) have had the natural stream functions altered by channelization, stormwater discharges, floodplain filling, streambank armoring, and loss of riparian vegetation. The resulting stream channels are mostly incised down to resistant clay layers. Two of the three streams are found within power line right-of-way (ROW) corridors that provide a wide riparian corridor. However, vegetation is actively managed and does not provide adequate bank support. The remaining unstable streams (2-2, 2-6, 2-8, and 2e) are in a relatively undeveloped part of the study area with a small number of houses dating back at least 100 years. Despite the lack of development, the area has been disturbed significantly by historical land practices including agriculture and forestry operations. The main channel was dammed in the past but has since been breached.

Photo 1 Reach 1-6, example of stable stream in the study area

Photo 2 Reach 2-5, example moderately stable stream in the study area

Streambank instability typically results from bank erosion during high flow events. Contributing factors are high banks resulting from channel incision, lack of deep-rooted vegetation, and highly erodible soil materials in the streambank. Local instability can also occur in isolated locations as a result of channel constrictions or flow obstructions (culverts, utility crossings, debris, or other structures). Streambanks are eroded by flowing water or by collapse (mass failure).

Collapse typically occurs when a bank is undercut by moving water and the strength of bank materials is insufficient to resist gravitational forces. Banks that are collapsing or about to collapse are considered geotechnically unstable. Many of the unstable streams in this watershed are actively eroding, contributing to downstream sedimentation and habitat degradation.

Based on typical channel morphology measurements, the Rosgen (1996) stream classification system was applied to each reach. The unstable streams all fell within the Rosgen classification of a G stream type, indicating severe entrenchment, lack of floodplain connection, and high shear stress and stream power during flood flows. The more stable streams were classified as either C or E stream types, which exhibit better floodplain access and lower shear stresses. The Rosgen stream classification system uses five delineative criteria: entrenchment ratio, width to depth ratio, water surface slope, sinuosity, and channel bed materials.

Low entrenchment ratios indicate that flood flows above bankfull discharge are carried in a narrow corridor, potentially causing erosion. Large entrenchment ratios indicate a wide floodplain that will dissipate energy during floods. Bank height ratio is another important parameter in determining the degree of channel incision and effectiveness of the active floodplain in dissipating energy during high flows. Bank height ratios greater than 1.5 indicate potentially severe bank instability resulting from high shear stresses experienced during high flows, especially where streambanks are not well protected by vegetation.

The unstable streams in the study area have entrenchment ratios less than 1.4 and bank height ratios ranging from 2 to 6, indicating severe incision, lack of floodplain connection, and high potential for future bank erosion and headcutting. Typical stream restoration projects are designed with entrenchment ratios of at least 5 and bank height ratios of 1 to optimize floodplain energy dissipation and other functions. Refer to Table 1 for the geomorphic parameters assessed for all streams in the study area.

Table 1 Stream existing conditions in the Neuse River Basin Phase II Watershed

Reach	Assessed Length (ft)	Rosgen Classification	Stability	Bank Erosion	Habitat
1-1	346	E	Stable	Low	Good
1-2	243	E/G	Stable	Moderate	Fair
1-3	481	G	Moderately Stable	Moderate	Fair
1-4	1005	G/E	Stable	Low	Good
1-5	572	G	Unstable	High	Poor
1-6	1870	B	Stable	Low	Good
1-7	3681	G	Moderately Stable	Moderate	Fair
1-8	1535	G	Moderately Stable	Moderate	Fair
1a[1]	1115	E	Stable	Low	Good

Reach	Assessed Length (ft)	Rosgen Classification	Stability	Bank Erosion	Habitat
1b	132	G	Moderately Stable	Moderate	Fair
1c-1	1053	G	Unstable	High	Poor
1c-2	1021	G	Unstable	High	Poor
1d	249	G	Moderately Stable	Moderate	Fair
2-1	1650	E	Stable	Low	Good
2-2	820	G	Unstable	High	Poor
2-3	590	G	Moderately Stable	Moderate	Fair
2-4	1308	G	Moderately Stable	Moderate	Fair
2-5	1770	G	Moderately Stable	Moderate	Fair
2-6	2368	G	Unstable	High	Poor
2-7	909	E	Stable	Moderate	Fair
2-8	1003	G	Unstable	High	Poor
2a	295	E	Stable	Low	Good
2b[1]	604	E	Stable	Low	Good
2c[1]	550	No Access			
2d	1744	G	Unstable	High	Poor
2e[1]	642	E	Stable	Low	Good
2f	990	G	Moderately Stable	Moderate	Fair
2g	64	E	Stable	Low	Good
2h	659	G	Moderately Stable	Mod	Fair
2i[1]	352	E	Stable	Low	Good
2j[1]	412	E	Stable	Low	Good
3-1	2241	G	Moderately Stable	Moderate	Fair
3-2	1477	G	Moderately Stable	Moderate	Fair
3-3	2127	E	Stable	Low	Good
4-1[1]	1218	B	Stable	Low	Fair

[1] Reaches 1a, 2b, 2c, 2e, 2i, 2j, and 4-1 do not appear on the USGS 7.5' topoquad or NRCS Soil Survey and therefore are not subject to buffer rules.

2.2 BUFFER ASSESSMENT

A stream buffer integrity assessment was conducted for the entire study area. Falling within the watershed of Neuse River, the Lake Crabtree watershed is subject to the Neuse Basin Nutrient Strategy. These rules and the Town's UDO require 50 feet of vegetated buffer on all perennial and intermittent streams. These rules have been in effect since 1998 and most of the densely developed Subbasin 52 was built after this. However, older development, prior to the adoption of a buffer ordinance, exists throughout the remainder of the study area. Desktop analyses and a visual assessment in the field were conducted to investigate stream buffer integrity in terms of buffer width and density, and the presence of invasive species in order to identify potential opportunities for buffer restoration or enhancement.

During field investigations, areas of poor buffer width and density, and the location and type of invasive vegetation species were cataloged using a mapping grade GPS. A desktop analysis was also conducted using GIS techniques by applying a 50-foot buffer to the field verified and updated channel layer described above. The field and desktop data were used to create a map of digitized streams and buffer integrity (Figure 4).

The field investigation revealed that the majority of the buffers on streams subject to the Neuse Rules in the study area are 50 feet wide with minimal impervious surfaces. In the newer developed areas (Subbasin 52), a 100-foot wide corridor containing the stream is most often owned by a homeowners association. Unfortunately, the stream does not always run down the middle of these 100-foot corridors. Often a stream migrates over time and a narrow buffer is left on one bank and a larger one on the other. In addition, there were a few instances where the edge of a house fell within the buffer or where a greenway was installed in the outer buffer zone. Greenways are an allowable use within Neuse buffers.

As in the previous two assessments, many other stream channels were piped in order to facilitate development. This occurred for the newer developments as well as for some of the older industrial areas found in Subbasin 44. It is impossible to determine how much of the streams that were piped in the past would be considered jurisdictional under current rules and regulations. However, many appear drawn in on the aerial images found within the 1970 USDA Soil Survey for Wake County.

In the areas with development prior to 1998, there are more instances of structures within the buffer especially in residential areas including Subbasin 45. In Subbasin 44, the current origin of many of the streams is at the mouth of a pipe as development has been focused on headwaters along Chapel Hill Road and Church Street. Buffer rules protect 50 feet on both sides of the stream as well as 50 feet above the origin. As such, all of the streams where the end of a pipe serves as the origin have impacted buffers in the upstream direction. Stream buffers are also impacted when the stream flows under roads via culvert.

The vegetation within the riparian buffers consisted of forest and herbaceous vegetation (Table 2). Subbasin 52 has a mix of pine, sweet gum and eastern red-cedar in the upper 3 reaches and

then again in the lower reaches (1-6 to 1-8). The middle reaches (1-4 to 1-6) along with 1c-2 were mainly herbaceous as the stream is located within a powerline ROW. This area contained a variety of wetland species. Herbaceous vegetation was also found in residential yards, road embankments, and sewer ROWs throughout this subbasin.

In Subbasin 44, the headwaters of Stream 2 along with most of the tributaries are dominated by pine trees of varying ages. Hardwood species are found mixed in with the pine further down along Stream 2 (2-4, 2-5, 2-7 and 2-8). Dominant species include sweetgum, red maple, and tulip poplar. Reach 2-6 has very little woody vegetation with almost the entire floodplain covered with the invasive *Microstegium vimineum* (stilt grass). Chinese privet is found throughout the subbasin.

Subbasin 45 has a mix of pine and hardwood species including sweetgum, red maple, and tulip poplar in the upper reach. In the middle of the subbasin, the buffer contains scattered trees surrounded by residential yards. A more defined riparian buffer reappears in the lower portion of the subbasin with the same species as the upper reach.

In both Subbasin 44 and 45, herbaceous vegetation was mainly found in sewer ROWs residential yards, and road embankments. Maintenance in these areas includes mowing and the removal of woody vegetation.

In sewer ROWs, the invasive *Microstegium vimineum* (stilt grass) was found. Stilt grass seeds are carried by streams and easily establish in disturbed areas such as a newly installed sewer line. The large powerline ROW in Subbasin 52 did not have as much stilt grass when visited in late winter as the area was too wet.

Photo 3. Reach 1-3

Photo 4. Reach 1-5

Photo 5. Reach 1-7

Photo 6. Reach 2-1

Photo 7. Reach 2-6

Photo 8. Reach 3-1

Photo 9. Reach 3-2

Photo 10. Privet dominated understory on Reach 2-8

Table 2 Stream buffer existing conditions in the Neuse River Phase II Watershed

Reach Name	Stream Buffer (ft) [2]		Composition of Buffer	Impervious Impact in Buffer
	Right Bank	Left Bank		
1-1	50	50	Forest, road embankment	Origin pipe, road crossing at downstream end
1-2	50	50	Forest	None
1-3	50	50	Forest	None
1-4	50	50	Forest, residential yards, power ROW, sewer line crossing	None
1-5	50	40	Residential yard, power ROW, sewer line crossing	Greenway, road crossing
1-6	45	45	Forest, residential yards, power ROW crossing	Greenway (RB upper reach, LB lower reach)
1-7	50	50	Forest	2 road crossings
1-8	50	50	Forest, sewer ROW, playground	None
1a[1]	50	50	Residential years	Houses
1b	50	45-50	Forest, residential yard	Edge of house
1c-1	50	50	Forest	Road crossing
1c-2	45-50	50	Forest, power ROW, sewer ROW at downstream end	Corner of a house
1d	50	50	Forest, road embankment, sewer line crossing	Road crossing
2-1	50	50	Forest, sewer ROW & crossing	Road crossing
2-2	50	50	Forest, sewer ROW	None
2-3	50	50	Forest, sewer ROW	None
2-4	50	50	Forest, sewer ROW	Road crossing
2-5	50	50	Forest, sewer ROW & crossing	Dirt road crossing
2-6	50	45-50	Forest, residential yards, sewer ROW & crossing,	House, railroad and road crossing
2-7	50	50	Herbaceous, scattered trees, sewer ROW	Road crossing
2-8	50	50	Forest, playing fields, sewer ROW	Road crossing
2a	50	50	Forest, herbaceous path, sewer line crossing	None
2b[1]	35-50	50	Forest, residential yard	Origin in pipe, house
2c[1]	NA	NA	NA	Origin in pipe

Reach Name	Stream Buffer (ft) [2]		Composition of Buffer	Impervious Impact in Buffer
	Right Bank	Left Bank		
2d	50	25-50	Forest, sewer ROW & crossing	Parking lot, railroad crossing, dirt road crossing (near downstream end)
2e[1]	10	50	Forest, herbaceous	Parking lot, apartments
2f	50	50	Forest	Origin in pipe, railroad crossing
2g	50	50	Forest, sewer line crossing	None
2h	50	50	Forest, sewer line crossing	Origin pipe
2i[1]	50	50	Forest	None
2j[1]	10-20	10-20	Forest, railroad & road embankments	Railroad tracks, road, buildings
3-1	0-50	0-50	Forest, residential yards, sewer ROW & multiple crossings	Piped under building, houses, road crossing
3-2	0-50	50	Forest, sewer ROW & crossing	2 road crossings, houses
3-3	50	40-50	Forest, playing fields, sewer ROW &crossing	Road crossings
4-1[1]	50	50	Forest, fallow fields	Origin pipe, road crossing

[1] Reaches 1a, 2a, 5a, 5b, and 9-1 do not appear on the USGS 7.5' topoquad or NRCS Soil Survey and therefore are not subject to buffer rules.
[2] Stream Buffer widths of less than 50 feet indicates the presence of impervious surface within 50 feet of the stream

2.3 STORMWATER OUTFALL ASSESSMENT

During the field assessment, all stormwater outfalls to streams in the study area were assessed. Those not included in the Town's stormwater inventory were located and cataloged with a mapping grade GPS. Additionally, the drainage source, description, and condition of the outfalls were recorded. In total, 90 outfalls were observed in the study area. Drainage sources included stormwater BMP outfalls, street drainage, and ephemeral ditches. Of the 90 outfalls, 22 were noted to be in poor condition. Poor conditions generally included clogged/buried pipes, broken and undercut outlet structures, observed active erosion, unstable outlet channels, and headcutting. The location of all outfalls and their existing condition are depicted in Figure 4. Outfall condition, source, and description are included in Table 3.

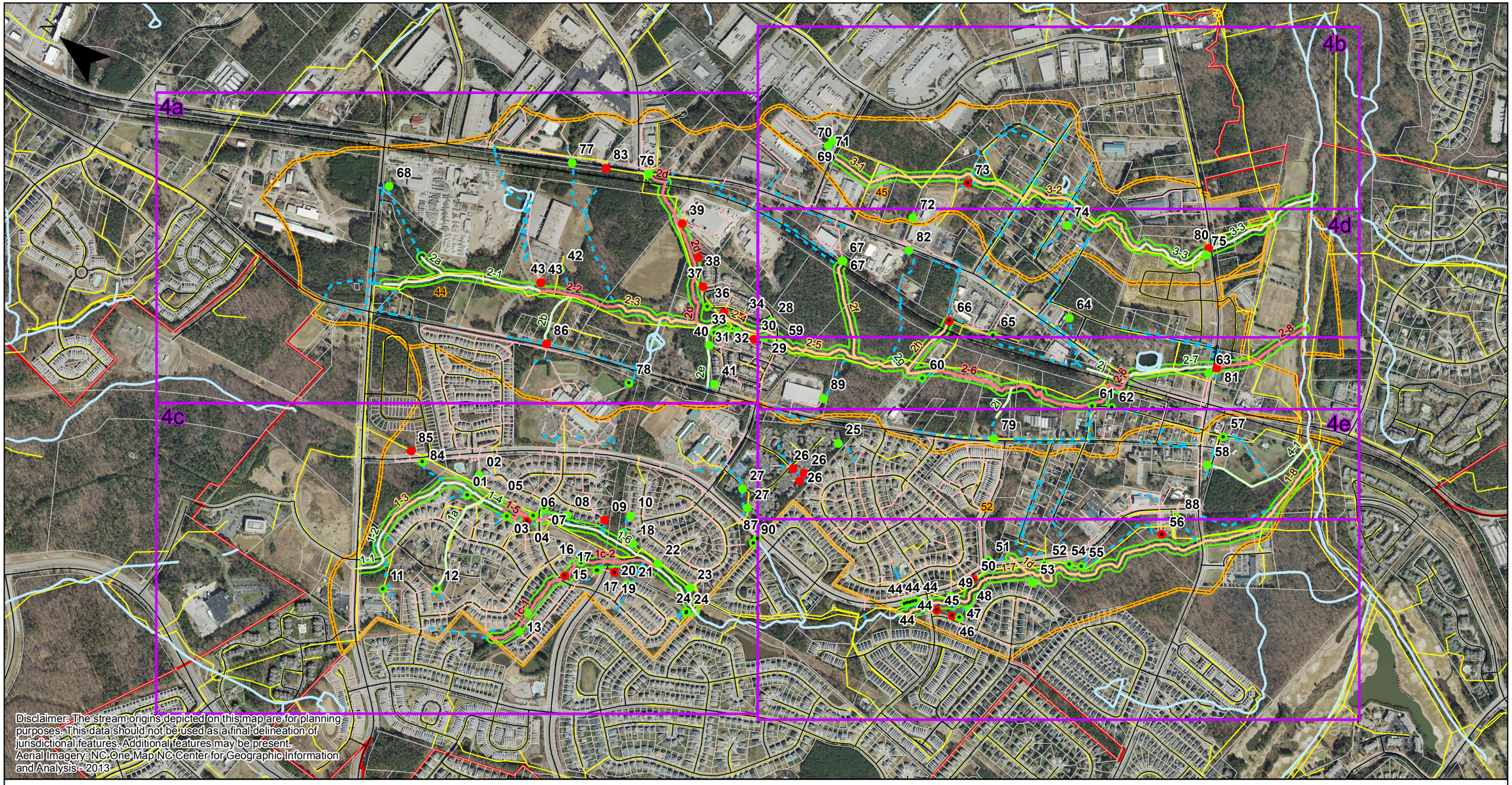
Table 3 Stormwater outfall existing conditions in the Neuse Phase II Watershed

Outfall	Receiving Stream	Source	Outfall Condition	Notes
1	1-4	Wetland	Good	18-inch RCP to rock basin
2	1-4	Street drain	Good	36-inch RCP to rock channel
3	1-5	Wetland	Good	18-inch RCP to rock basin
4	1-5	Wetland	Poor	18-inch RCP to rock basin
5	1-4	Street drain	Good	18-inch RCP to rock basin
6	1-5	Street drain	Good	18-inch RCP to rock basin
7	1-6	Street drain	Good	30-inch RCP to rock basin
8	1-6	Street drain	Good	12-inch RCP to rock basin
9	1-6	Dry pond	Poor	18-inch RCP to rock basin, unstable channel
10	1b	Street drain	Good	30-inch RCP to rock basin
11	1-1	Street drain	Good	18-inch RCP to floodplain
12	1a	Street drain	Good	18-inch RCP to stable ditch
13	1c-1	Street drain	Good	18-inch RCP to stream, in buffer
14	1c-1	Street drain	Good	18-inch RCP to stream, in buffer
15	1c-2	Street drain	Poor	18-inch RCP to stream, in buffer
16	1c-2	Wetland	Good	18-inch RCP to rock basin
17	1c-2	Wet Pond	Good	18-inch RCP to level spreader
18	1-6	Street drain	Good	18-inch RCP to rock basin
19	1c-2	Street drain	Poor	18-inch RCP to rock basin

Outfall	Receiving Stream	Source	Outfall Condition	Notes
20	1c-2	Street drain	Good	18-inch RCP to rock basin
21	1c-1	Street drain	Good	18-inch RCP to rock basin
22	1-6	Street drain	Good	18-inch RCP to rock basin
23	1-6	Street drain	Good	18-inch RCP to rock basin
24	1-6	Wet Pond	Good	18-inch RCP to level spreader
25	1-7	Street drain	Good	18-inch RCP to rock basin
26	1-7	Street drain	Poor	18-inch RCP to rock basin
27	1-6	Street drain	Good	18-inch RCP to rock basin
28	2-4	Street drain	Good	24-inch RCP to rock basin
29	2-4	Street drain	Good	24-inch RCP to level spreader
30	2-4	Street drain	Poor	12-inch RCP to rock basin
31	2-4	Street drain	Good	24-inch RCP to level spreader
32	2-4	Street drain	Good	Concrete Flume to level spreader
33	2-4	Street drain	Good	Concrete Flume to level spreader
34	2-4	Street drain	Poor	24-inch RCP to level spreader
35	2-4	Street drain	Poor	24-inch RCP to level spreader
36	2-4	Street drain	Good	Concrete Flume to level spreader
37	2e	Street drain	Poor	18-inch RCP buried and clogged
38	2e	Street drain	Poor	18-inch RCP to level spreader
39	2e	Street drain	Poor	18-inch RCP to stream, in buffer
40	2f	Street drain	Good	18-inch RCP to stream, in buffer
41	2f	Street drain	Good	18-inch RCP to rock basin
42	2-2	Street drain	Good	12-inch RCP to rock basin
43	2-2	Street drain	Poor	18-inch RCP to stream, in buffer
44	1-7	Street drain	Good	24-inch RCP (5) to sewer easement
45	1-7	Street drain	Poor	18-inch RCP buried and clogged
46	1-7	Street drain	Poor	18-inch RCP perched
47	1-7	Street drain	Good	24-inch RCP to rock basin
48	1-7	Street drain	Good	18-inch RCP to rock basin
49	1-7	Street drain	Good	18-inch RCP to rock basin

Outfall	Receiving Stream	Source	Outfall Condition	Notes
50	1-7	Street drain	Poor	24-inch RCP to unstable channel
51	1d	Street drain	Good	24-inch RCP to rock basin
52	1-7	Street drain	Good	18-inch RCP to rock basin
53	1-7	Street drain	Good	12-inch RCP to rock basin
54	1-7	Street drain	Good	18-inch RCP to rock basin
55	1-7	Wetland	Good	12-inch RCP to rock basin
56	1-7	Street drain	Poor	12-inch RCP to rock basin, breached
57	Crabtree Cr	Street drain	Good	18-inch RCP to stable ditch
58	Crabtree Cr	Street drain	Good	18-inch RCP to stable ditch
59	2-5	Street drain	Good	18-inch RCP to rock basin
60	2-5	Street drain	Good	12-inch RCP to level spreader
61	2-6	Wet Pond	Good	30-inch RCP to rock basin
62	2-6	Street drain	Good	18-inch RCP to rock basin
63	2-7	Street drain	Good	30-inch RCP to rock basin
64	2k	Street drain	Good	24-inch RCP to rock basin
65	2k	Street drain	Good	24-inch RCP to rock basin
66	2i	Street drain	Poor	30-inch RCP to rock basin
67	2g	Street drain	Good	30-inch RCP & 12-inch RCP to rock basin
68	2a	Street drain	Good	12-inch RCP to rock basin
69	3-1	Street drain	Good	12-inch RCP to rock basin
70	3-1	Street drain	Good	12-inch RCP to rock basin
71	3-1	Street drain	Good	12-inch RCP to rock basin
72	3-1	Street drain	Good	Rock swale to sed trap
73	3-1	Sediment Basin	Poor	6-inch PVC to floodplain, dam failing
74	3-2	Street drain	Good	18-inch RCP to grass swale
75	3-3	Wet Pond	Good	24-inch RCP (2) to stream, in buffer
76	2e	Street drain	Good	24-inch RCP to rock basin
77	2c	Street drain	Good	24-inch RCP to rock basin
78	2d	Dry pond	Good	24-inch RCP to rock basin
79	2j	Street drain	Good	24-inch RCP to rock basin

Outfall	Receiving Stream	Source	Outfall Condition	Notes
80	3-3	Street drain	Poor	24-inch RCP to stream, in buffer, clogged
81	2-8	Street drain	Poor	24-inch RCP to stream, in buffer, clogged
82	2h	Street drain	Good	15-inch RCP to roadside depression
83	2-3	Street drain	Good	18-inch RCP to ditch along railroad
84	1-4	Dry pond & street drain	Good	42-inch RCP to wetland in ROW
85	1-4	Dry pond	Poor	42-inch RCP to rock basin, channel eroding
86	2b	Dry pond & street drain	Poor	24-inch RCP to rock basin, broken
87	1-6 (Cary)	Street drain	Good	30-inch RCP to rock basin
88	1-7	Street drain	Good	15-inch RCP to undefined channel
89	2-5	Street drain	Good	30-inch RCP to rock basin
90	1-6	Dry Pond	Good	18-inch RCP to rock basin



Condition
- Good
- Poor
- Town Owned Outfalls
- Stable Streams
- Moderately Stable Streams
- Unstable Streams
- Ephemeral Streams
- Unassessed Streams
- Pipes and Culverts
- Ponds
- Streets
- Railroad
- Sewer Lines
- 50-foot Riparian Buffer
- Neuse PII Study Area and Subbasin Boundary
- Property Boundaries
- Morrisville Town Limits
- Atlas Pages

Stantec

Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4. Assessment Overview Map

1,000 500 0 1,000 Feet

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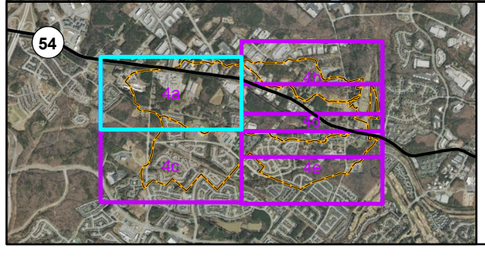

Stable Streams
Moderately Stable Streams
Unstable Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts

Condition
Good
Poor
Town Owned Outfalls
Streets
Railroad

Sewer Lines
Ponds
50-foot Riparian Buffer
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits

Stantec

Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4a. Detailed Assessment Map

400 200 0 400 Feet

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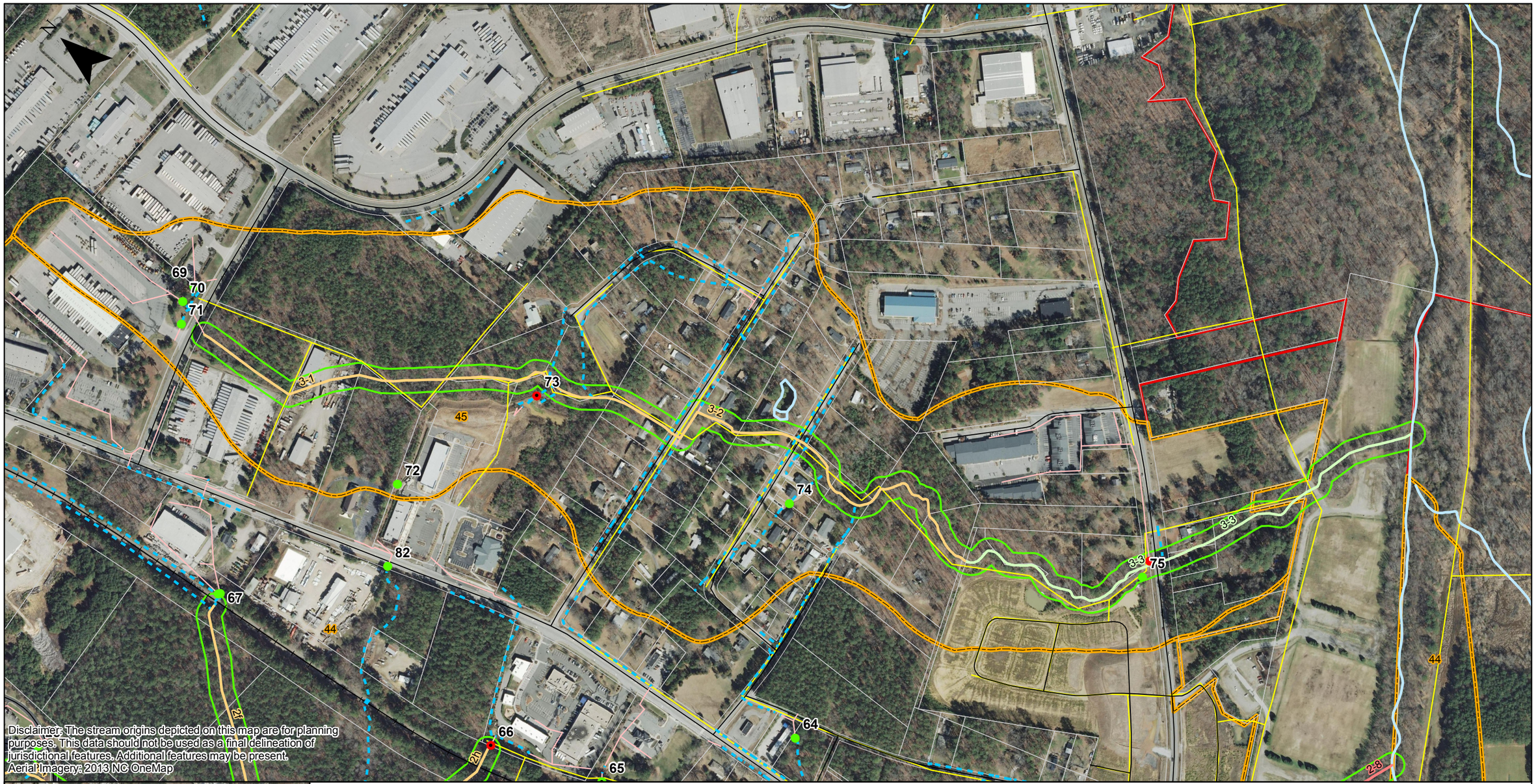

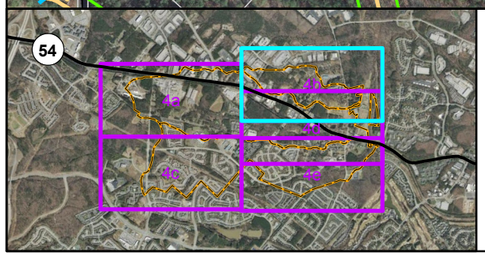

Stable Streams
Moderately Stable Streams
Unstable Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts

Condition
Good
Poor
Town Owned Outfalls
Streets
Railroad

Sewer Lines
Ponds
50-foot Riparian Buffer
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits

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Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4b. Detailed Assessment Map

410 205 0 410 Feet

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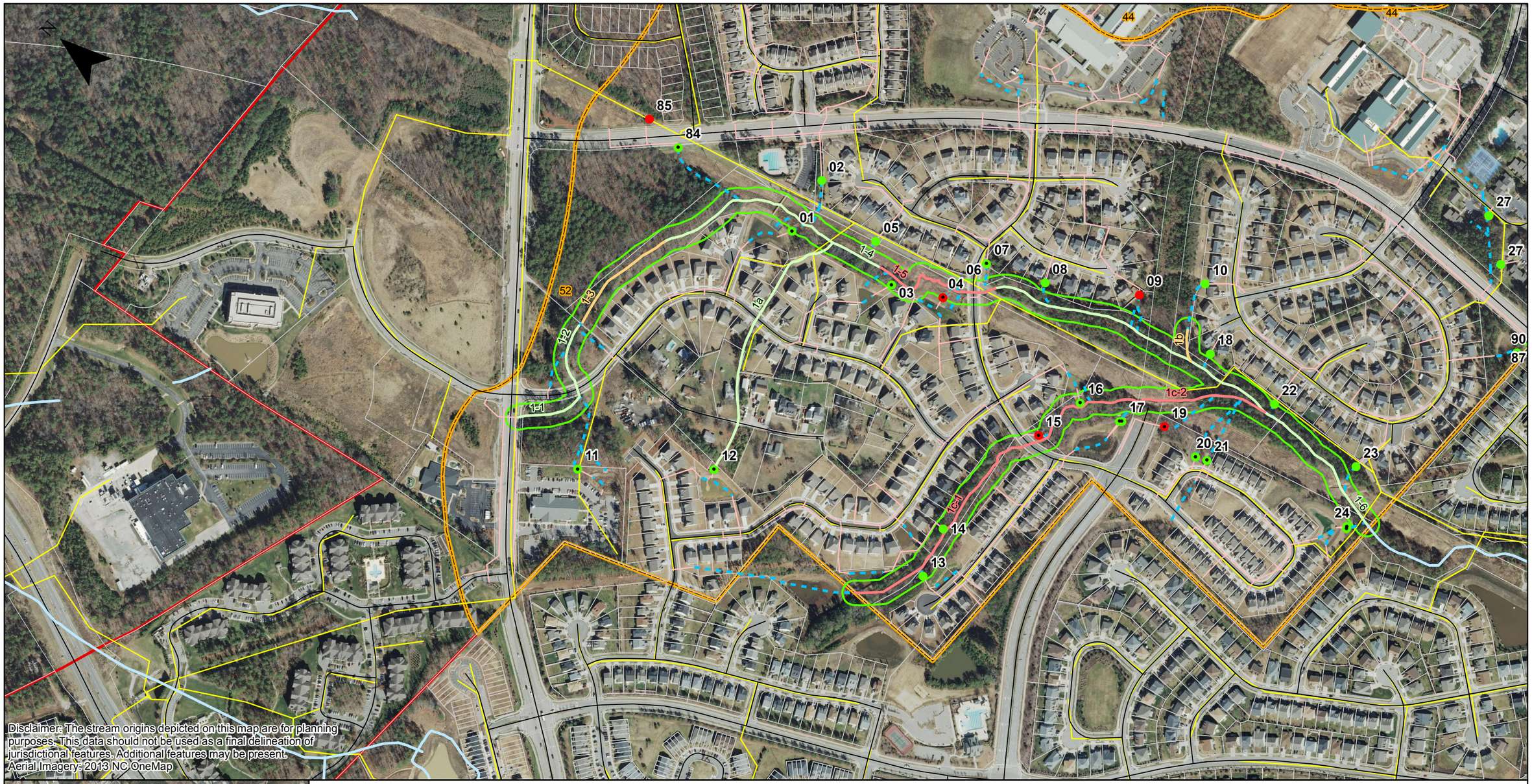

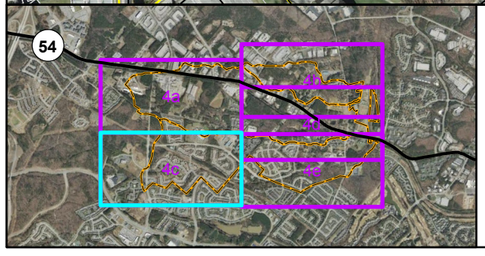

Stable Streams
Moderately Stable Streams
Unstable Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts

Condition
Good
Poor
Town Owned Outfalls
Streets
Railroad

Sewer Lines
Ponds
50-foot Riparian Buffer
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits

TOWN OF MORRISVILLE
EST. NORTH CAROLINA

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Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4c. Detailed Assessment Map

410 205 0 410 Feet

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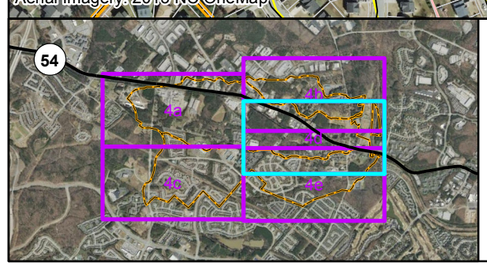
Disclaimer: The stream origins depicted on this map are for planning purposes. This data should not be used as a final delineation of jurisdictional features. Additional features may be present.
Aerial Imagery: 2013 NC OneMap



Stable Streams
Moderately Stable Streams
Unstable Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts

Condition
Good
Poor
Town Owned Outfalls
Streets
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Sewer Lines
Ponds
50-foot Riparian Buffer
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits

TOWN OF MORRISVILLE
NORTH CAROLINA

Stantec

Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4d. Detailed Assessment Map

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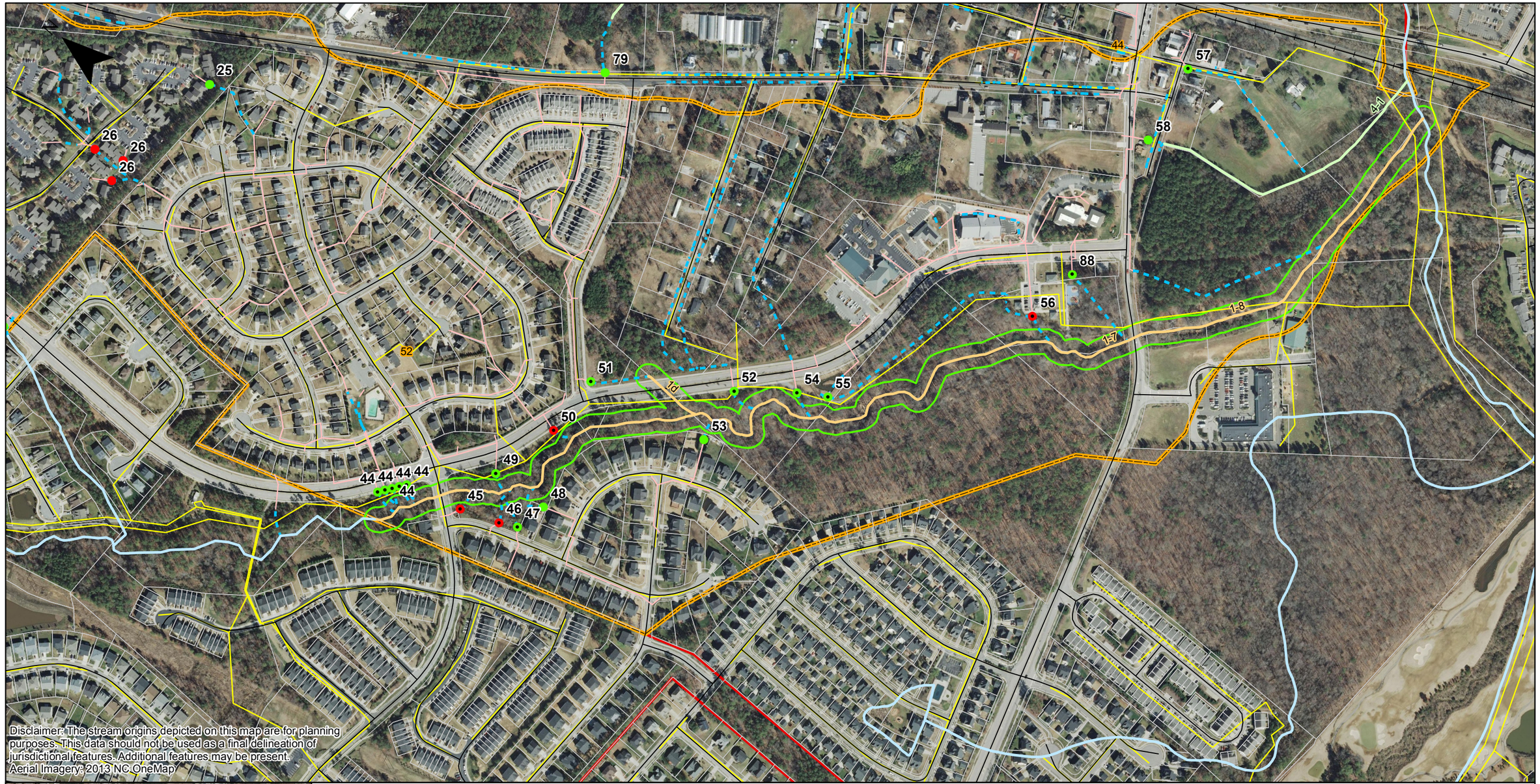


Stable Streams
Moderately Stable Streams
Unstable Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts

Condition
Good
Poor
Town Owned Outfalls
Streets
Railroad

Sewer Lines
Ponds
50-foot Riparian Buffer
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits

Stantec

Neuse Phase 2 Watershed Assessment

Morrisville, North Carolina

Figure 4e. Detailed Assessment Map

400 200 0 400 Feet

3.0 RESTORATION AND RETROFIT OPPORTUNITIES

During the field assessment, opportunities for restoring or enhancing streams, stream buffer, and stormwater outfalls were observed. In addition, opportunities to improve stormwater treatment with retrofits were investigated. A summary of all restoration/enhancement/retrofit opportunities is presented in Table 4 below. The opportunities are described in more detail, including general costs and feasibility, in Section 3.1, 3.2, 3.3, and 3.4. The location of restoration opportunities is included in Figure 5.

3.1 STREAM OPPORTUNITIES

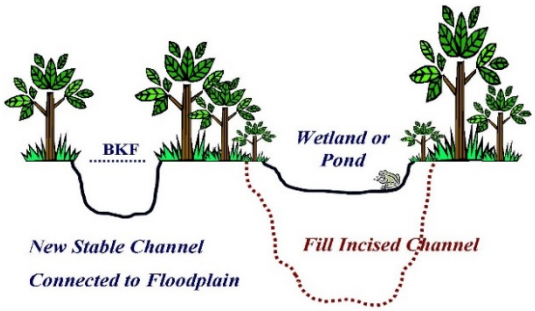
The goal of stream restoration and enhancement is to produce a healthy, sustainable stream system that can maintain stable conditions during the range of hydraulic forces produced by its watershed. Recommendations for stream restoration and enhancement for the study area are based on natural channel design principles, taking into account constraints presented by the existing stream and surrounding land uses. The general approach to restoration and enhancement is to create stable channel morphology (dimension, pattern, and profile) with wide floodplain access during flood (bankfull) flows.

The most critical aspect of stabilizing incised stream channels is to reestablish floodplain access for high flow events. Floodplains function to dissipate energy during high flows by allowing water to spread out and decrease velocity. The result is reduced shear stress in the active channel, resulting in reduced bed scour and streambank erosion. Rosgen (1997) described multiple restoration options (priorities) for addressing incised streams as described below and range from Priority 1 to 4. Priority 1 and 2 Stream Restoration involves restoring dimension, pattern and profile to appropriate and stable conditions. Priorities 3 and 4 are generally regarded as Stream Enhancement where dimension, pattern, or profile are unable to be restored. Enhancement is generally undertaken where site constraints limit the use of full restoration or only minimal work is needed to stabilize the stream and can include activities such as creating a floodplain bench, bioengineering practices, or placement of stream structures. Priority 1 Stream Restoration is proposed for restoration opportunities onsite. All sites have constraints that should be further assessed, including but not limited to: 1) access, 2) property ownership, 3) impacts to existing trees, and 4) potential flooding inundation. Depending on site constraints, Priority 2 Stream Restoration may be used in place of Priority 1. Both Priority 1 and 2 are described in greater detail below. The proposed projects may be considered for mitigation credits.

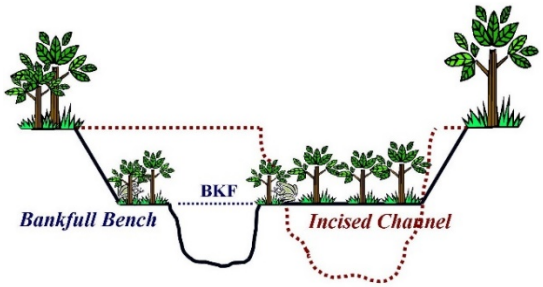
Priority 1 projects replace incised channels with new stable stream channels at a higher elevation, with full access to a wide floodplain at bankfull flows. This is accomplished by excavating a new channel with the appropriate dimension, pattern, and profile based on reference reach data to fit the watershed and valley type. The new channel is typically a meandering stream with bankfull stage located at the ground surface of the original floodplain. Surrounding land uses can limit the use of a Priority 1 approach if there are concerns about increased flooding or widening the stream corridor. Priority 1 projects typically result in higher

flood stages above bankfull discharge in the vicinity of the project and downstream. This approach also requires sufficient land area on one or both sides of the existing incised stream to construct the new meandering channel on the floodplain. For many incised streams, this is the recommended approach to restore optimal stream stability and health.

Priority 1



Priority 2



Priority 2 projects create new stable stream channels and floodplains at or near the existing channel elevation. This is accomplished by excavating a new floodplain and stream channel that can convey the expected range of flows while maintaining stream stability and health. The new channel is typically a meandering stream with bankfull stage located at the elevation of the newly excavated floodplain. A Priority 2 project can produce a long-term stable stream system if designed and constructed properly. Priority 2 projects can be constructed in dry conditions while streamflow continues in its original channel or is diverted (or pumped) around the construction site. A major advantage of the Priority 2 approach is that flooding does not increase and may in some cases decrease as the floodplain is excavated at a lower elevation. Surrounding land uses can limit the use of this approach if there are concerns about widening the stream corridor. This approach is an alternative to Priority 1 when constraints such as potential flooding inundation exist.

Costs for stream restoration opportunities are based on estimates from the North Carolina Ecosystem Enhancement Program of $374 per linear foot of restoration (NCEEP 2014). However, there are several factors affecting cost and the projects may be able to be completed more economically. For example, if projects are not completed for mitigation credit or are conducted using a design-build approach, they may be completed for a lower cost. Also, the length is equal to the length of reach within the Town's jurisdiction but restoration may only be necessary on portions of the reach depending on the location of headcuts and/or other unstable features. Costs provided in this report are planning level estimates and may change based on more detailed information during final design. Additionally, these estimated costs do not incorporate maintenance costs.

All of the unstable reaches were identified as having restoration opportunities. They all had headcuts migrating up valley. The reaches all scored the same with poor habitats, high bank erosion, and unstable banks. They are located in wide, unconfined valleys with sand or sand and gravel substrates. In addition, 2h, a moderately unstable reach is a potential restoration

opportunity. It also has a headcut migrating up valley. It received scores of fair habitat, moderate bank erosion, and moderately unstable banks. It is also located in a wide, unconfined valley.

Table 4 Stream restoration opportunities in the Neuse Phase II Watershed

Reach	Length	Width	Depth	Cost	Constraints/Property Ownership
1-5	572	3-5	2-4	$214,000	Power ROW, greenway 2 owners – HOA & Town
1c-1	1053	2-4	3-5	$394,000	Narrow area ~100' wide 1 owner – HOA
1c-2	1021	2-4	3-5	$382,000	Power ROW 2 owners – HOA & Town
2-2	820	3-6	2-5	$306,700	Sewer ROW 2 owners
2-6	2368	8-12	2-4	$885,600	Sewer ROW Town & 5 other owners,
2-8	1003	10-15	4-6	$375,100	Playing fields & parking areas near stream, loss of trees Wake County & 5 other owners
2d	1744	1-2	0.5-1	$652,300	Sewer ROW, railroad crossing 75% owned by Town, 25% private owner
2h	659	3-5	2-4	$246,500	Railroad crossing, loss of trees 2 owners

Photo 11 Reach 1-5

Photo 12 Reach 1c-1

Photo 13 Reach 1c-2

Photo 14 Reach 2-2

Photo 15 Reach 2-6

Photo 16 Reach 2-8

Photo 17 Reach 2d

Photo 18 Reach 2h

3.2 BUFFER OPPORTUNITIES

During the stream walk, wooded riparian buffers were found in varying ages throughout the study area. Many buffers had trees between five and twenty years old. However, older trees were found scattered throughout. The undeveloped and forested area in the lower portion of Subbasin 52 had more mature trees. Many large areas with herbaceous vegetation and lacking overstory were observed; however, these cannot be reforested as almost all are utility ROWs. Smaller areas with herbaceous vegetation include residential yards. These areas have potential for small scale reforestation. Homeowners could be encouraged to plant trees or shrubs along the banks. A no cost solution is to stop mowing along the banks and allow the herbaceous vegetation to grow. Over time, woody volunteer species will begin to appear. It is important to specify to residents that woody vegetation should not be planted in sewer ROWs found on their properties.

On the handful of reaches with riparian buffers less than 50-feet wide due to the construction of impervious surfaces, there are no feasible opportunities to expand the buffer.

Privet is a dominant species in the understory of many of the reaches in Subbasin 44. The Town undertook a privet removal project in 2014 in the riparian buffer near Outfall 66. However, privet shoots are returning throughout the area. It will take multiple years of removal to eradicate privet from this area. As stream restoration and retrofit projects are undertaken, care should be taken to treat the areas for privet and other invasive species before and after construction. This will help the success of native vegetation that would likely be planted as part of the restoration and retrofit projects.

In addition, as development continues, invasive species may continue to spread, especially when used for sediment and erosion control. The Town should promote or require the use of native grasses and herbaceous vegetation for sediment and erosion control of construction sites and utility ROWs. Chapter 6.11 of The North Carolina Erosion and Sediment Control Planning and Design Manual includes a list of native herbaceous species for primary stabilization (Appendix A). In addition, the NCSU Stream Restoration Program has a created a list native plant species for riparian buffers restoration. The list for the Piedmont Region is also included in Appendix A.

3.3 OUTFALL STABILIZATION OPPORTUNITIES

During the stream walks, 90 stormwater outfalls were assessed for stability and potential impacts to stream health. These outfalls included pipes and channels carrying stormwater discharge from street drainage and best management practices (BMPs). BMP types include dry ponds, wet ponds, sediment basins, and constructed wetlands. In general, most outfalls were in stable condition, with no evidence of erosion or headcutting between the outfall and the natural stream. Problems observed at 11 of the outfalls included pipes clogged with sediment, insufficient rock to dissipate energy and prevent scour, headcutting in downstream channels, and undermining of pipes. Outfalls 4, 15, 46, and 66 can be stabilized with appropriate rock treatments to improve water quality and stream health while maintaining infrastructure integrity

in the drainage network. Outfalls 37, 45, 80, and 81 need to be cleaned out to allow for improved flow. Outfall 85 is stable however the channel immediately downstream is eroding and the geotextile fabric is exposed. This area needs to be stabilized with additional rock. Outfall 86 has a broken pipe, however

401/404 permitting for the treatments would likely not be required, as the outfall itself is not jurisdictional. However, due to proximity of jurisdictional streams and their associated Neuse Buffer Rules it is possible that construction-related clearing within the buffer or necessary outfall protection (rip-rap) may require coordination and/or minor permitting with the US Army Corps of Engineers and NC Division of Water Resources.

Table 5 Outfall recommendations in the Neuse Phase II Watershed

Outfall	Receiving Stream	Issue	Recommendation	Estimated Cost
4	1-5	Erosion downstream of pipe	Rock armoring	$4,000
15	1c-2	Erosion downstream of pipe	Rock armoring	$4,000
37	2d	Sedimentation in pipe and channel	Unclog	$4,000
45	1-7	Sedimentation in pipe and channel	Unclog	$4,000
46	1-7	Erosion downstream of pipe	Rock armoring	$4,000
66	2h	Erosion downstream of pipe	Rock armoring	$4,000
80	3-3	Sedimentation in pipe and channel	Unclog	$4,000
81	2-8	Sedimentation in pipe and channel	Unclog	$4,000
85	1-3	Erosion downstream of pipe	Stabilize downstream channel	$4,000
86	2b	Pipe broken, falling into channel	Replace broken pipe	*

* outfall owned by NCDOT, repair may impact roadway therefore estimate to repair is not included

Photo 19 Outfall 4

Photo 20 Outfall 15

Photo 21 Outfall 37 - buried

Photo 22 Outfall 46

Photo 23 Outfall 80

Photo 24 Outfall 81

Photo 25 Outfall 85 – downstream of outfall

Photo 26 Outfall 86 – broken pipe under Church Street (NCDOT owned)

3.4 STORMWATER RETROFIT OPPORTUNITIES

In addition to investigating the condition of the streams and outfalls in the study area, the project also included a search for stormwater BMP retrofit opportunities. The search focused on two types of retrofit opportunities (end of pipe and source) that are distinguished by location in the watershed (Figure 5). End of pipe types are located at outfalls of a catchment area or collection systems while source types intercept stormwater before entering a collection system. The following graphic illustrates an example of the two types – the end of pipe retrofit could be located downstream of Outfall 2 before the confluence with Reach 1-4. The source type retrofit could be located in the two wooded areas between the rows of houses. In general, both locations have advantages and disadvantages depending on the site and the drainage area as discussed below.

Figure 5 Source and End of Pipe Retrofit Example

Installing a BMP retrofit just downstream of the outfall, at the end of pipe, takes advantage of the existing stormwater collection system. All of the stormwater is concentrated in one area and the retrofit doesn't need to involve rerouting of surface flow. The BMP can be designed to treat the whole drainage area as long as space allows. However, in many areas elsewhere in the

study area the outfall discharge occurs directly into an intermittent or perennial stream. Generally, it is difficult to obtain a jurisdictional waters permit for a stormwater BMP within an intermittent or perennial stream. Other constraints include the presence of regulated riparian buffers within the proposed retrofit area which limits the options for proposed improvements.

Source retrofits may work better or be more beneficial in these areas with multiple constraints at the downstream end of the system. These retrofits are placed higher in the watershed before the stormwater enters the collection system. Source retrofits can be designed for individual buildings or lots and are usually smaller in size. However, in areas that are already developed, source retrofits can be challenging. Stormwater may need to be rerouted to get to the desired BMP location. This could be as easy as cutting curb and gutter or as challenging as regrading a site. Space is often an issue in these types of projects. Providing adequate space may rely on the costly removal of large areas of pavement or the removal of the only open space on the lot which may be wooded. Lack of space and inability to easily reroute stormwater are the main constraints found within the study area for source type retrofits.

In Subbasin 52, whole neighborhoods are piped and there is very little opportunity for source treatment as the land use is currently high density residential with large houses on small lots. Most of the piped systems have quantity control in the form of a dry pond prior to discharge. Five end of pipe treatment areas were identified in the Subbasin: Outfall 9, 19-21, 26, 50 and 56/88.

Outfall 9 discharges into a wooded buffer, however a level spreader or other energy dissipater is not present. The flow is leading to erosion and the formation of channels in the buffer. Eventually, trees will be lost as the channel continues to incise. Stormwater in the incised channel bypasses any treatment that the buffer would provide. A level spreader should be installed to promote diffuse flow and the discharge channel should be filled or stabilized to prevent further erosion.

Outfalls 19, 20, and 21 are located along the southern edge of a large power line ROW. The pipes discharge into a small wooded area before entering into the ROW. The discharge from all three pipes could be treated in a stormwater wetland. If the wetland is located outside of the ROW, some trees will be lost. Upon coordination with the utility company, the stormwater wetland could be built in the power line ROW and the project could be coupled with stream restoration of Reach 1c-2. Only low growing shrubs and herbaceous vegetation should be used at the proposed site due to the presence of overhead power lines.

Outfall 26 is a set of three outfalls that carry runoff from parking lots and buildings in the Treybrooke Gardens apartment complex. The stormwater is briefly above ground before entering another collection system at the edge of the property. Space is limited at the site so the retrofit must be able to be near housing and should not pond water as there are rows of houses within 50 feet downstream of the treatment area. Due to these limitations, an infiltration device such as a bioretention cell may be the most suitable.

Concentrated stormwater flow at Outfall 50 has led to downstream channel erosion and an active headcut is moving upstream towards the unstable outfall. Since this channel is not a jurisdictional stream, it would be a suitable location to install a step-pool conveyance system

that would dissipate the energy of flow events, treat stormwater through filtration and prevent further erosion of the discharge channel.

Outfalls 56 and 88 both carry stormwater from institutional properties including Town offices and discharge at the parking lot of the Indian Creek Greenway and Trailhead Park. While there appears to be ample room to construct a stormwater wetland, a sewer ROW and existing wetlands are present. An additional outfall could be added to the pipe in the trailhead parking lot in order to route stormwater to an additional treatment area found along Town Hall Drive.

Much of Subbasin 44 is still undeveloped although it has been altered and impacted in the past due to historic agricultural and silvicultural activities. The Waterford Place apartments in the middle of the watershed are located on both banks of Stream 2. While the stream buffer was left intact, there are a number of outfalls on both banks with undersized level spreaders. A level spreader works to dissipate stormwater energy and diffuse stormwater flows in the buffers. If sized and installed according to guidelines, the level spreader should prevent the formation of ditches or concentrated flow paths from the outfall to the receiving water. Outfalls 29, 31, 32, 33, 36 and 38 all have level spreaders in place that are ineffective. Most of them are not sized correctly or erosion is occurring around the structure. On at least one (Outfall 38), a headcut is forming at the base of the level spreader. A level spreader should be installed at Outfall 30 as it currently does not have any energy dissipation.

Outfalls 34 and 35 are near each other on the edge of a parking lot in the Waterford Place apartment complex. These two outfalls have fewer constraints than the others in the complex as the sewer ROW is on the opposite side of the stream. Both pipes discharge to a large grassy area that is an ideal location for a stormwater wetland.

Reach 2d, Outfalls 39 and 76 are located to the east of the Waterford Place apartment complex. Both outfalls discharge directly into the stream. It is possible to remove parking near outfall 39 in order to install a stormwater wetland. There is no space to install a BMP at Outfall 76 since it is located next to the railroad ROW. A combination project could include restoration of Reach 2d coupled with stormwater treatment of both outfalls. This would require diverting non baseflow from the stream into offline stormwater wetlands. This may be an option to compensate for the lack of available space at both the source and outfall locations which usually preclude implementation of traditional stormwater treatment practices.

Further upstream in Subbasin 44, the outfall channels are ephemeral making them ideal locations for stormwater treatment. This is the case with Outfalls 43 and 77. Outfall 43 is located near the main stream channel (Reach 2-2) but far enough away to provide stormwater treatment without impacting the riparian buffer. Treatment for stormwater from Outfall 77 needs to be installed downstream of the outfall as there is limited space available between Chapel Hill Road and the railroad.

Outfalls 61 and 62 discharge to a Town-owned parcel. They were assessed in a previous study (338 Page Street Feasibility Study 2014) to determine feasibility of constructing a stormwater wetland at Outfall 62. The Page Street study looked at that option, an option of treating

stormwater from both outfalls simultaneously. A third option included stormwater treatment and stream restoration of Reach 2-6. Restoring Reach 2-6 while diverting stormwater to offline stormwater wetlands could improve water quality in the majority of Subbasin 44.

A final project in Subbasin 44 is a stormwater wetland retrofit at Outfall 64. A vacant lot next to the outfall could provide space to treat existing and future development in that portion of the subbasin.

Subbasin 45 is much smaller than the other two and land use is mainly low density residential development. It has numerous roadside swales that encourage infiltration of stormwater runoff from the surrounding houses. Higher density development is limited in this subbasin and much of it is currently under construction. This includes a shopping center that drains to Outfalls 72 and 73. Both outfalls need to be repaired and can be improved to include water quality treatment. However, the shopping center is still under construction so any work on these outfalls should wait until the development is complete.

Table 6 Retrofit opportunities in the Neuse Phase II Watershed

OUTFALL	Reach	Type	Drainage Area (ac) and Land Use*	Treatment Area (ft²)	Distance to Stream	Property Ownership	Constraints/Notes
9	1-6	level spreader	6.02 HDR	NA	138	Town Hall Commons Property Owners Association	need to stabilize/remove discharge channel that has formed in buffer
19	1c-2	stormwater wetland	1.21 HDR	1055	107	Terraces at Town Hall Commons (& Town parcel for BMP)	if BMP on private property will avoid working in powerline ROW however would result in tree loss
20	1c-2	stormwater wetland	2.67 HDR	2323	300	Terraces at Town Hall Commons (& Town parcel for BMP)	Same as 19
21	1c-1	stormwater wetland	8.17 HDR	7118	285	Terraces at Town Hall Commons (& Town parcel for BMP)	Same as 19
26	1-7	infiltration	6.01 HDR	13089	NA	Treybrooke Gardens	limited space, use infiltration in place of wetland as there are houses downstream
28	2-4	stormwater wetland	3.39 HDR	2950	105	Waterford Place	BMP would be located on Town-owned property
29	2-4	level spreader	0.37 HDR	323	67	Waterford Place (& Town parcel for BMP)	sewer ROW, BMP would be located on Town-owned property
30	2-4	level spreader	1.57 HDR	1365	78	Waterford Place	sewer ROW
31	2-4	level spreader	0.36 HDR	310	71	Waterford Place (& Town parcel for BMP)	sewer ROW, BMP would be located on Town-owned property
32	2-4	level spreader	0.16 HDR	142	110	Waterford Place	sewer ROW
33	2-4	level spreader	0.18 HDR	153	81	Waterford Place	sewer ROW

OUTFALL	Reach	Type	Drainage Area (ac) and Land Use*	Treatment Area (ft²)	Distance to Stream	Property Ownership	Constraints/Notes
34	2-4	stormwater wetland	0.70 HDR	609	81	Waterford Place (& Town parcel for BMP)	BMP would be located on Town-owned property
35	2-4	stormwater wetland	3.19 HDR	2779	57	Waterford Place (& Town parcel for BMP)	sewer ROW, BMP would be located on Town-owned property
36	2-4	level spreader	0.46 HDR	404	92	Waterford Place	
38	2e	level spreader	0.48 HDR	414	58	Waterford Place	
39	2e	stormwater wetland	4.11 IND	4472	40	PBS Real Estate LLC (& Town parcel for BMP)	would need to remove some parking lot to have enough treatment area & avoid buffer impacts
40	2f	level spreader	3.02 HDR	2627	20	Waterford Place	remove pipe to get outfall out of buffer, install level spreader
43	2-2	stormwater wetland	18.24 IND	15891	97	RBW Realty LLC	can serve as secondary treatment for concrete plant, redirect stormwater in parking lot to capture watershed of OUT42
50	1-7	step-pool conveyance	11.90 HDR	NA	90	DR Horton	
56	1-7	stormwater wetland	15.11 INST	13168	105	Town of Morrisville	potential for jurisdictional wetlands in treatment area, additional treatment area north of parking lot
61	2-6	stormwater wetland	4.57 LDR	3981	22	Nathan B Carson Trustee	see Page Street Feasibility Study
62	2-6	stormwater wetland	2.25 LDR	1960	115	Town of Morrisville	see Page Street Feasibility Study

OUT	Reach	Type	Drainage Area (ac)	Treatment Area (ft^2)	Distance to Stream	Property Ownership	Constraints/Notes
64	2k	stormwater wetland	6.81 COM LDR	5937	700	Julia W Cotton Heirs	potential for jurisdictional wetlands in treatment area
72	3-1	stormwater wetland	0.39 COM	344	415	Calvary Baptist Church of Morrisville; Greenwood Village Condominiums; BDG Highway 54 Associates LLC	concentrated flow is creating a channel on the church parcel. Stormwater should be rerouted around parcel to BMP on east side of development
73	3-1	stormwater wetland	1.22 COM	1062	90	New Life Church of Cary INC.	existing pond in need of repairs/retrofit when development is complete. Consider routing stormwater from 72 to the pond
76	2e	stormwater wetland	5.40 IND	4704	NA	Town of Morrisville	only if group with restoration of Reach 2d
77	2c	stormwater wetland	7.68 COM	6692	NA	RBW realty LLC.	BMP would be located downstream of railroad, large treatment area available to treat very small watershed
88	1-7	stormwater wetland	1.15 INST	999	335	Town	potential for jurisdictional wetlands in treatment area

* Land use classifications for drainage area are: COM – commercial; IND – industrial; INST – institutional; HDR – high density residential; LDR – low density residential

Photo 27. Outfall 9

Photo 28. Outfall 9 discharge channel

Photo 29. Outfall 19

Photo 30. Outfall 20

Photo 31. Outfall 21

Photo 32. Outfall 26

Photo 33. Outfall 28 in background, BMP would be in foreground

Photo 34. Outfall 29

Photo 35. Outfall 30

Photo 36. Outfall 31

Photo 37. Outfall 32

Photo 38. Outfall 33

Photo 39. Outfall 34

Photo 40. Outfall 35

Photo 41. Outfall 36

Photo 42. Outfall 38

Photo 43. Outfall 39

Photo 44. Outfall 40

Photo 45. Outfall 43

Photo 46. Outfall 50

Photo 47. Outfall 56

Photo 48. Outfall 62

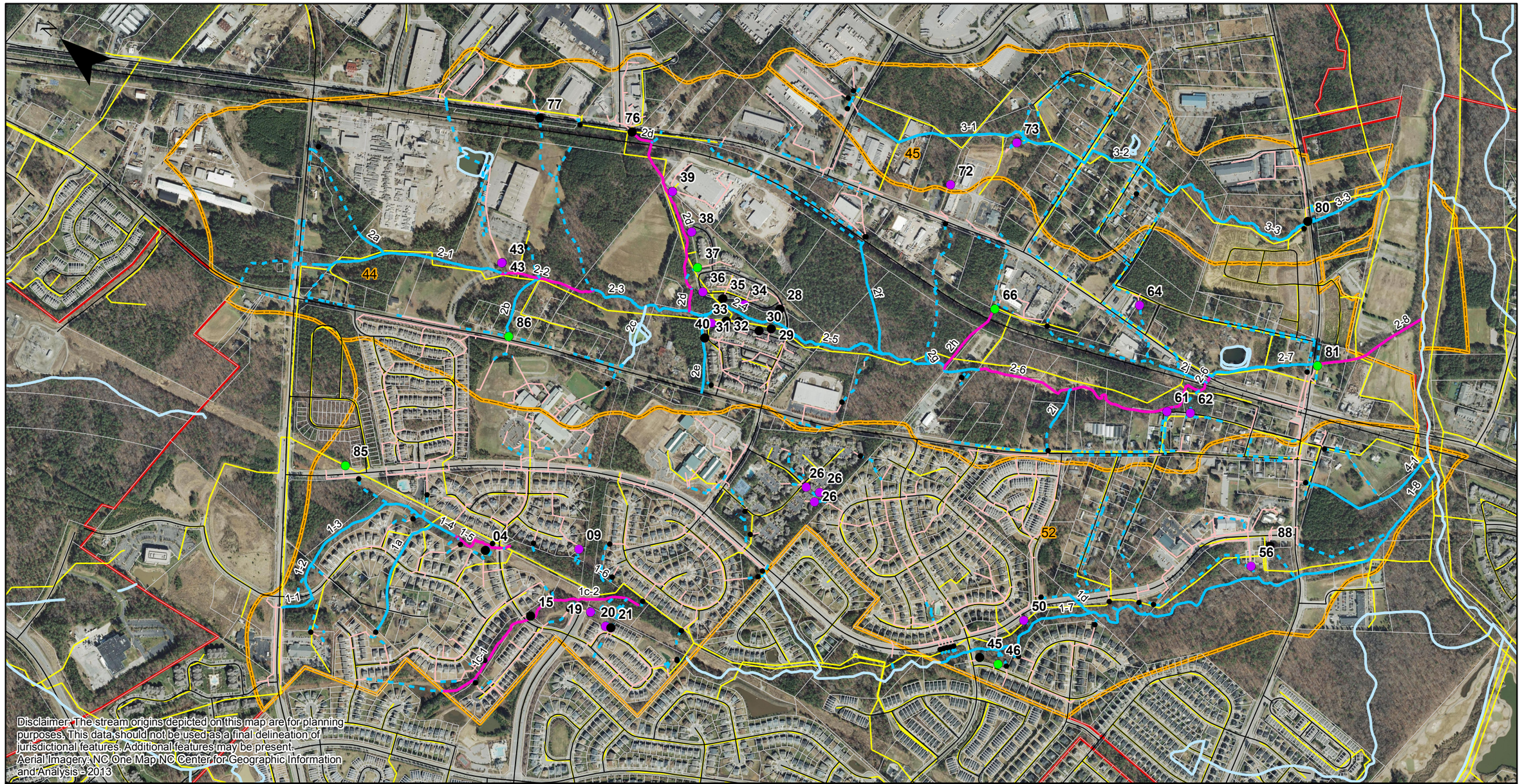
Photo 49. Downstream of Outfall 64

Photo 50. Outfall 72

Photo 51. Outfall 73

Photo 52. Outfall 76

Photo 53. Outfall 88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Disclaimer: The stream origins depicted on this map are for planning purposes. This data should not be used as a final delineation of jurisdictional features. Additional features may be present.
Aerial Imagery: NC One Map NC Center for Geographic Information and Analysis - 2013
Retrofit Opportunity
Outfall Stabilization Opportunity
Other Outfalls
Stream Opportunity
Intermittent and Perennial Streams
Ephemeral Streams
Unassessed Streams
Pipes and Culverts
Ponds
Streets
Railroad
Sewer Lines
Neuse PII Study Area and Subbasin Boundary
Property Boundaries
Morrisville Town Limits
TOWN OF MORRISVILLE
NORTH CAROLINA
Stantec
Neuse Phase 2 Watershed Assessment
Morrisville, North Carolina
Figure 6. Restoration Opportunities Map
860 430 0 860 Feet

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4.0 FUTURE PLANNING NEEDS

In addition to the opportunities outlined in this document, several other watershed planning needs exist for the study area. The Town should continue to update and maintain geospatial data for its stormwater inventory. A few unmapped outfalls were found however, most were associated with new development and will likely be added to the inventory once as-built drawings have been submitted to the Town.

Some of the opportunities identified in this report were known to the Town and may fall under the responsibility of private developers. The Town should continue to monitor these locations and ensure the appropriate rules and regulations are followed based on individual permit dates. The Town should prioritize the opportunities contained in this document. High priorities could include outfalls that the Town owns or retrofits that can be built on Town-owned land. Other opportunities identified in undeveloped areas could be used in the future as the area continues to develop.

As noted, industrial land is a component of the land use in the study area. The Town prohibits illicit discharges to the stormwater system and streams and is working to enforce this regulation through dry weather monitoring. Three industry owners have industrial stormwater permits within the study area and one has a certificate of no exposure. Those with permits have stormwater pollution prevention plans that may include monitoring during rain events or other times of the year. While NCDWR regulates these permits, the Town could use the sampling data to better determine where to target funds for BMP improvements and installation.

There are several sources of funding which could be used to implement the opportunities outlined in this report, as well as future watershed initiatives. Sources include:

- Nonpoint Source Section 319 Grant Program (USEPA and NCDWR)
- Clean Water Management Trust Fund (NCDENR)
- State Revolving Fund (USEPA and NCDENR Infrastructure Finance Section)
- Water Resources Development Project Grants (NCDWR)
- Section 206 Aquatic Restoration Grants (USACE)
- Environmental Enhancement Grant Program (NC Attorney General's Office)
- Environmental Education Grants (USEPA)

Funding sources vary by year. NCDENR maintains a list of available financial resources at the state level at: http://www.ncdenr.gov/web/wq/ps/bpu/urw/funding. Additionally, financial resources at the federal level can be viewed at:

https://ofmpub.epa.gov/apex/watershedfunding/f?p=fedfund:1. These resources should be utilized to investigate available funding sources for a given year.

5.0 REFERENCES

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Appendix A

A.1 Example Visual Assessment Form

A.2 NCDWQ Forms

A.3 Native Plant Lists

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A.1 EXAMPLE VISUAL ASSESSMENT FORM

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A.1 Example Visual Assessment Form

Stream Assessment for Potential Restoration

Stream name & location	
Assessed by	Site visit date
Watershed area (square miles)	Available buffer width (ft)
Watershed % forest	Stream length (ft)
Watershed % agriculture	Stream width in riffle/run (ft)
Watershed % urban	Depth from top of bank (ft)
Streambed substrate (sand, gravel, cobble, bedrock)	Stream slope (< 2%, 2-4%, > 4%)

Stream Condition and Function: Score from 0 to 4 indicating natural stream integrity and health (circle contributing factors): *0 = extremely poor; 1 = poor; 2 = fair; 3 = good; 4 = excellent*

	Before	**After**
Morphology (channelized, incised, over-wide, cutting into hillslope, head-cutting)		
Bank stability (eroding bends, high banks, steep banks, lack of roots, high stress)		
Bed sediment (embedded with fines, excessive scour, excessive bars)		
Floodplain (disconnected, filled, drained, levees, aggrading)		
Vegetation (natives removed, invasive plants, poor shade and food sources)		
Habitat (poor bedform, poor cover, uniform flow, lack of food & refuge, poor WQ)		
Discharges (stormwater, wastewater, agricultural runoff, livestock, dumping)		
Constraints (roads, bridges, culverts, sewer lines, utilities, property lines)		
Interventions (armoring, piping, filling, dredging)		
Upstream impacts (stormwater, sediment, wastewater, agriculture, roads)		
Total Score		

Comments:

A.2 NCDWQ FORMS

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A.3 NATIVE PLANT LISTS

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HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c

NATIVE SPECIES

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	NR	NR	Sun	NR	Well drained	No	Responds well to	
	Cave-in-Rock									only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*		A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to	
	Blackwell	N								only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to	
	Shelter									only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	Yes	Yes	No	Responds well to	
	Carthage											controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	No	Poorly	No	Responds well to	
	Kanlow									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	NR	12/1 - 5/1	1/1 - 5/1	Sun	No	Poorly	No	Responds well to	
	Alamo									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well	No	Responds well to	Western coastal plain only
	Rumsey									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well	No	Responds well to	Western coastal plain only
	Osage									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c (con't)

NATIVE SPECIES

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well	No	Responds well to controlled	Western coastal plain only
	Cheyenne									drained		burns. Mix with 3 to 5 other seed	
												varieties that have similar soil	
												drainage adaptations.	
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	NR	12/1 - 5/1	1/1 -5/1	Sun	NR	Well	No	Responds well to	Only Indiangrass adaptable to
	Lomenta									drained		controlled burns. Mix with	Eastern coastal plain (Zone 8)
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Deertongue	*Dichanthelium*	N	C	By soil test	5/1-4/15	5/1 - 4/1	NR	Sun &	Yes	Poorly	No	Responds well to	
	clandestinum / Tioga							Shade		drained to		controlled burns. Mix with	
										drought		3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Big Bluestem	*Andropogon gerardii /*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll	No	Responds well to	Warm season grass
	Rountree									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Big Bluestem	*Andropogon gerardii /*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll	No	Responds well to	Warm season grass
	Kaw									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Big Bluestem	*Andropogon gerardii /*	N	D	By soil test	12/1-4/15	12/1 - 4/1	12/1-5/1	Sun	NR	Welll	No	Responds well to	Warm season grass
	Earl									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Little Bluestem	*Schizachyrium*	N	E	By soil test	12/1-4/15	NR	NR	Sun	NR	Welll	No	Responds well to	Warm season grass
	scoparium / Aldous									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Little Bluestem	*Schizachyrium*	N	E	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll	No	Responds well to	Warm season grass
	scoparium / Cimmaron									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c (con't)

NATIVE SPECIES

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Little Bluestem	*Schizachyrium*	N	E	By soil test	NR	NR	12/1-4/1	Sun	NR	Welll	No	Responds well to	Warm season grass
	scoparium / Common									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Sweet Woodreed	*Cinna arundinacea*	N	F	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun &	Yes	Poorly to	No	Mix with 3 to 5 other seed	Warm season grass
								mod. Shade		well drained		varieties that have similar	
												soil drainage adaptations	
Rice Cutgrass	*Leersia oryzoides*	N	G	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	Yes	Poorly	No	Mix with 3 to 5 other seed	Warm season grass
										drained		varieties that have similar	
												soil drainage adaptations	
Indian Woodoats	*Chasmanthium latifolium*	N	H	By soil test	3/1 - 5/15	2/15 - 4/1	2/15-3/20	Sun &	NR	Well	No	Mix with 3 to 5 other seed	Cool season grass
					7/15-8/15	8/15 - 10/15	9/1 - 11/1	mod. Shade		drained		varieties that have similar	
												soil drainage adaptations	
Virginia Wild Rye	*Elymus virginicus*	N	I	By soil test	3/1 - 5/15	2/15 - 4/1	2/15-3/20	Sun &	NR	Well	No	Mix with 3 to 5 other seed	Cool season grass
					7/15-8/15	8/15 - 10/15	9/1 - 11/1	mod. Shade		drained		varieties that have similar	
												soil drainage adaptations	
Eastern Bottlebrush	*Elymus hystrix*	N	J	By soil test	3/1 - 5/15	2/15 - 4/1	NR	Sun &	NR	Well	No	Mix with 3 to 5 other seed	Cool season grass
Grass					7/15-8/15	8/15 - 10/15		mod. Shade		drained		varieties that have similar	
												soil drainage adaptations	
Soft Rush	*Juncus effusus*	N	K	By soil test	12/1 - 5/15	12/1 - 5/1	12/1-4/15	Sun	Yes	Poorly	No	Mix with 3 to 5 other seed	
					8/15-10/15	9/1 - 11/1				drained		varieties that have similar	
												soil drainage adaptations	
Shallow Sedge	*Carex lurida*	N	L	By soil test	12/1 - 5/15	12/1 - 5/1	12/1-4/15	Sun	Yes	Poorly	No	Mix with 3 to 5 other seed	
					8/15-10/15	9/1 - 11/1				drained		varieties that have similar	
												soil drainage adaptations	
Fox Sedge	*Carex vulpinoidea*	N	L	By soil test	12/1 - 5/15	12/1 - 5/1	12/1-4/15	Sun	Yes	Poorly	No	Mix with 3 to 5 other seed	
					8/15-10/15	9/1 - 11/1				drained		varieties that have similar	
												soil drainage adaptations	

NOTE:

1. Seeding rates are for hulled seed unless otherwise noted.
2. Fertilizer & Limestone - rates to be applied in absense of soils tests. Recommended application rate assumes significantly disturbed site soils with little or no residual value.
3. NR means Species not recommended for this region or application area.
4. Native, warm season grasses require six or more months to germinate under optimum conditions. If they are planted in the summer, then a whole year will have to pass before they germinate.
5. Invasive designation as determined by the N.C. Exotic Pest Pant Council and N.C. Native Plant Society .
6. Sprigging is not recommended for immediate stabilization unless terrain is flat, heavymulch is applied and no other immediate stabilization method is practical.
7. Sodding for immediate stabilization - see primary stabilization charts (other information column) and Section 6.12.
8. Long term stabilization can only be accomplished with an adequate, immediate, and primary stabilization program. To achieve long term protective cover with the species listed in

Table 6.11.d

Seed Mixes for Native Species (lbs/ac)
When Mixed with 3, 4, or 5 Other Native Species
(See Table 6.11.a for nurse crop species to be added to these mixes)

	3 Other (total 4 species)	4 Other (total 5 species)	5 Other (total 6 species)
Switch Grasses (A)	3.5 lbs.	3.0 lbs.	2.5 lbs.
Indian Grasses (B)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Deertongue (C)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Big Bluestem (D)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Little Bluestem (E)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Sweet Woodreed (F)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Rice Cutgrass (G)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Indian Woodoats (H)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Virginia Wild Rye (I)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Eastern Bottlebrush Grass (J)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Soft Rush (K)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Sedges (L)	2.5 lbs.	2.0 lbs.	1.5 lbs.

NOTE:
With the native varieties, the seed mix should be in the range of 15 pounds per acre. Depending on availability of native seeds adaptable to North Carolina, the percentage of a particular variety used may be reduced or increased accordingly. Although diversity is desirable, it is imperative that the primary crop develop and become an effective protective cover. In addition to the native species mix, additional nurse crop species must be included to provide immediate stabilization and an adequate ground cover.

Piedmont Riparian Species

TREES	SMALL TREES/SHRUBS	HERBACEOUS FLOWERING PLANTS	GRAMINOIDS AND FERNS
Acer negundo	*Aesculus pavia*	*Arisaema triphyllum*	*Andropogon gerardii**
box elder	red buckeye	jack-in-the-pulpit	big bluestem
Acer rubrum	*Aesculus sylvatica*	*Asclepias incarnata*	*Arundinaria gigantea*
red maple	painted buckeye	swamp milkweed	river cane
Acer barbatum	*Alnus serrulata*	*Bidens frondosa*	*Athyrium filix-femina* ssp. *asplenioides*
southern sugar maple	tag alder	beggartick	southern lady fern
Betula nigra	*Amelanchier arborea*	*Chelone glabra*	*Carex crinata*
river birch	common serviceberry	turtlehead	fringed sedge
Carya cordiformis	*Amelanchier canadensis*	*Eupatorium fistulosum*	*Carex intumescens*
bitternut hickory	shadbush serviceberry	Joe-pye-weed	bladder sedge
Carya ovata	*Aronia arbutifolia (Photinia pyrifolia)*	*Eupatorium perfoliatum*	*Carex lupulina*
shagbark hickory	red chokeberry	boneset	hop sedge
Celtis laevigata	*Asimina triloba*	*Helenium autumnale*	*Carex lurida*
sugarberry	common pawpaw	common sneezeweed	lurid sedge
Diospyros virginiana	*Callicarpa americana*	*Helenium flexuosum*	*Carex scoparia*
persimmon	beautyberry	purplehead sneezeweed	broom sedge
Fraxinus pennsylvanica	*Calycanthus floridus*	*Helianthus angustifolius*	*Carex stricta*
green ash	sweet-shrub	swamp sunflower	tussock sedge
Halesia caroliniana	*Carpinus caroliniana*	*Impatiens capensis*	*Carex vulpinoidea*
silverbell	ironwood	jewel-weed	fox sedge
Juglans nigra	*Cephalanthus occidentalis*	*Lobelia cardinalis*	*Chasmanthium latifolium*
black walnut	buttonbush	cardinal flower	river oats
Magnolia virginiana	*Cornus alternifolia*	*Lobelia elongata*	*Chasmanthium laxum*
sweetbay	alternate leaf dogwood	longleaf lobelia	slender woodoats

Piedmont Riparian Species

TREES	SMALL TREES/SHRUBS	HERBACEOUS FLOWERING PLANTS	GRAMINOIDS AND FERNS
Nyssa sylvatica	*Cornus amomum*	*Ludwigia alternifolia*	*Cyperus strigosus*
blackgum	silky dogwood	bushy seedbox	umbrella sedge
Platanus occidentalis	*Corylus americana*	*Mimulus ringens*	*Elymus hystrix*
sycamore	hazel-nut	monkeyflower	bottlebrush grass
Populus deltoides	*Fothergilla gardenii*	*Physostegia virginiana*	*Elymus virginicus*
eastern cottonwood	dwarf witch-alder	obedient plant	Virginia wild rye
Prunus serotina	*Hamamelis virginiana*	*Polygonum sagittatum*	*Juncus coriaceus*
black cherry	witch-hazel	tearthumb	leathery rush
Quercus lyrata	*Hibiscus moscheutos*	*Pycnanthemum tenuifolium*	*Juncus tenuis*
overcup oak	marsh mallow	narrowleaf mountainmint	poverty rush
Quercus michauxii	*Ilex decidua*	*Pycnanthemum muticum*	*Juncus effusus*
swamp chestnut oak	deciduous holly	bigleaf mountainmint	soft rush
Quercus nigra	*Ilex verticillata*	*Rhexia mariana*	*Leersia oryzoides*
water oak	winter berry	Maryland meadowbeauty	rice cutgrass
Quercus pagoda	*Itea virginica*	*Rhexia virginica*	*Onoclea sensibilis*
cherrybark oak	Virginia willow	Virginia meadowbeauty	sensitive fern
Quercus phellos	*Lindera benzoin*	*Rudbeckia laciniata*	*Osmunda cinnamomea*
willow oak	spicebush	cutleaf coneflower	cinnamon fern
Quercus shumardii	*Lyonia ligustrina*	*Sparganium americanum*	*Osmunda regalis*
Shumard oak	male-berry	bur-reed	royal fern
Salix nigra	*Lyonia lucida*	*Symphyotrichum novi-belgii*	*Panicum clandestinum (Dichanthelium*
black willow	fetterbush	New York aster	deertongue
	Magnolia tripetala	*Vernonia noveboracensis*	*Panicum rigidulum*
	umbrella tree	ironweed	redtop panicgrass

Piedmont Riparian Species

TREES	SMALL TREES/SHRUBS	HERBACEOUS FLOWERING PLANTS	GRAMINOIDS AND FERNS
	Physocarpus opulifolius ninebark		*Panicum virgatum* switchgrass
	Rhododendron maximum rosebay		*Polystichum acrostichoides* Christmas fern
	Rhododendron periclymenoides wild azalea		*Saccharum giganteum* sugarcane plumegrass
	Rhododendron viscosum swamp azalea		*Schizachyrium scoparium** little bluestem
	Rosa palustris swamp rose		*Scirpus atrovirens* green bulrush
	Salix sericea silky willow		*Scirpus cyperinus* woolgrass
	Salix caroliniana coastal plain willow		*Scirpus validus (Schoenoplectus* soft stem bulrush
	Sambucus nigra ssp. *canadensis* elderberry		*Sorghastrum nutans** indiangrass
	Spiraea tomentosa steeplebush		*Thelypteris palustris* marsh fern
	Staphlea trifolia bladdernut		*Tripsacum dactyloides* eastern gamagrass
	Styrax americanus American snowbell		
	Vaccinium corymbosum highbush blueberry		

Piedmont Riparian Species

TREES	SMALL TREES/SHRUBS	HERBACEOUS FLOWERING PLANTS	GRAMINOIDS AND FERNS
	Viburnum dentatum southern arrowwood		
	Viburnum nudum possumhaw		
	Xanthorhiza simplicissima yellow-root		

*Indicates plants that prefer drier conditions.