

Freshwater Mussel Survey Report

Monroe Connector/Bypass (STIP No R-3329/R-2559)

Mecklenburg and Union Counties, North Carolina

Prepared for:

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July 13, 2009

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1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) proposes construction of the Monroe Connector/Bypass on new location from I-485 near Indian Trail, NC to NC 74 just west of Marshville, NC (Figure 1). Project construction will impact streams within the Rocky River Subbasin of the Greater Pee Dee River Basin, and potentially the headwaters of Four Mile Creek within the Sugar Creek Subbasin of the greater Catawba River Basin. Construction within these watersheds could potentially impact freshwater mussels, in particular, the Federally Endangered Carolina heelsplitter (*Lasmigona decorata*) and the state Endangered /Federal Species of Concern (FSC) Atlantic pigtoe (*Fusconaia masoni*) and Savannah liliput (*Toxolasma pullus*), all of which are known to occur in the Rocky River Subbasin. The non-regulated Atlantic pigtoe and Savannah liliput were targeted in this survey along with the regulated Carolina heelsplitter because the US Fish and Wildlife Service (USFWS) is in the process of putting together “Elevation to Candidate Species Status” packages for these species as they may be listed in the near future. The NCTA has determined it prudent to address these species during this phase of project development in the event that they become federally listed.

In addition to these species, there are several other rare freshwater mussel species that are known to occur in this portion of the Rocky River Subbasin: Carolina creekshell (*Villosa vaughaniana*), eastern creekshell (*V. delumbis*), creeper (*Strophitus undulatus*), and notched rainbow (*Villosa constricta*). Carolina creekshell is also a Federal Species of Concern and is considered Endangered (E) by North Carolina. The creeper is considered Threatened and the notched rainbow and eastern creekshell are considered Special Concern and Significantly Rare by North Carolina.

In order to assess potential project related impacts, The Catena Group (TCG) was retained by PBS&J, the primary environmental consultant for the project, to conduct mussel surveys for the Monroe Connector/Bypass.

2.0 TARGET FEDERALLY PROTECTED SPECIES DESCRIPTION (Carolina heelsplitter)

2.1. Species Characteristics



The Carolina heelsplitter (*Lasmigona decorata*), originally described as *Unio decoratus* by (Lea 1852), synonymized with *Lasmigona subviridis* (Conrad 1835, Johnson 1970), and later separated as a distinct species (Clarke 1985), is a federally Endangered freshwater mussel, historically known from several locations within the Catawba and Pee Dee River systems in North Carolina and the Pee Dee, Savannah, and possibly the Saluda River systems in South Carolina.

The Carolina heelsplitter is characterized as having an ovate, trapezoid-shaped, unsculptured shell. The outer surface of the shell ranges from greenish brown to dark brown in color, with younger specimens often having faint greenish brown or black rays.

The shell's nacre is often pearly white to bluish white, grading to orange in the area of the umbo (Keferl 1991). The hinge teeth are well developed and heavy and the beak sculpture is double looped (Keferl and Shelly 1988). Morphologically, the shell of the Carolina heelsplitter is very similar to the shell of the green floater (Clarke 1985), with the exception of a much larger size and thickness in the Carolina heelsplitter (Keferl and Shelly 1988).

Prior to collections in 1987 and 1990, by Keferl (1991), the Carolina heelsplitter had not been collected in the 20th century and was known only from shell characteristics. Because of its rarity, very little information of this species' biology, life history, and habitat requirements was known. Feeding strategy and reproductive cycle of the Carolina heelsplitter have not been documented, but are likely similar to other native freshwater mussels (USFWS 1996).

The feeding processes of freshwater mussels are specialized for the removal (filtering) of suspended microscopic food particles from the water column (Pennak 1989). Documented food sources for freshwater mussels include detritus, diatoms, phytoplankton, and zooplankton (USFWS 1996).

Freshwater mussels have complex reproductive cycles, which include a larval stage (glochidium) that is an obligatory parasite on a fish. The glochidia develop into juvenile mussels and detach from the "fish host" and sink to the stream bottom where they continue to develop, provided suitable substrate and water conditions are available (USFWS 1996). Many species of naiads require a particular species of fish to serve as the host. The host species(s) for the Carolina heelsplitter is unknown (USFWS 1996). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

2.2.Distribution and Habitat Requirements

Currently the Carolina heelsplitter has a very fragmented, relict distribution. Until recently, it was known to be surviving in only six streams and one small river (USFWS 1996); however, recent discoveries have increased the number of known populations to eleven:

Pee Dee River Basin:

1. Duck Creek/Goose Creek - Mecklenburg/Union counties, NC
2. Flat Creek/Lynches River - Lancaster/Chesterfield/Kershaw counties, SC

Catawba River Basin:

3. Sixmile Creek (Twelvemile Creek Subbasin) - Lancaster County, SC
4. Waxhaw Creek - Union County, NC and Lancaster County, SC
5. Cane Creek/Gills Creek - Lancaster County, SC

6. Fishing Creek Subbasin - Chester County, SC

7. Rocky Creek Subbasin (Bull Run Creek/UT Bull Run Creek/Beaverdam Creek - Chester County, SC

Saluda River Basin:

8. Redbank Creek - Saluda County, SC

9. Halfway Swamp Creek- Greenwood/Saluda County, SC

Savannah River Basin:

10. Little Stevens Creek/Mountain Creek/Sleepy Creek /Turkey Creek (Stevens Creek Subbasin) - Edgefield/McCormick counties, SC.

11. Cuffytown Creek (Stevens Creek Subbasin) - Greenwood/McCormick counties, SC

Habitat for this species has been reported from small to large streams and rivers as well as ponds. These ponds are believed to be millponds on some of the smaller streams within the species' historic range (Keferl 1991). Keferl and Shelly (1988) and Keferl (1991) reported that most individuals have been found along well-shaded streambanks with mud, muddy sand, or muddy gravel substrates, however, numerous individuals in several of the populations have been found in cobble and gravel dominated substrate, usually in close proximity to bedrock outcroppings (Savidge, personal observations). The stability of stream banks appears to be very important to this species (Keferl 1991).

2.3.Threats to Species

The low numbers of individuals and the restricted range of each of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (USFWS 1996). The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modification (impoundments, channelization, etc.) have contributed to the decline of this species throughout its range (USFWS 1996).

Siltation resulting from improper sedimentation control of various land usage practices, including agriculture, forestry, and development activities, has been recognized as a major contributing factor to the degradation of mussel populations (USFWS 1996). Siltation has been documented to be extremely detrimental to mussel populations by degrading substrate and water quality, increasing potential exposure to other pollutants, and by direct smothering of mussels (Ellis 1936, Markings and Bills 1979). Sediment accumulations of less than one inch have been shown to cause high mortality in most mussel species (Ellis 1936).

Sewage treatment effluent has been documented to significantly affect the diversity and abundance of mussel fauna (Goudreau et al. 1988). Goudreau et al. (1988) found that recovery of mussel populations might not occur for up to two miles below points of chlorinated sewage effluent.

The impact of impoundments on freshwater mussels has been well-documented (USFWS 1992a, Neves 1993). Dam construction transforms lotic habitats into lentic habitats, which results in changes within aquatic community composition. Muscle Shoals on the Tennessee River in northern Alabama, once the richest site for naiads (mussels) in the world, is now at the bottom of Wilson Reservoir and covered with 19 feet of muck (USFWS 1992b). Large portions of all of the river basins within the Carolina heelsplitter's range have been impounded; this is believed to be a major factor contributing to the species decline (USFWS 1996).

The introduction of exotic species such as the Asian clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*) has also been shown to pose significant threats to native freshwater mussels. The Asian clam is now established in most of the major river systems in the United States (Fuller and Powell 1973); including those streams still supporting surviving populations of the Carolina heelsplitter (USFWS 1996). Concern has been raised over competitive interactions for space, food, and oxygen with this species and native mussels, possibly at the juvenile stages (Neves and Widlack 1987, Alderman 1995). The zebra mussel is not known from any waterbodies supporting the Carolina heelsplitter (USFWS 1996).

3.0 TARGET FEDERAL SPECIES OF CONCERN DESCRIPTIONS

3.1. Atlantic pigtoe

***Fusconaia masoni* (Atlantic pigtoe)** - The Atlantic pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Its range extends from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia (Johnson 1970). The Atlantic pigtoe occurs in medium size streams to large rivers, but has experienced major declines throughout its entire range. The preferred habitat is a substrate composed of gravel and coarse sand, usually at the base of riffles, however, it can be found in a variety of other substrates and habitat conditions (Dickinson, personal observations). Shells of the Atlantic pigtoe are subrhomboidal in outline, with a parchment, or cloth-like yellow to dark brown periostracum. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin. The dorsal margin is also marked by a short, thick hinge ligament. The Atlantic pigtoe has not been collected in South Carolina for more than 100 years, (Bogan and Alderman 2004). Williams et al. (1993) list this species as endangered.



3.2.Savannah lilliput

***Toxolasma pullus* (Savannah lilliput)** - Described by Conrad in 1838 from the Wateree River in South Carolina, this species ranges from the Altamaha River basin in Georgia north to the Neuse River basin in North Carolina. The Savannah lilliput is a small mussel (35 mm is a large specimen) with an oval or elliptical shell. This species may be found in creeks, rivers, and impounded habitats. It is typically found in sand, silty-sand or mud substrate and appears to prefer near shore, still, shallow water, less than 6 inches in



depth. Shells are usually inflated with a broadly rounded to angular double posterior ridge. Shells are sexually dimorphic. Periostracum is coarse due to numerous closely spaced growth lines and is brownish to greenish with fine rays that are usually not visible. Nacre is bluish white with a pink to purplish iridescence towards the posterior. Williams et al. (1993) consider this species as threatened and it is listed as a Federal Species of Concern.

4.0 MUSSEL SURVEY EFFORTS

4.1.Mussel Survey Methodology

Survey locations were chosen based on mapping and pre-survey investigations as provided by NCTA, accessibility, and appropriate habitat for the target species as determined in the field.

Surveys were conducted by TCG personnel on the following dates; April 28, 2009 (Tim Savidge, Tom Dickinson and Jonathan Hartsell), April 29-30 (Tom Dickinson and Jonathan Hartsell), May 12-14, 2009 (Tim Savidge, Tom Dickinson, Chris Sheats, and Jonathan Hartsell), May 20-21, 2009 (Tim Savidge, Tom Dickinson, and Jonathan Hartsell). The respective stream survey segments are reported by NCTA stream number, and by USGS stream name, and are depicted in their respective figures in Appendix A (Sheet Index; Sheets 1-15).

In each stream segment, a habitat evaluation was first performed by accessing a specific stream or stream system downstream of the corridor and walking the drainage for at least 0.5 person-hour. If, during this evaluation, it was determined by professional judgment that further efforts were warranted, then surveys were conducted for the full survey length or until habitat was no longer deemed suitable. In larger streams with a known mussel fauna and where a full survey effort was determined to be warranted, the survey length was at least 500 meters. Within the surveyed reaches, all habitat types (riffle, run, pool, slack-water, etc.) were sampled by a minimum of a two-person team. The survey team began at the downstream end of the survey reach and proceeded upstream with the team spread across the stream into survey lanes. A combination of visual, bathyscope (glass-bottom view buckets), and tactile methodologies were employed as appropriate. Upstream and downstream survey limits were recorded using a hand-held Garmin 12 or

e-trex Vista GPS unit. Timed searches were employed in each reach to provide a catch per unit effort (CPUE). Searches were also conducted for relict shells. Natural buffer widths were placed into one of the following categories, as required by the collection permit:

<u>Category</u>	<u>Buffer Width</u>
none	no buffer
narrow	1-10 meters
moderate	10-30 meters
wide	> 30 meters

4.2. Mussel Survey Results

Survey site descriptions and results are summarized below in order from west to east within the project alignment (Appendix A: Sheet Index). Unnamed tributaries are noted as "UT" to the named receiving water body. Site numbers (i.e. S003) are in accordance with the enumeration scheme provided on the NCTA mapping.

S003/S004 UTs Four Mile Creek

This stream system was evaluated downstream of the corridor study area in the vicinity of the Tank Town Road crossing (SR 3453) in order to determine if potential habitat was present upstream (Sheet 1). The very small stream was approximately 1 meter wide with little flow and mostly pool habitat. There was a significant amount of scour and erosion. Substrate was dominated by silt, and sand, with some areas of cobble also present. The surrounding area consisted of a narrow to moderate natural buffer, residential areas, road, and utility corridor. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey due to small size and degraded condition.

S005/S006 UTs North Fork Crooked Creek

This stream system was evaluated downstream of the corridor study area in order to determine if potential habitat was present upstream (Sheet 2). The stream was approximately 1 meter wide with intermittent flow, periodically flowing underground. Substrate was dominated by clay, silt, sand, with some areas of gravel. Most of the substrate was covered in iron-oxidizing bacteria. A moderate to wide mature hardwood forest buffered the reach from surrounding residential and commercial areas. A habitat evaluation was performed for 0.67 person-hours during which it was determined that due to its small size, the stream did not contain appropriate habitat to warrant a full survey. Additionally, Stream S005 was also evaluated just upstream from the project impacts, where it was determined to be inappropriate habitat to support mussel fauna.

S014/S015/S016 UTs North Fork Crooked Creek

This stream system, of which S016 is the largest and receiving stream, was evaluated from its confluence with S006 upstream and throughout the project crossing (Sheet 2). The S016 stream channel ranged from 2-3 meters wide with 1-2 meter high stream banks that were generally heavily scoured. In order of dominance, substrate consisted of

unconsolidated sand, gravel, cobble, and silt. Trash and automotive debris were common throughout. There is a narrow to moderately wide natural buffer along most of the reach to surrounding commercial area and road. Surveys were conducted in S016 for 1.5 person-hours during which no mussels were located. Short 0.5 person-hour habitat evaluations in both S014 and S015 determined that they did not contain appropriate habitat due to small size and degradation.

S008 North Fork Crooked Creek

Two separate crossings of North Fork Crooked Creek were surveyed: 1) from the proposed upstream crossing accessed in the vicinity of the Stallings Road crossing (SR 1365) and, 2) from the downstream crossing accessed from the new Fairhaven residential development (Sheet 2).

1) At the upstream crossing, North Fork Crooked Creek was an incised stream channel ranging from 2-4 meters wide with approximately 2 meter high stream banks that were generally unstable. In order of dominance, substrate consisted of unconsolidated sand, gravel, silt, and cobble. A thick layer of algae was noted covering most substrates. A narrow to moderately wide natural buffer was present along most of the reach to surrounding residential area, active crop, and road. Surveys were conducted in North Fork Crooked for a total of 2.3 person-hours during which no mussels were located.

2) At the downstream crossing, North Fork Crooked Creek was a stream channel ranging from 3-6 meters wide with approximately 2 meter high generally unstable stream banks. A few isolated areas of bed rock outcropping provided grade control and stability in short sections of the reach. In order of dominance, substrate in the reach consisted of unconsolidated sand, silt, clay, cobble, gravel, and bedrock. There is a non-existent to moderately wide natural buffer, along with surrounding residential neighborhoods and active pasture. Cattle had access to the reach in several locations. Surveys were conducted through the downstream crossing of North Fork Crooked for a total of 2.16 person-hours during which two eastern elliptio (*Elliptio complanata*) were located (Table 1). Both of the individuals were located in an area where bedrock outcropping provided some stream bed stability.

Table 1. CPUE for Freshwater Mussels: Lower North Fork Crooked Creek S008

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio complanata</i>	eastern elliptio	2	0.44/hr

S009 UT North Fork Crooked Creek

A short 0.5 person-hour habitat evaluation in S009 at its confluence with S008 determined that the small incised clay channel did not contain appropriate habitat for mussels due to small size and degradation (Sheet 2).

S028 UT North Fork Crooked Creek

This stream was surveyed from the Stinson-Hartis Road crossing upstream through the project corridor (Sheet 3). Channel width ranged from 1-3 meters wide, with moderately eroded banks 1-3 meters high. Surrounding landuse consisted of cropland, with a 5-10 meter forested buffer along the stream. One live eastern elliptio was found during 1.0 person-hours of survey time (Table 2).

Table 2. CPUE for Freshwater Mussels: S028 UT North Fork Crooked Creek

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio complanata</i>	eastern elliptio	1	1/hr

S017 UT North Fork Crooked Creek

This small incised stream was approximately 1 meter wide with 1-2 meter high stream banks that were generally unstable (Sheet 2). Substrate was dominated by sand, silt, gravel, with some areas of rocky cobble. There is a narrow natural buffer bordering various urban land uses. A habitat evaluation was performed for 0.67 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey due to small size and degraded conditions.

S034/S036 UTs North Fork Crooked Creek

This stream system was evaluated from a point in S034 approximately 400 meters downstream of the corridor upstream through both channels to the Oakland Avenue crossings (Sheet 3). Channel width ranged from 1-2 meters in S034, and 1 meter in S036. Both channels flow through a forested bottomland section of a rural residential development. The clay streambanks were fairly stable throughout and were less than 0.5 meters high. Substrate consisted of sand, cobble, submerged tree roots and occasional bedrock. No mussels were found in either channel in 1.0 person-hours of survey time. The aquatic snail *Physella* sp. was fairly common throughout.

S037/S038 UTs North Fork Crooked Creek

Within the corridor, S037 flows through an exotic animal farm with no riparian vegetation (Sheet 4). The channel ranges from 1-2 meters wide, with banks less than 1 meter high. The stream was also evaluated downstream of the corridor below Faith Church Road, near the confluence with S038. Substrate in both channels consisted of cobble and clay overlain with large accumulations of silt and sand. The channel beds were mostly dry with only pool habitats retaining water. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey due to small size and degraded conditions.

S039/S041 UTs North Fork Crooked Creek

This stream system was accessed from a new development off Secrest Shortcut Road (SR 1501) and surveyed through the project corridor (Sheet 4). S039, the receiving stream, consisted of a channel ranging from 2-3 meters wide with 1-1.5 meter high clay banks that ranged from stable to showing moderate signs of erosion. In order of dominance, substrate consisted of gravel, sand, and silt. A narrow to moderately wide natural buffer was present along most of the reach to surrounding residential area, active crop, and road. Surveys were conducted in S039 for 2.3 person-hours during which no mussels were located. An aquatic snail, *Physella* sp., was present but uncommon. A short 0.5 person-hour habitat evaluation in S041 at its confluence with S039 determined that the small incised mud channel did not contain appropriate habitat for mussels.

S047 South Fork Crooked Creek

South Fork Crooked Creek was evaluated in two sections; 1) from Unionville-Indian Trail Rd (SR 1367) to Rocky River Road (SR 1007) and 2) from Rocky River Road to Secrest-Short Cut Road, upstream of the corridor (Sheet 5).

1) The stream channel ranged from 4-9 meters wide with approximately 2 meter high clay stream banks. Banks ranged from unstable and scoured to exhibiting some areas of erosion and undercutting. The surveyed reach consisted of mostly long pool and slow moving run habitat with occasional riffles where significant bedrock outcroppings were present. Substrate was dominated by sand, hard-packed clay, gravel, cobble, and silt with occasional slaty bedrock outcropping and boulders. The surrounding area consisted of a moderate to wide forested buffer, a nursery operation, pasture, and residences. The majority of the reach was parallel to a sewer line. A total of 332 *Elliptio* spp., 2 lanceolate *Elliptio* sp., 1 eastern floater, 1 eastern creekshell, 1 Carolina creekshell, and 3 Savannah lilliput were found in 6.17 person hours of survey time (Table 3). In addition, the Asian clam was common and the aquatic snails *Physella* sp. and *Helisoma anceps* (two-ridged rams horn) were also present.

Table 3. CPUE for Freshwater Mussels: South Fork Crooked Creek S047 Section 1

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio</i> spp	elliptio species	332	53.8/hr
<i>Elliptio</i> sp	lanceolate elliptio species	2	0.3/hr
<i>Pyganadon cataracta</i>	eastern floater	1	0.16/hr
<i>Villosa delumbis</i>	eastern creekshell	1	0.16/hr
<i>Villosa vaughaniana</i>	Carolina creekshell	1	0.16/hr
<i>Toxolasma pullus</i>	Savannah lilliput	3	0.3/h

2) The stream channel ranged from 4-8 meters wide with approximately 2 meter high clay stream banks. Banks ranged from unstable and scoured to more stable areas exhibiting only minor erosion and undercutting. The surveyed reach consisted of mostly long pool and slow moving run habitat with the occasional riffle areas where significant bedrock outcroppings were present. Substrate was dominated by sand, hard-packed clay, gravel, cobble, and silt with occasional slate bedrock outcropping. The surrounding

landuse was predominately cropland, with riparian buffers of varying width. A total of 1,454 *Elliptio* spp., 5 lanceolate *Elliptio* sp., 3 eastern floater, 5 eastern creekshell, 1 Carolina creekshell, and 8 Savannah lilliput were found in 12.5 person hours of survey time (Table 4). Seven of the 8 Savannah lilliput were found in an approximately 10 meter section of the creek at 35.06540, -80.59915. The Asian clam was common and the aquatic snails *Physella* sp. and *Helisoma anceps* (two-ridged rams horn) were also present.

Table 4. CPUE for Freshwater Mussels: South Fork Crooked Creek S047 Section 2

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio</i> spp	elliptio species	1,454	121.6/hr
<i>Elliptio</i> sp	lanceolate elliptio species	5	0.41/hr
<i>Pyganadon cataracta</i>	eastern floater	3	0.25/hr
<i>Villosa delumbis</i>	eastern creekshell	5	0.41/hr
<i>Villosa vaughaniana</i>	Carolina creekshell	1	0.08/hr
<i>Toxolasma pullus</i>	Savannah lilliput	8	0.66/h

S064/S068 UTs Stewarts Creek

This stream system was accessed from a development off Poplin Road (SR 1508) and surveyed to a point where habitat was no longer appropriate for mussel fauna because of heavy degradation from upstream agricultural operations (Sheet 6). S064 consisted of a channel ranging from 2-3 meters wide with approximately 1 meter high clay banks that were generally unstable. In order of dominance, substrate consisted of mud, sand, hard-packed clay and occasional gravel. A thick layer of algae was noted covering most substrates. A narrow to non-existent buffer was present to surrounding residential area, active crop, and poultry operations. Surveys were conducted for 1 person-hour during which no mussels were located. An aquatic snail, *Physella* sp., was common in the pools. Additionally, a short 0.5 person-hour habitat evaluation in S068 just downstream from the corridor indicated that the small incised degraded channel did not contain appropriate habitat for mussels.

S076 Stewarts Creek

This upper section of Stewarts Creek was accessed from the Fowler Road crossing (SR 1502) and surveys were conducted through the project corridor (Sheet 7). The stream channel ranged from 3-7 meters wide and clay stream banks were approximately 2 meters high. Banks were generally unstable. There was a sequence of gravel/cobble riffle/run areas transitioning into pool and slack water habitats. In order of dominance, substrate consisted mostly unconsolidated gravel, sand, hard-packed clay and occasional cobble. The surrounding area consisted of a moderate to wide forested buffer to residential areas, active crop, and road. Surveys were conducted for a total of 2.5 person-hours during which no mussels were located.

S078 UT Stewarts Creek

This small stream was evaluated at its confluence with Stewarts Creek (Sheet 7). The stream channel ranged from 1-2 meter wide with 1 meter high stream banks that showed signs of erosion and undercutting. Substrate was dominated by mud, sand, gravel, with some areas of rocky cobble also present. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S080 UT Stewarts Creek

This small stream was evaluated just downstream of the project crossing (Sheet7). The stream channel ranged from 1-2 meter wide with approximately 0.5 meter high stream banks that showed signs of erosion and undercutting. Substrate was dominated by mud and gravel, with some areas of rocky cobble also present. Stream flows were intermittent, with water only present in pools. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S081 UT Stewarts Creek

This drainage was evaluated just downstream of a project interchange (Sheet 8). The stream was evaluated upstream and downstream of a pond. The channel ranged from 1-2 meter wide with 1-2 meter high banks that were generally unstable. Substrate was dominated by mud and gravel, with some areas of rocky cobble. Stream flow was intermittent, with water only present in pools below the pond. Upstream of the pond, substrate was covered in thick algae. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S082 Stewarts Creek

In this downstream project crossing of Stewarts Creek, the stream channel ranged from 5-10 meters wide and stream banks ranged from 1-2 meters high (Sheet 9). Banks ranged from stable to exhibiting some areas of erosion and undercutting. The surveyed reach sequenced from a rock fall riffle/run to a pool and slack water habitat often lined with bedrock outcroppings. Substrate was dominated by unconsolidated sand, angular cobble, and boulder, with areas of clay banks, silt, gravel, and bedrock. The surrounding area consisted of a moderate to wide forested buffer to poultry houses, and a utility corridor. A total of 17 eastern elliptio, and one shell of the eastern floater were located during 2.83 person-hours of survey time (Table 5). The Asian clam was common.

Table 5. CPUE for Freshwater Mussels: Stewarts Creek S082

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio complanata</i>	eastern elliptio	17	6.0/hr
<i>Pyganadon cataracta</i>	eastern floater	1 shell	n/a

S085 Stumplick Branch

A short section of Stumplick Branch was surveyed from its confluence with Stewart's Creek until it exited the project study corridor (Sheet 9). The stream channel ranged from 2-5 meters wide with approximately 1 meter high banks that ranged from stable to exhibiting some areas of erosion and undercutting. The surveyed reach consisted of a relatively high gradient sequence of rock fall riffle/run areas transitioning into small pool habitats often bordered with bedrock outcroppings. Substrate was dominated by cobble, gravel, boulder, and bedrock, with limited interstitial sand and silt. The surrounding area consisted of an extensive forested buffer to surrounding land use. No mussels were located in the reach during 1 person-hour of survey time. The Asian clam was uncommon, found only near the mouth of Stewarts Creek.

S089/S091 UTs Stewarts Creek

This stream system was evaluated downstream of the corridor crossing and accessed from a poultry operation near the Stewarts Creek crossing (Sheet 9). Each channel was approximately 1 meter wide with 0.5 meter high banks. Substrate was dominated by mud and gravel. The surrounding area consisted of a narrow natural buffer/ wetland areas to the poultry operation and hayfields. A habitat evaluation was performed for a total of 1.0 person-hour in the system during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S098 UT Lake Twitty

This UT to Lake Twitty was evaluated downstream of the corridor crossing and accessed from Brentwood Lane to determine if potential habitat was present upstream (Sheet 9). The small stream was approximately 2 meters wide with a mostly dry channel and only pool habitat. Substrate was dominated by mud and gravel. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S103/S108 UTs Richardson Creek

Each stream in this system was evaluated downstream of their respective project crossings and accessed from a grain farming operation (Sheet 11). S103 was approximately 2 meters wide with 1 meter high banks and dry except for a few remnant pools near a culvert crossing. Substrate consisted of mud, gravel, and bedrock. S108 was a very small channel approximately 1 meter wide with 0.5 meter high stream banks and also contained no flow. Substrate in the channel was dominated by cobble and mud. The surrounding area consisted of stands of mostly yellow pine forest surrounded by extensive hay and grain fields. Each stream was evaluated for 0.5 person-hours during which it was determined that it did not contain appropriate habitat to warrant a full survey.

S122 UT Richardson Creek

This small and heavily incised stream was accessed at its confluence with the main stem of Richardson Creek (Sheet 12). The stream ranged from 1-2 meters wide with unstable 2-3 meter high banks. Substrate was dominated by hard packed clay, gravel, cobble, sand, and silt. A narrow to moderately wide natural buffer was present along most of the reach to surrounding rural land uses. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream too small and degraded to warrant a full survey.

Richardson Creek

This section of Richardson Creek is where the City of Monroe has its waste water discharge (Sheet 12). The stream channel ranged from 15-20 meters wide with 2-3 meter high clay stream banks. Banks generally exhibited some areas of erosion and undercutting. The surveyed reach consisted of mostly long pool and slow moving run habitat with occasional riffles where significant bedrock outcroppings were present. In order of dominance substrate consisted of unconsolidated sand, silt, gravel, cobble, boulder, and slaty bedrock outcrops. Significant algal growth on substrates and an overwhelming smell of effluent were observed during the survey. A moderate to wide forested buffer was present to surrounding rural land uses. No live mussels were located during 6 person-hours of survey time, likely a function of the impact of the waste water discharge on this section of the stream. However, shells of variable spike, eastern elliptio, eastern floater, eastern creekshell, and Florida pondhorn were found. The Asian clam was common and the aquatic snail *Helisoma anceps* (two-ridged rams horn) was also present.

Rays Fork

Rays Fork was surveyed from its confluence with Richardson Creek upstream to outside the project corridor (Sheet 12). The stream channel ranged from 10-12 meters wide and with 1-2 meter high banks that had some areas of erosion and undercutting. The reach consisted of a sequence of rocky riffle/run areas transitioning into pool and slack water habitats often lined with bedrock outcroppings. In order of dominance, substrate consisted of angular cobble, bedrock, unconsolidated sand, silt, and clay. The surrounding area consisted of a moderate to wide forested buffer to surrounding neighborhoods, rural land uses, and road. There was a large beaver impoundment upstream of the survey extent. The only evidence of mussel fauna during 3.67 person-hours of survey time was one shell fragment of an eastern elliptio found below the beaver impoundment. The Asian clam was uncommon and the aquatic snail *Physella* sp. was common with a patchy distribution.

S115/S118 UTs Richardson Creek

This stream system was accessed at its confluence with main stem Richardson Creek (Sheet 12). In the evaluated reach, the relatively high gradient stream ranged from 1-2 meters wide with generally stable 1-2 meter high banks. Substrate was dominated by cobble, gravel, and sand with some areas of boulder and bedrock also present. An

extensive hardwood forest (wide buffer) surrounded the reach. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream was too small to warrant a full survey.

S140/S143/S144 UTs Rays Fork

This stream system was evaluated downstream from the project crossings as accessed from Bob White Circle (SR 1786) (Sheet 12). In the evaluated reaches, both S140 and S143 were approximately 2 meters wide with 1 meter high banks that exhibited signs of erosion and undercutting. Both channels were intermittently dry with occasional standing water in pools. Substrates in the channels were dominated by cobble, gravel, and sand. A narrow to moderately wide natural buffer was present along most of the reaches to surrounding residential area and road. Short 0.5 person-hour habitat evaluations in both S014 and S015 determined that they did not contain appropriate habitat due to small size and apparent drought intolerance. As S144 was well upstream within the system, it was determined that habitat was also not present.

S138 UT Richardson Creek

S138 was evaluated for habitat at the Trull Hinson Road (SR 1757) crossing (Sheet 12). The stream channel was approximately 2 meters wide with 1 meter high banks. Substrate consisted mud, sand, pebble, and cobble. A narrow to moderately wide natural buffer was present along most of the reach to surrounding residential area and road. A habitat evaluation was performed for 0.83 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey

S146 UT Meadow Branch

This stream system was evaluated from the confluence with Meadow Branch upstream through the corridor (Sheet 13). The very small stream was approximately 1 meter wide with little flow and slackwater habitat. A significant amount of scour and erosion was present. Substrate was dominated by clay overlain with silt and sand. The surrounding area consisted of active pastureland. A habitat evaluation was performed for 0.5 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey due to small size and degraded condition.

S152 Meadow Branch/UT Meadow Branch

The stream was evaluated from a point approximately 500 meters below the McIntyre Road crossing upstream through the project corridor (Sheet 13). Below the culvert crossing on McIntyre Road the channel ranged from 3-4 meters wide and stream banks ranged from 2-2.5 meters high. The banks were generally unstable, and in some areas, bricks, concrete and other structure have been placed along the bank for stabilization. Habitat within this section consisted of deep, slackwater channel, with a silt-clay substrate, and large amounts of woody debris. The surveyed portion of Meadow Branch upstream of the McIntyre Road crossing ranged from 3-4 meters wide, with fairly stable clay banks 1 meter high. Habitat consisted of a series of short riffle/run/pool sequences, with a well sorted substrate composed of cobble, sand and gravel, with occasional

bedrock. Active pastureland bordered the creek throughout the surveyed reach, as well as a sewer line on the left descending side of the channel. A total of 2.5 person-hours of survey time was spent in Meadow Branch. No mollusks were observed in the stream, below McIntyre Road, while the Asian clam, fingernail clams (Spharidae), and an aquatic snail *Physella* sp. were present in low numbers above the road.

S156 Spring Branch

The stream was evaluated from the confluence with Meadow Branch upstream to the Austin Chaney Road crossing (Sheet 13). The channel ranged from 2-3 meters wide and stream banks ranged from 1.5-2 meters high. The banks were relatively stable throughout, with the exception of a few small sections, usually associated with windthrow. Habitat consisted of a series of shallow riffle/run/pool sequences, with a well sorted substrate composed of cobble, sand and gravel, with occasional bedrock. A narrow forested buffer adjacent to cropland bordered the creek throughout. No mussels were found in 1 person-hour of survey time; however, fingernail clams (Spharidae), and an aquatic snail *Physella* sp. were fairly common.

S158 UT Meadow Branch

This system was evaluated for habitat downstream of the project alignment and accessed from the College Park neighborhood (Sheet 13). The stream was approximately 2 meters wide with approximately 1 meter high banks. The stream channel was intermittently dry with occasional standing water in pools. In order of dominance, substrate consisted of mud, cobble, sand, and gravel. There was a variably narrow to wide natural buffer along most of the reach to surrounding residential area and road. A habitat evaluation was performed for 0.67 person-hours during which it was determined that the stream did not contain appropriate habitat to warrant a full survey.

S161/S164/S166 UTs Salem Creek

This stream system was evaluated from private land off Phifer Road (SR 1347) (Sheet 14). In the evaluated reaches, both S161 and S164 ranged from 1-2 meters wide with 0.5-1 meter high banks that exhibited some signs of erosion and undercutting. Both channels were intermittently dry with occasional standing water in pools. In order of dominance, substrates in the channels were dominated by bedrock, clay, cobble, and gravel. An extensive, early successional forest surrounded the streams in these reaches. Short 0.5 person-hour habitat evaluations in both S161 and 164 determined that they did not contain appropriate habitat due to small size and apparent drought intolerance. S166 was evaluated further downstream in the system. The channel was approximately 2 meters wide with 1 meter high stream banks. Substrate consisted of mud, sand, and gravel. A 0.5 person-hour habitat evaluation determined that habitat did not warrant a full survey in S166.

S169 Salem Creek

Salem Creek consisted of a scoured stream channel ranging from 2-4 meters wide with 1-2 meter high stream banks that were generally unstable (Sheet 14). In order of

dominance, substrate consisted of gravel, rocky cobble, unconsolidated sand, hard-packed clay, and bedrock. An extensive forest was present downstream and a narrow to moderate natural buffer was present upstream to surrounding pasture and road. Surveys were conducted for a total of 2.0 person-hours during which no mussels were located. The aquatic snail *Physella* sp. was uncommon.

4.3. Additional Area Mussel Survey Results

Additional area mussel surveys outside of the project study corridor were conducted as part of this project in the best potential mussel habitat in the watersheds proposed to be impacted by the Monroe Connector/Bypass. The areas chosen for this effort were Richardson Creek upstream of the WWTP discharge facility and lower Crooked Creek, near its confluence with the Rocky River.

Richardson Creek

The additional mussel survey efforts in Richardson Creek were focused upstream of the Monroe WWTP discharge in the vicinity of the Walkup Road (SR 1106) crossing (Sheet 10). In this section, Richardson Creek ranged from 12-15 meters wide with approximately 2 meter high stream banks. Banks generally exhibited some areas of erosion and undercutting, but were stabilized in areas with bedrock outcroppings. The surveyed reach mostly consisted of long shallow pool and slow moving run habitat punctuated with shallow gravel riffle areas. In order of dominance, substrate consisted of cobble, gravel, clay banks, silt, boulder, and bedrock. The surrounding area consisted of a narrow to moderate natural buffer to residential/ commercial areas and road. A total of 709 *Elliptio* spp., 2 lanceolate *Elliptio* sp., 5 eastern floater, 16 Florida pondhorn, 14 eastern creekshell, 2 Carolina creekshell, and 4 Savannah lilliput were found in 13.67 person hours of survey time (Table 6). In addition, the Asian clam was common and the aquatic snails *Helisoma anceps* (two-ridged rams horn), *Planorbella trivolvis* (marsh rams-horn), and *Campeloma decisum* (pointed campeloma) were all uncommon while the *Physella* sp. was common.

Table 6. CPUE for Freshwater Mussels: Richardson Creek Additional Area

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio</i> spp.	elliptio species	709	51.87/hr
<i>Elliptio</i> sp.	lanceolate elliptio species	2	0.15/hr
<i>Pyganadon cataracta</i>	eastern floater	5	0.37/hr
<i>Unio merus carolinianus</i>	Florida pondhorn	16	1.17/hr
<i>Villosa delumbis</i>	eastern creekshell	14	1.02/hr
<i>Villosa vaughaniana</i>	Carolina creekshell	2	0.15/hr
<i>Toxolasma pullus</i>	Savannah lilliput	4	0.29/hr

Crooked Creek

The additional mussel survey efforts in Crooked Creek watershed were focused on the last several miles of the main stem of Crooked Creek from its confluence with Rocky River to the vicinity of Brief Road (SR 1547) (Sheet 15). In this section, Crooked Creek

ranged from 12-20 meters wide with approximately 0.5-2 meter high and mostly stable clay stream banks. The entire reach consisted of a relatively high gradient sequence of riffle/run to pool habitats marked by a dominance of slate bedrock that provided grade control and stability throughout. In order of dominance, substrate consisted of angular cobble, bedrock, gravel, boulder, sand, clay, and silt. The stream reach was surrounded by an extensive hardwood forest that buffers the areas mostly agricultural land use. A total of 480 *Elliptio* spp., 14 Florida pondhorn, 19 eastern creekshell, and 13 Carolina creekshell were found in 21.25 person hours of survey time (Table 7). In addition, the Asian clam was common and the aquatic snails *Helisoma anceps* (two-ridged rams horn) and *Campeloma decisum* (pointed campeloma) were uncommon. *Physella* sp. was common with a patchy distribution.

Table 7. CPUE for Freshwater Mussels: Crooked Creek Additional Area

Scientific Name	Common Name	Number	CPUE #/person hr
<i>Elliptio</i> spp	elliptio species	480	53.8/hr
<i>Unio merus carolinianus</i>	Florida pondhorn	14	1.17/hr
<i>Villosa delumbis</i>	eastern creekshell	19	0.16/hr
<i>Villosa vaughaniana</i>	Carolina creekshell	13	0.16/hr

4.4. Mussel Survey Discussion

Most of the streams in the study area have been subject to anthropomorphic impacts that have significantly altered the habitats available for mussel colonization. Additionally, many of the smaller streams surveyed limit mussel colonization due to small size and periodic intermittent stream flow.

Of the streams surveyed in the project corridor, only the mainstem of North Fork Crooked Creek, UT North Fork Crooked Creek (S028), South Fork Crooked Creek, Stewarts Creek, Richardson Creek, and Rays Fork contained a mussel fauna. Of these, only South Fork Crooked Creek contains a viable and relatively diverse mussel assemblage including state and FSC listed species. The population of the target Savannah lilliput in South Fork Crooked Creek is perhaps the strongest stream population of this species (Savidge, personal observations).

These efforts have established that outside of the direct impact area of the project, there is a viable and diverse mussel fauna present in the lower Crooked Creek watershed and in Richardson Creek upstream of the Monroe WWTP. These populations are regionally significant and may contain additional species that these one-time survey efforts did not locate.

5.0 MUSSEL SPECIES LOCATED

5.1. *Elliptio complanata* (eastern elliptio)



This species was described as *Mya complanata* from the Potomac River in Maryland (Lightfoot 1786). Shell characteristics are highly variable. Shell shape is typically trapezoidal to rhomboid and compressed to inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Shell thickness varies from thin to solid. This species is widely distributed along the Atlantic Slope from Altamaha

River Basin in Georgia north to the St. Lawrence River Basin, and west to Lake Superior and parts of the Hudson Bay Basin. It can be found in a variety of habitats from large rivers and lakes to small headwater streams. The species is widespread and common throughout its range and considered stable (Williams et al. 1993).

5.2. *Elliptio icterina* (variable spike)



Described from the Savannah River near Augusta Georgia (Conrad 1834), this highly variable species represents a complex of nearly 50 named species (Johnson 1970). The shell shape is oblong, subelliptical, or subrhomboid, with a prominent posterior ridge, and moderately elevated beaks. The periostracum is usually smooth and greenish yellow to tawny-brown. This species is considered common

and currently stable throughout its range (Williams et al. 1993).

5.3. *Elliptio* sp. (lanceolate *Elliptio*)

This undescribed lance appears to be morphologically distinct from other described lance forms. Like other lances, it is more than twice as long as high, approaching more than three times as long as high. Periostracum is generally dark brown to black in older specimens. It has currently been observed in the Cape Fear River basin in North Carolina and the Pee Dee River basin in North and South Carolina (Savidge, personal observations). Because of taxonomic uncertainty, the status of this potential “new” species is undetermined.

5.4. *Elliptio* spp. (*Elliptio* mussels)

Mussels in the genus *Elliptio* were the most common species found in all of the streams containing a mussel fauna. Based on shell morphologies, Johnson (1970) synonymized nearly 150 named species into two complexes: *E. complanata* (102 species) and *E. icterina* (47 species). Many of these species were described in the Carolinas. Preliminary genetic research suggests that some of these may be valid species. In some of the streams surveyed for this project there appeared to be several forms of *Elliptios*,

with gradation between each form, making separation difficult. In these instances they were lumped into 1 group (*Elliptio* spp.).

5.5. *Pyganadon cataracta* (eastern floater)



Described by Say (1817) in the deep part of a milldam presumably near Philadelphia, this species is wide ranging in the Atlantic drainages from the lower St. Lawrence River Basin south to the Altamaha River Basin, Georgia, and in the Alabama-Coosa River drainage, and the Apalachicola and Coctawhatchee River Basins, Florida. The shells of this species are uniformly thin, and lack hinge teeth. The shell shape is ovate, subelliptical and elongate, with an evenly rounded anterior margin and a broadly rounded ventral margin. The periostracum is light to dark green with broad green rays on the posterior slope. Ortman (1919) recognized three generalized shell forms, the pond form, the creek/small river form and the big river form, that were related to environmental conditions. The pond form occurs in small ponds with muddy substrates, and is characterized by very thin elongate inflated shells. The creek form occurs in riffle-pool habitats in gravel substrates, and is much thicker and more compressed. The big river form is generally short and inflated and occurs in soft substrates. This species is considered common and currently stable throughout its range (Williams et al. 1993).

5.6. *Unio merus carolinianus* (Florida pondhorn)



Described by (Bosc 1801-1804) from “the Carolinas,” this species ranges from Ocmulgee River in Georgia north to the Chowan River in Virginia. Johnson (1970) synonymized the *U. ineptus* Lea (1852) described from the Savannah River Basin with *U. carolinianus*. Shells are usually inflated rhomboid, to long rhomboid and reach lengths to 114 mm. The species generally exhibits a dark brown to black periostracum with a slightly roughened, satiny sheen. Teeth of the left valve contain two subequal pseudocardinals, often with a vestigial tooth above them, and one lateral tooth. This species is considered common and currently stable throughout its range (Williams et al. 1993).

5.7. *Villosa delumbis* (eastern creekshell)



This species, described by Conrad (1834) from small streams near the Cooper River South Carolina, ranges from Ocmulgee River, Georgia north to the Cape Fear River in North Carolina. Johnson (1970) synonymized three other species described from the greater CSB with *V. delumbis*. One of these, *V. vaughnmaniana*, is currently recognized as a valid species (Bogan and Alderman 2004), and was found

during this study (see description below). The eastern creekshell has a generally thin shell that is ovate in outline. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. The periostracum is yellow with numerous green rays that are broken along the prominent growth lines. Williams et al. (1993) consider this species to be stable; however, Bogan and Alderman (2004) propose it a conservation status of special concern in South Carolina

5.8. *Villosa vaughaniana* (Carolina creekshell)



This species was described from Swaney's Creek near Camden, South Carolina (Lea 1838). Like other members of this genus, this species is sexually dimorphic, with the shell of the male being more elongate, and the female more inflated and rounded in the posterior margin. The periostracum is usually dark yellow brown with many green, unbroken rays. The shell of this species is generally thicker, with more prominent pseudocardinal teeth than the similar eastern creekshell. The Carolina creekshell ranges from the Santee River Basin in South Carolina north to the Cape Fear River Basin in North Carolina. This species is typically found near the banks in shaded shallow pools of small streams and in muddy or silty gravel (Bogan 2002). Williams et al. (1993) lists this species as Special Concern. It is considered Endangered in North Carolina.

5.9. *Toxolasma pullus* (Savannah lilliput)

See Target Species Description

6.0 CONCLUSIONS

These survey efforts represent updated survey data targeting freshwater mussels within the Monroe Connector/Bypass project area corridor.

The only federally protected species targeted by these survey efforts, the Carolina heelsplitter, was not found, and, given the degraded conditions of most of the streams surveyed, is unlikely to occur within the project corridor.

Adverse impacts to the noted freshwater mussel populations may occur as a result of project construction. Stringent erosion control and other measures to offset potential direct impacts to the aquatic resources in the streams to be crossed by the Monroe Connector/Bypass project should be implemented during project construction.

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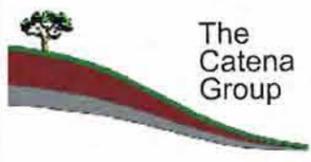
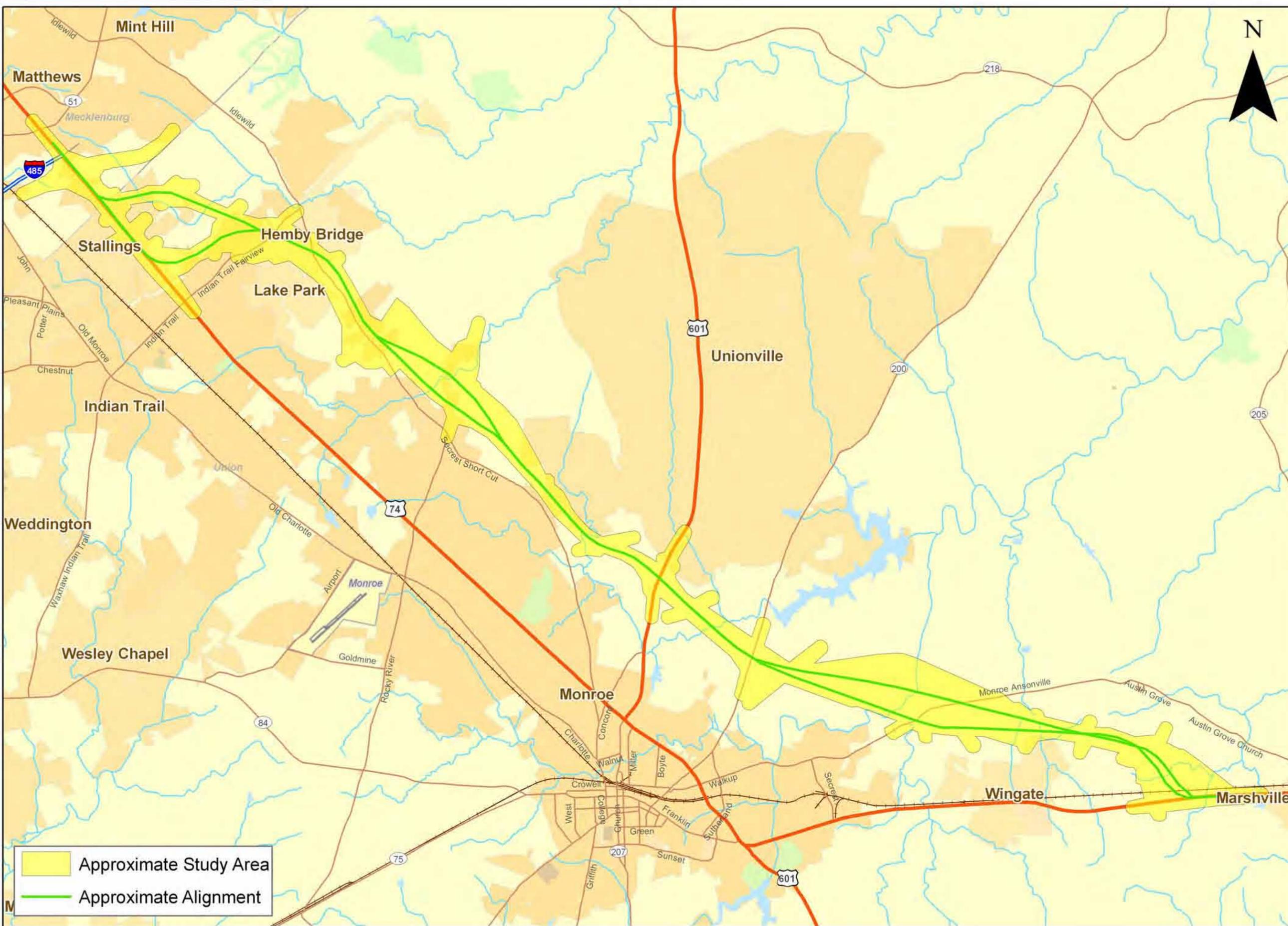
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APPENDIX A
Project Figure/Survey Location Sheets



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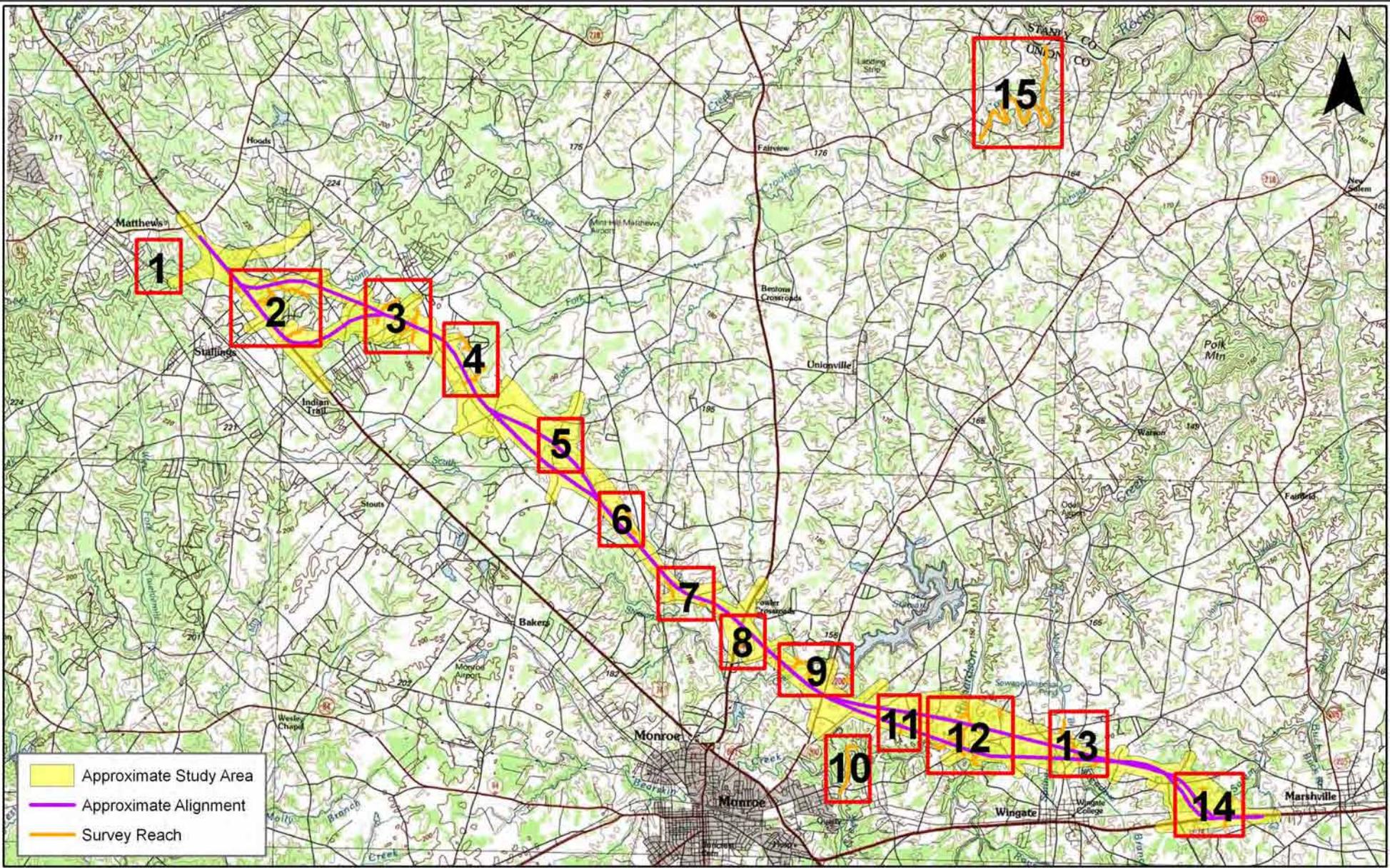
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Monroe Connector / Bypass (STIP R-3329 / R-2559)

Mecklenburg and Union Counties, North Carolina

Client: North Carolina Turnpike Authority

Figure 1



The
Catena
Group

Client:

North
Carolina
Turnpike
Authority

Freshwater Mussel Surveys
Monroe Connector / Bypass
(STIP R-3329 / R-2559)

Mecklenburg and Union Counties, North Carolina

Date:

June 2009

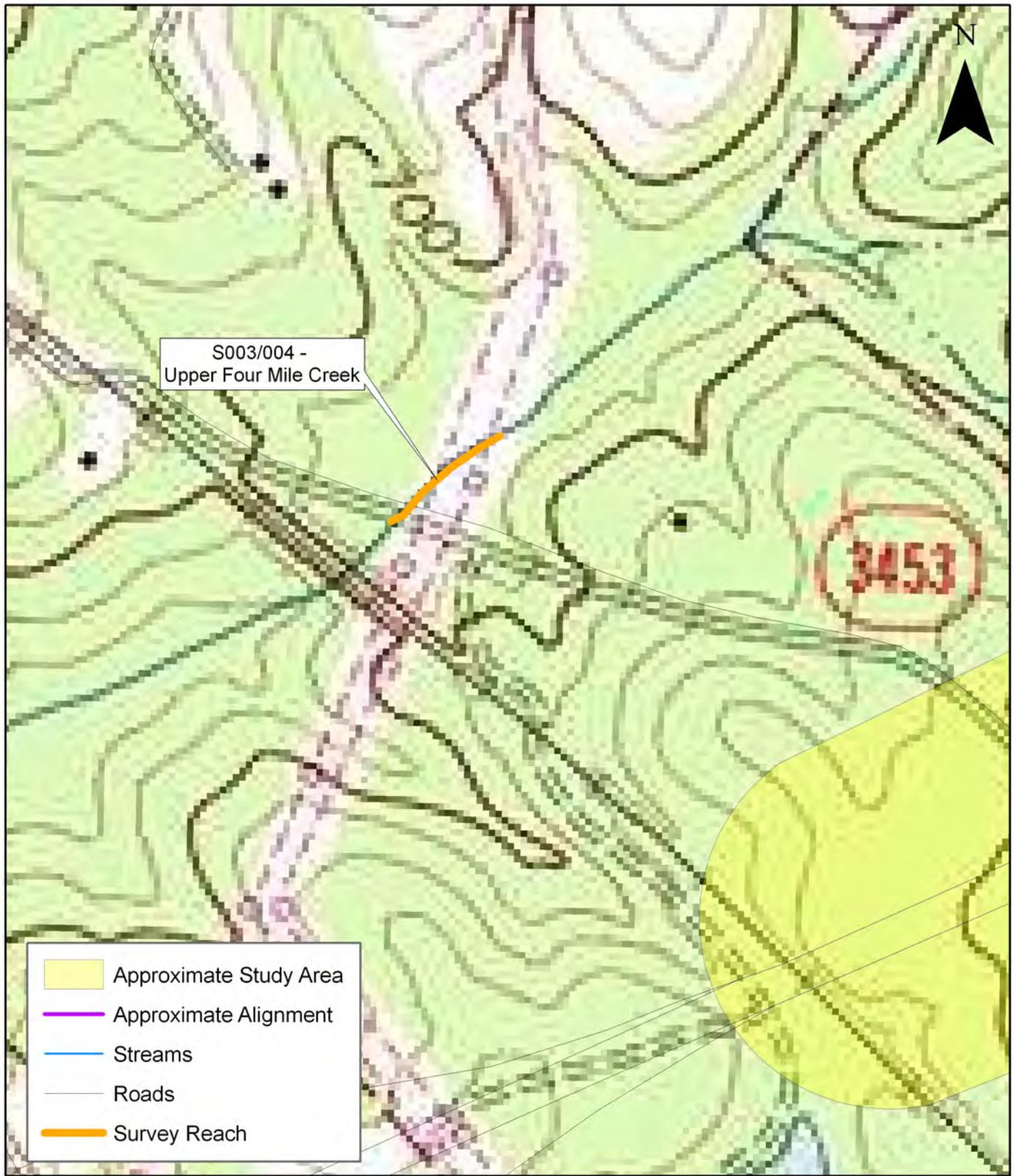
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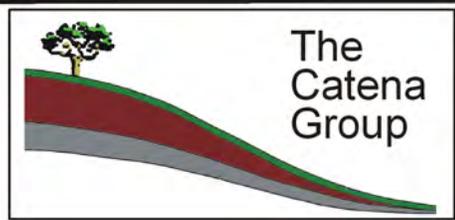
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Sheet
Index



-  Approximate Study Area
-  Approximate Alignment
-  Streams
-  Roads
-  Survey Reach



Freshwater Mussel Surveys
 Monroe Connector / Bypass
 (STIP R-3329 / R-2559)

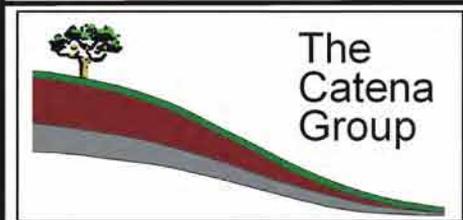
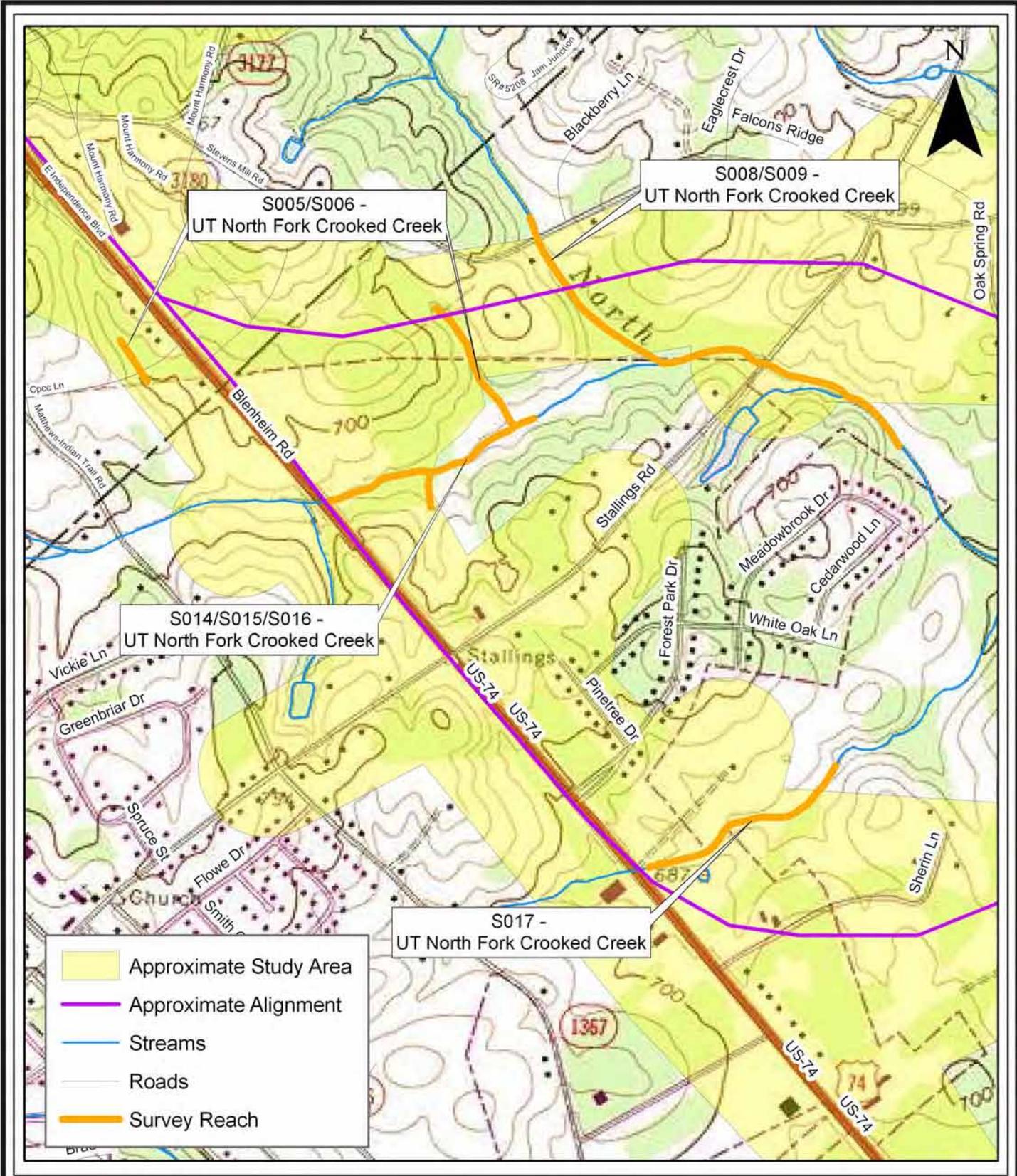
Mecklenburg and Union
 Counties, North Carolina

Date: June 2009

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Sheet
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 Monroe Connector / Bypass
 (STIP R-3329 / R-2559)

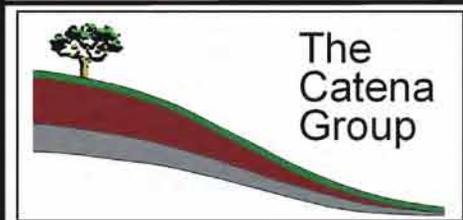
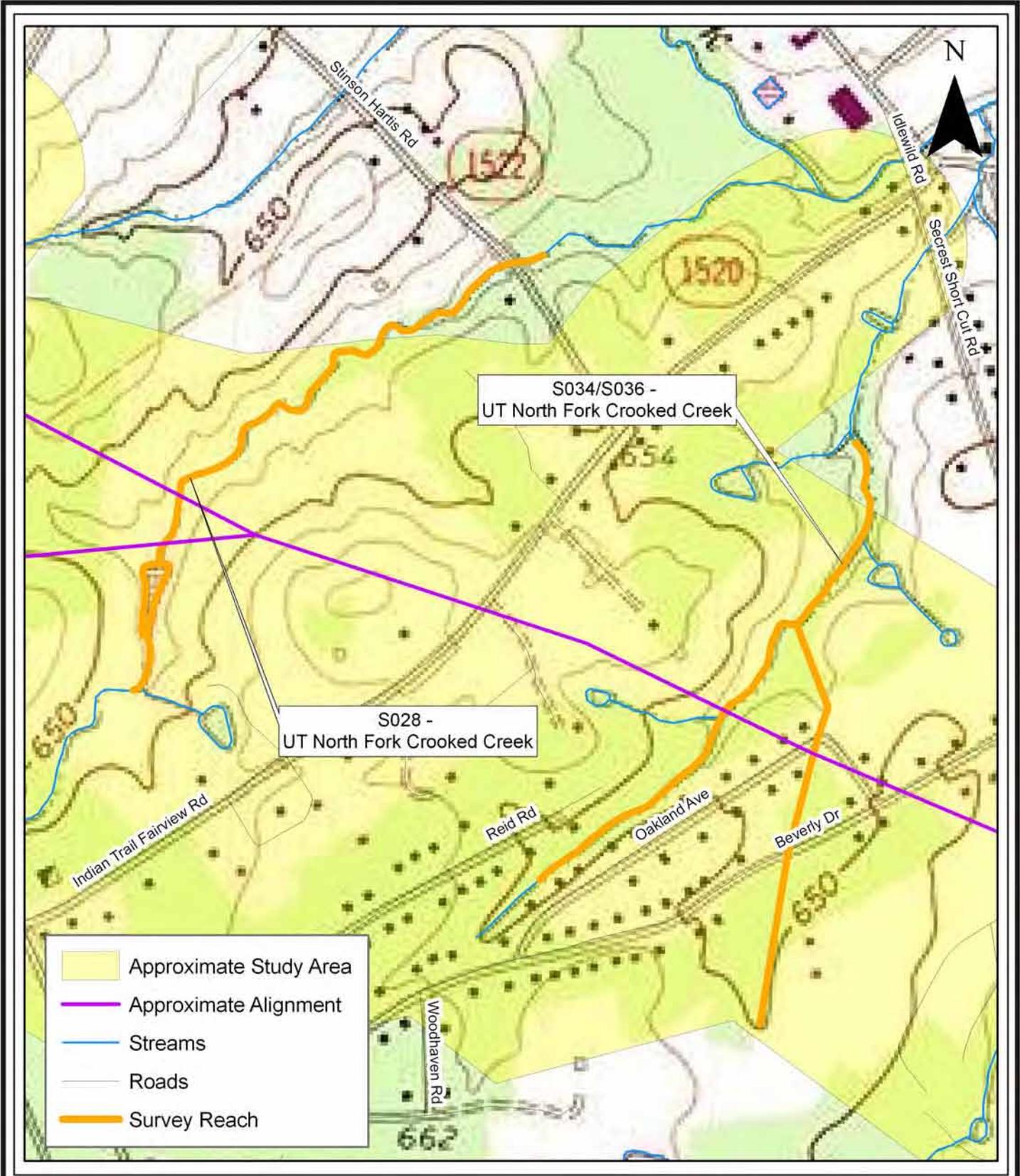
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Date: June 2009

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Freshwater Mussel Surveys
 Monroe Connector / Bypass
 (STIP R-3329 / R-2559)

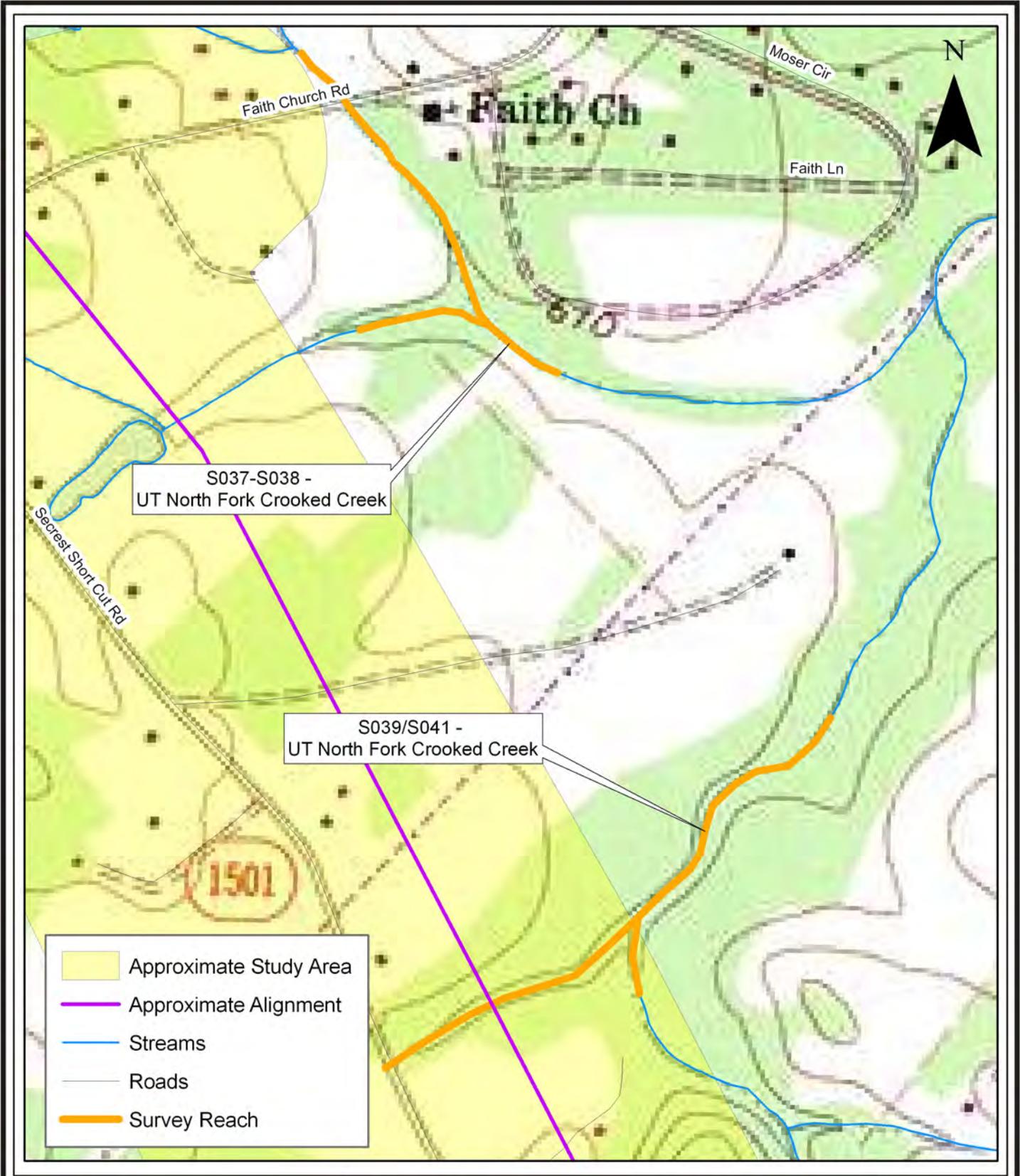
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Date: June 2009

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Job No.: 3247

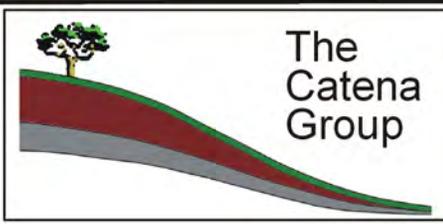
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3



S037-S038 -
UT North Fork Crooked Creek

S039/S041 -
UT North Fork Crooked Creek

-  Approximate Study Area
-  Approximate Alignment
-  Streams
-  Roads
-  Survey Reach



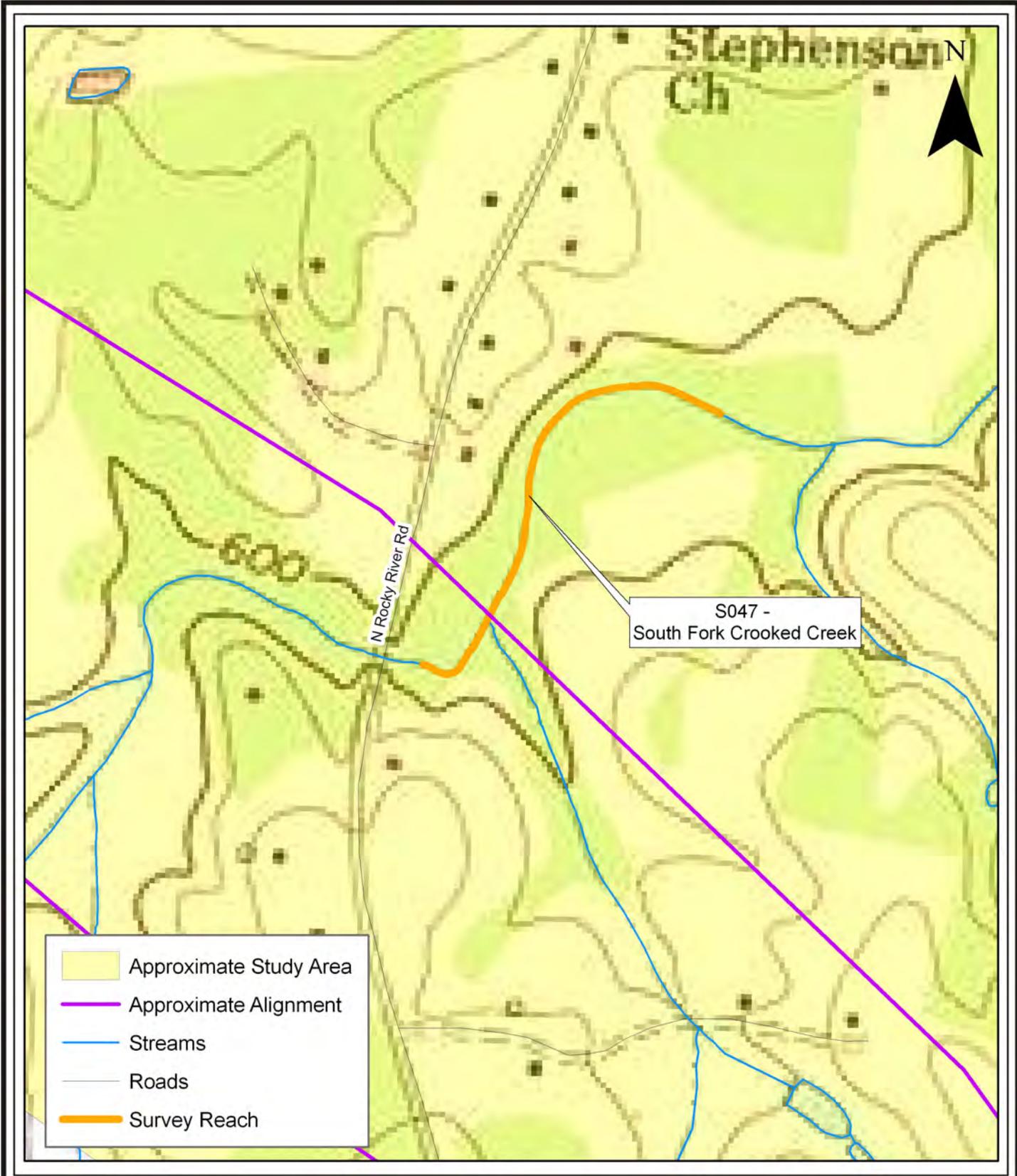
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**Freshwater Mussel Surveys
Monroe Connector / Bypass
(STIP R-3329 / R-2559)**

Mecklenburg and Union
Counties, North Carolina

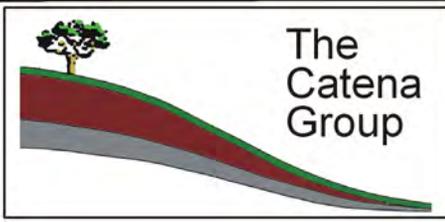
Date:	June 2009
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Job No.:	3247

Sheet
4



-  Approximate Study Area
-  Approximate Alignment
-  Streams
-  Roads
-  Survey Reach

S047 -
South Fork Crooked Creek



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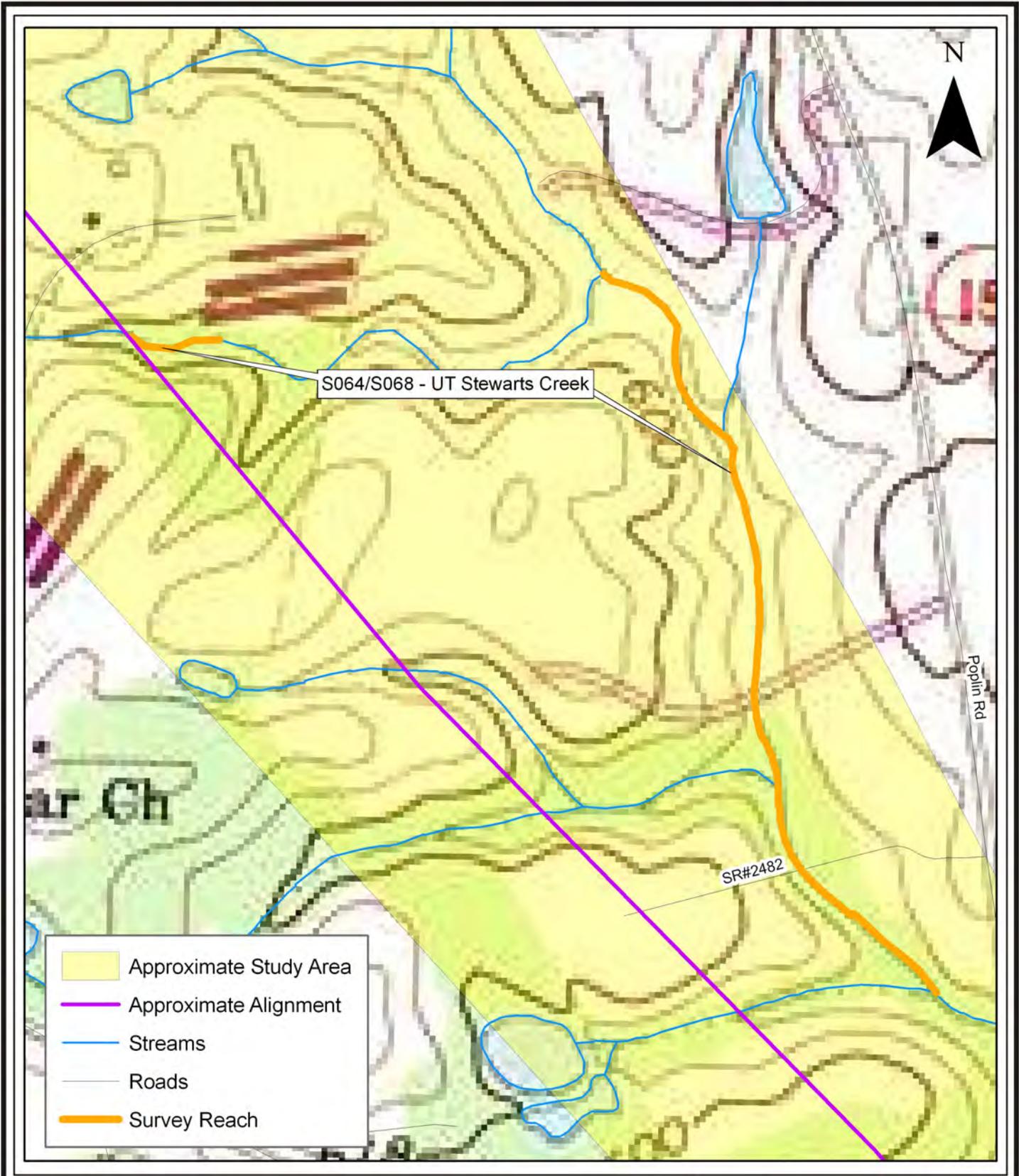
Mecklenburg and Union
Counties, North Carolina

Date: June 2009

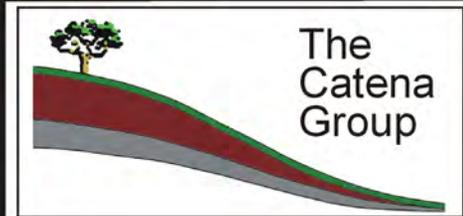
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Job No.: 3247

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5



-  Approximate Study Area
-  Approximate Alignment
-  Streams
-  Roads
-  Survey Reach



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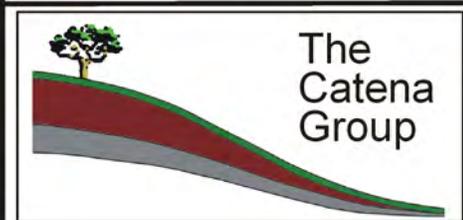
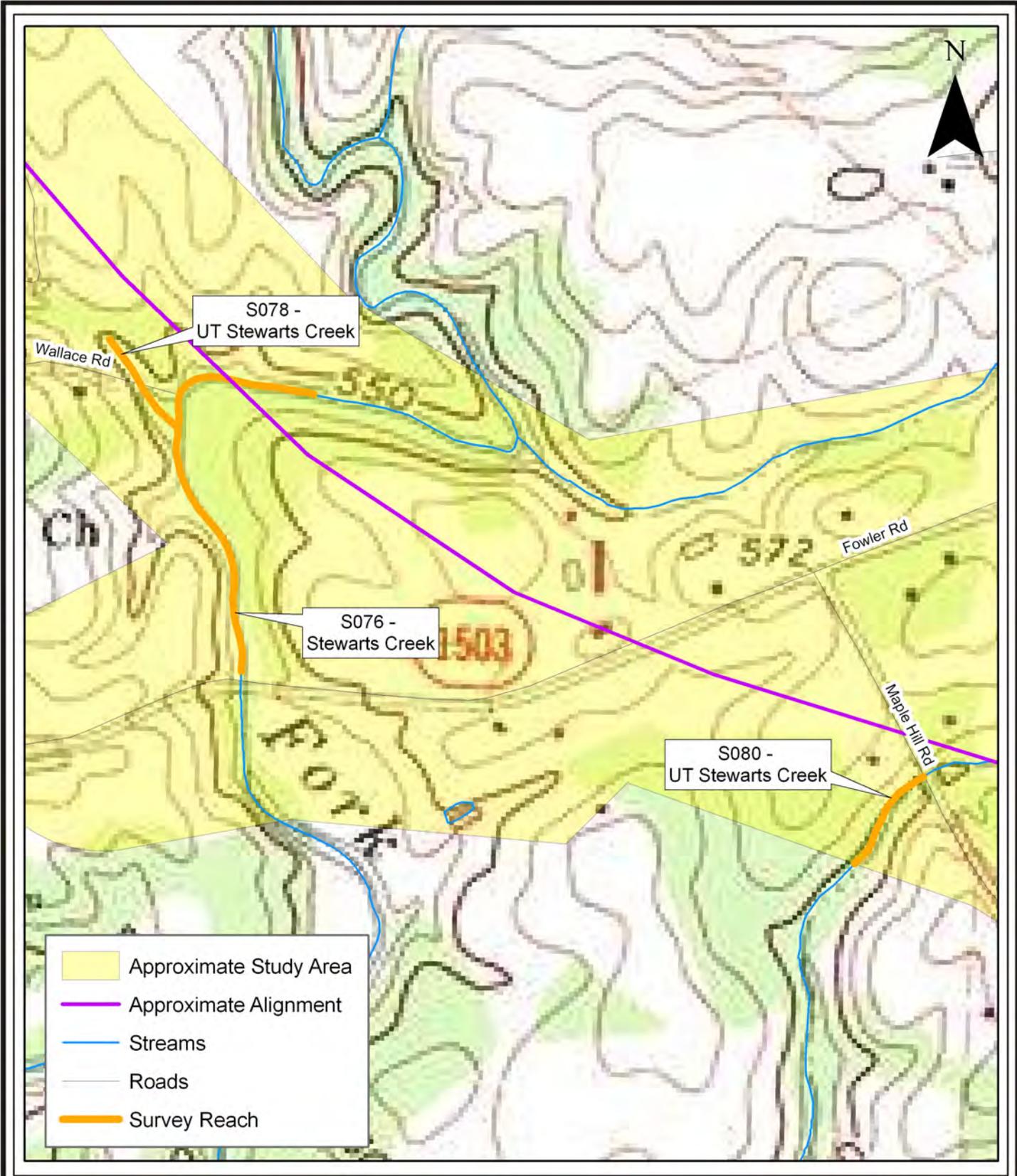
Mecklenburg and Union
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Date: June 2009

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Job No.: 3247

Sheet
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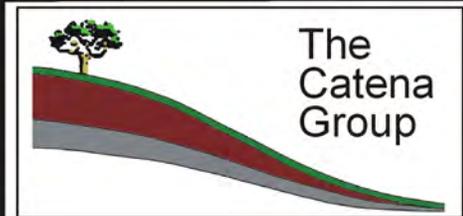
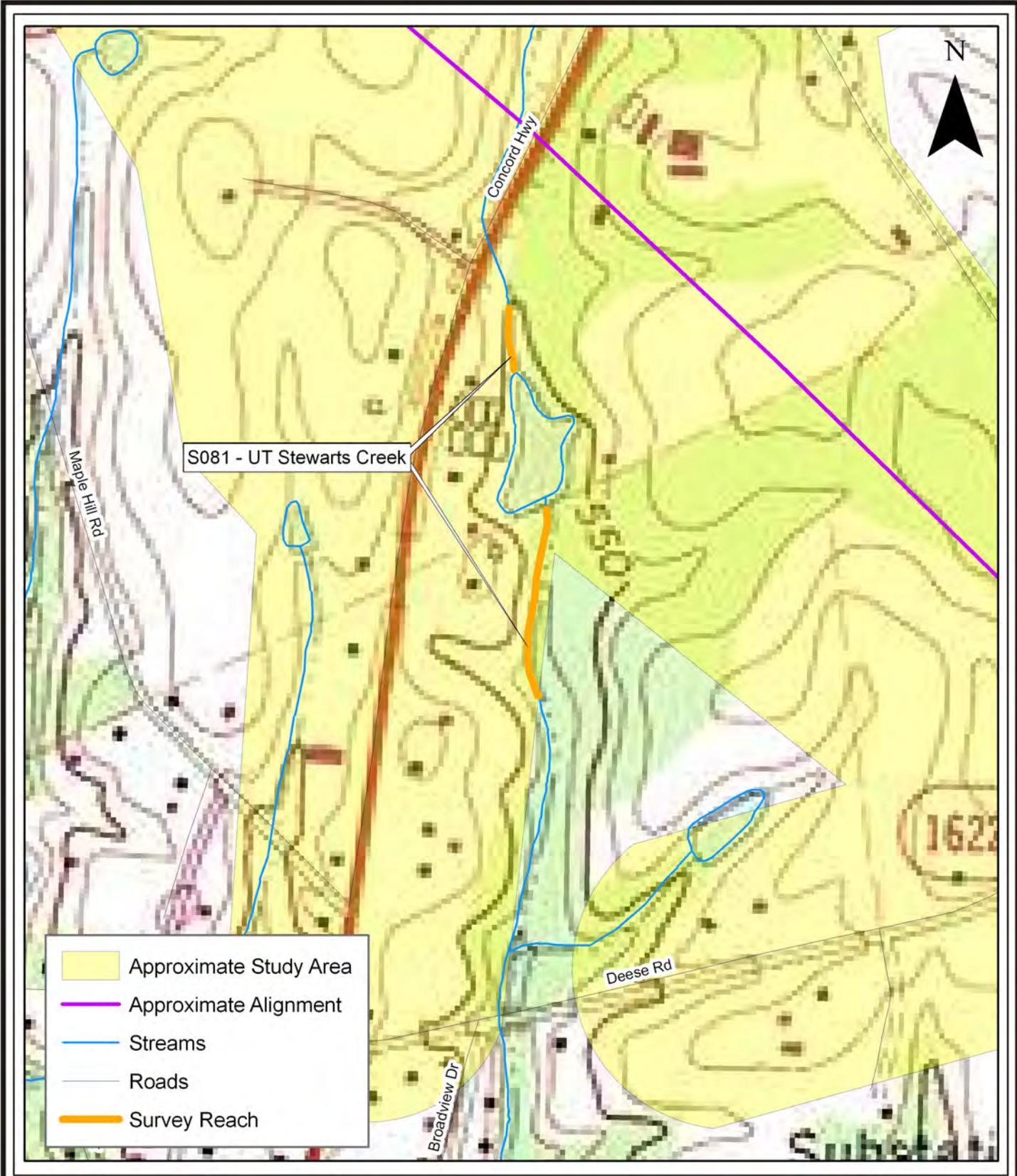
Mecklenburg and Union
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Date: June 2009

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Job No.: 3247

Sheet
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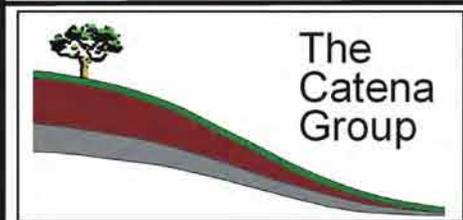
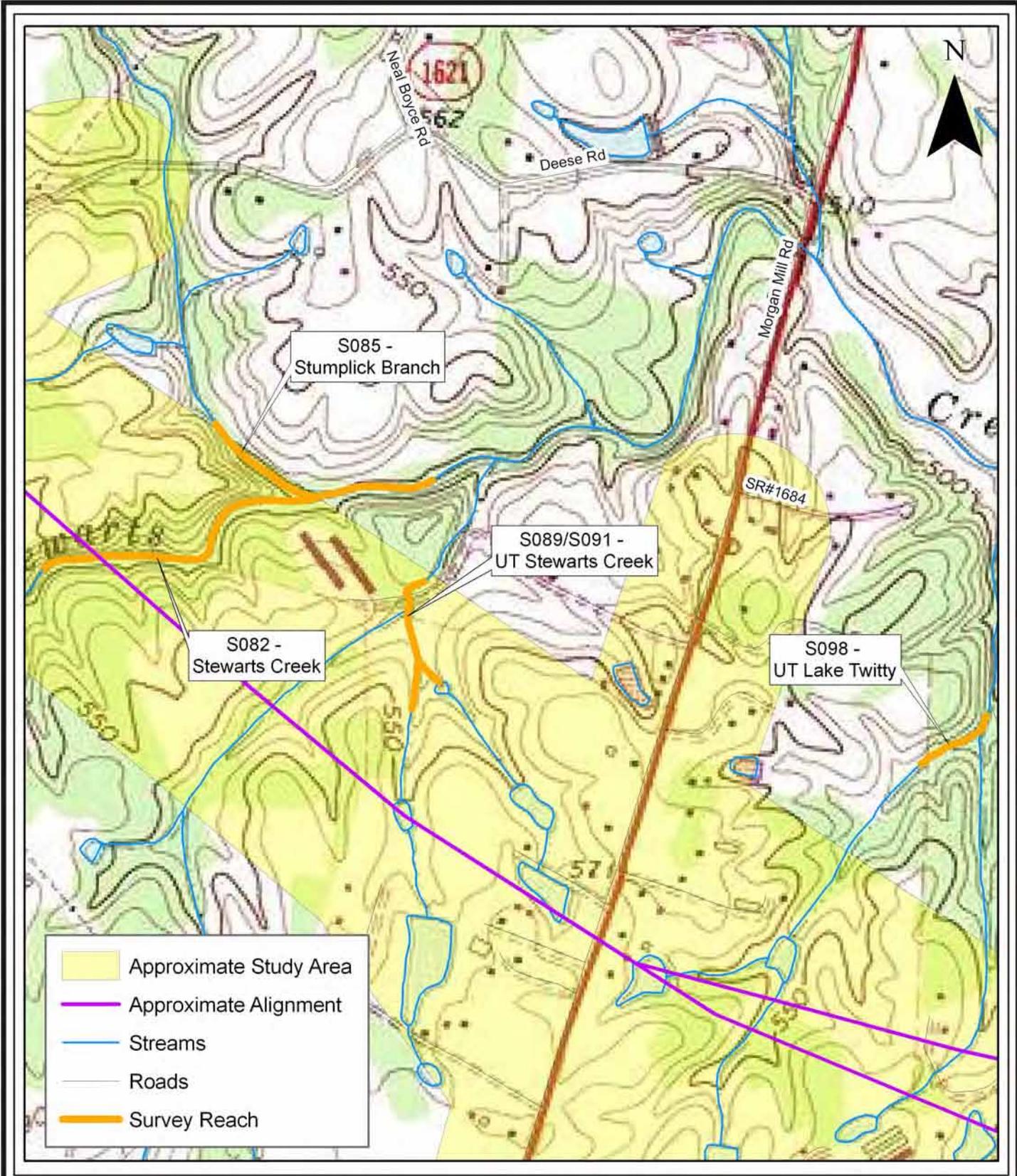
Mecklenburg and Union
 Counties, North Carolina

Date: June 2009

Scale: 0 50 100 Meters

Job No.: 3247

Sheet
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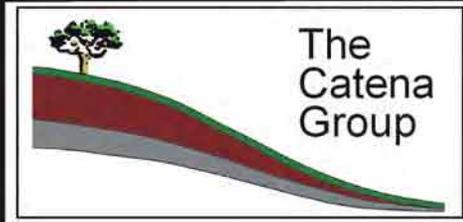
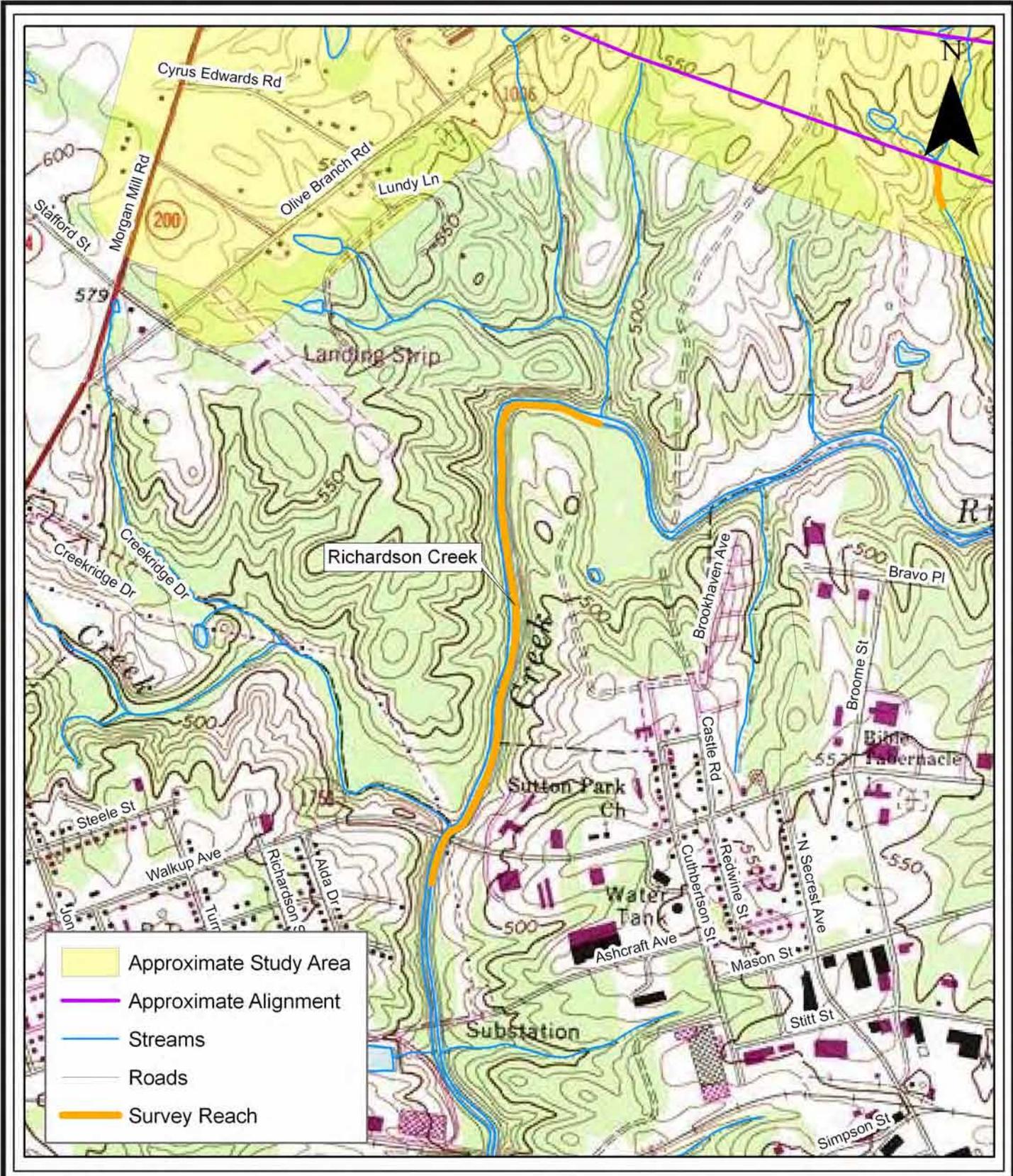
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 Counties, North Carolina

Date: June 2009

Scale: 0 100 200 Meters

Job No.: 3247

Sheet
9



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 (STIP R-3329 / R-2559)

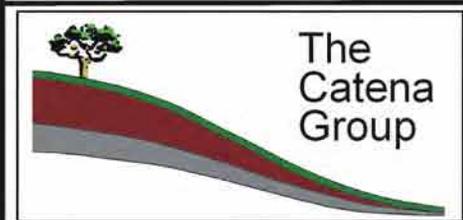
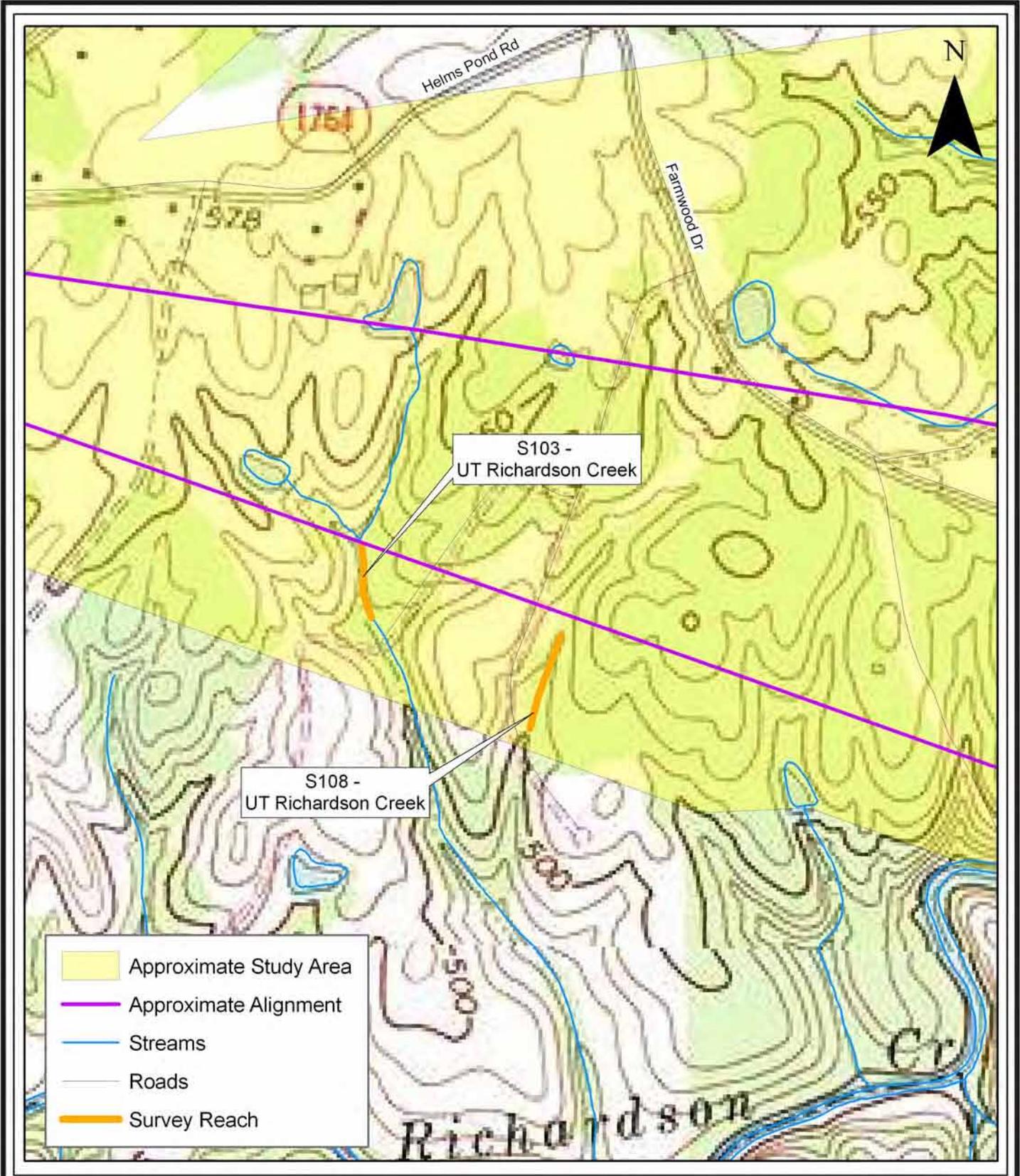
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 Counties, North Carolina

Date: June 2009

Scale: 0 125 250 Meters

Job No.: 3247

Sheet
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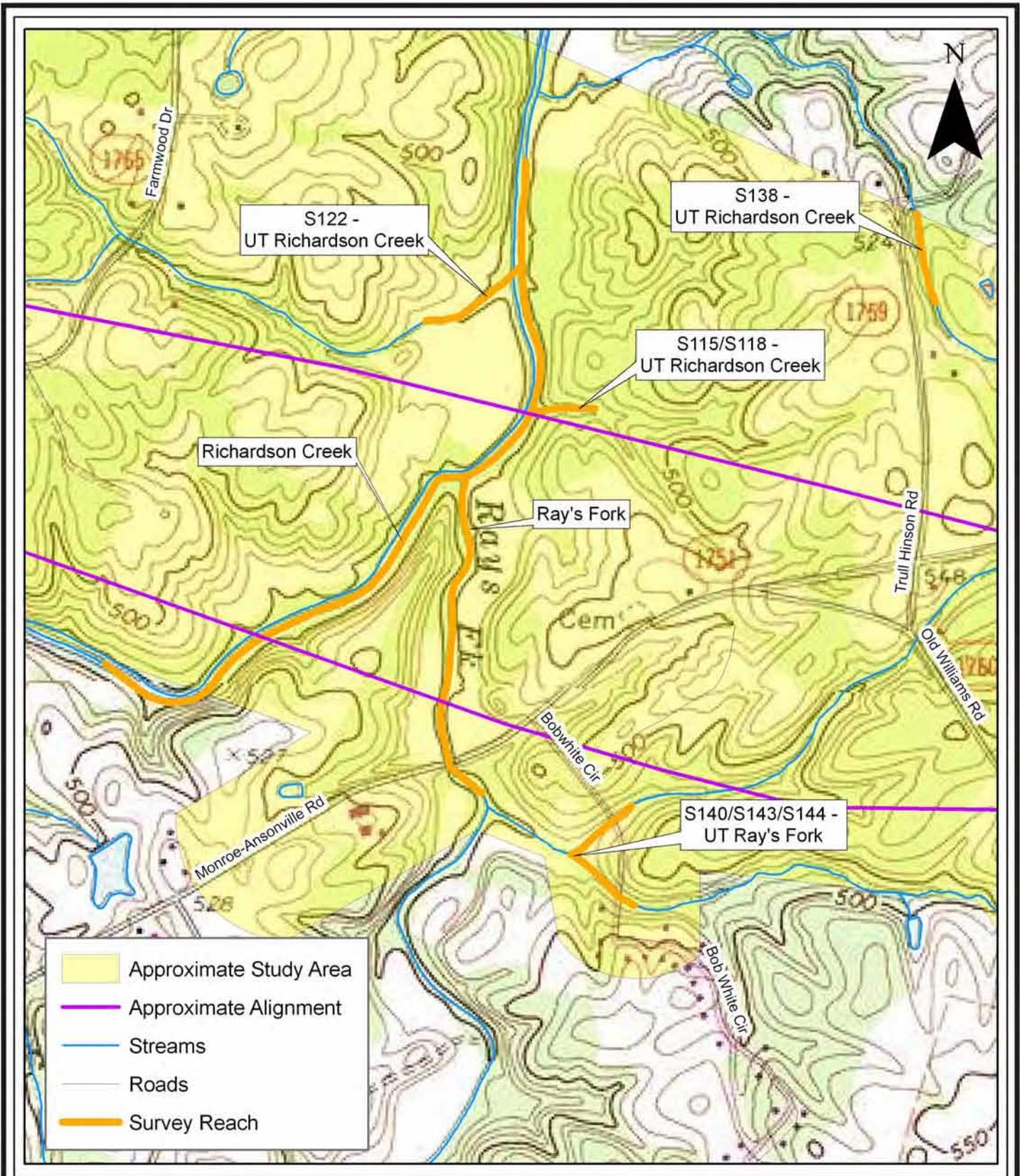
Mecklenburg and Union
 Counties, North Carolina

Date: June 2009

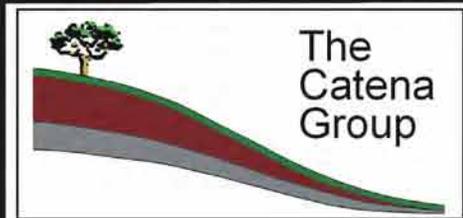
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Job No.: 3247

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-  Approximate Study Area
-  Approximate Alignment
-  Streams
-  Roads
-  Survey Reach



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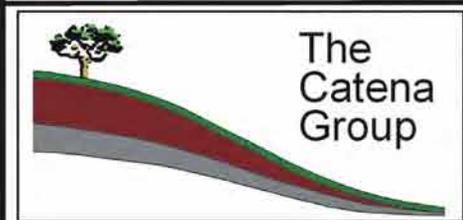
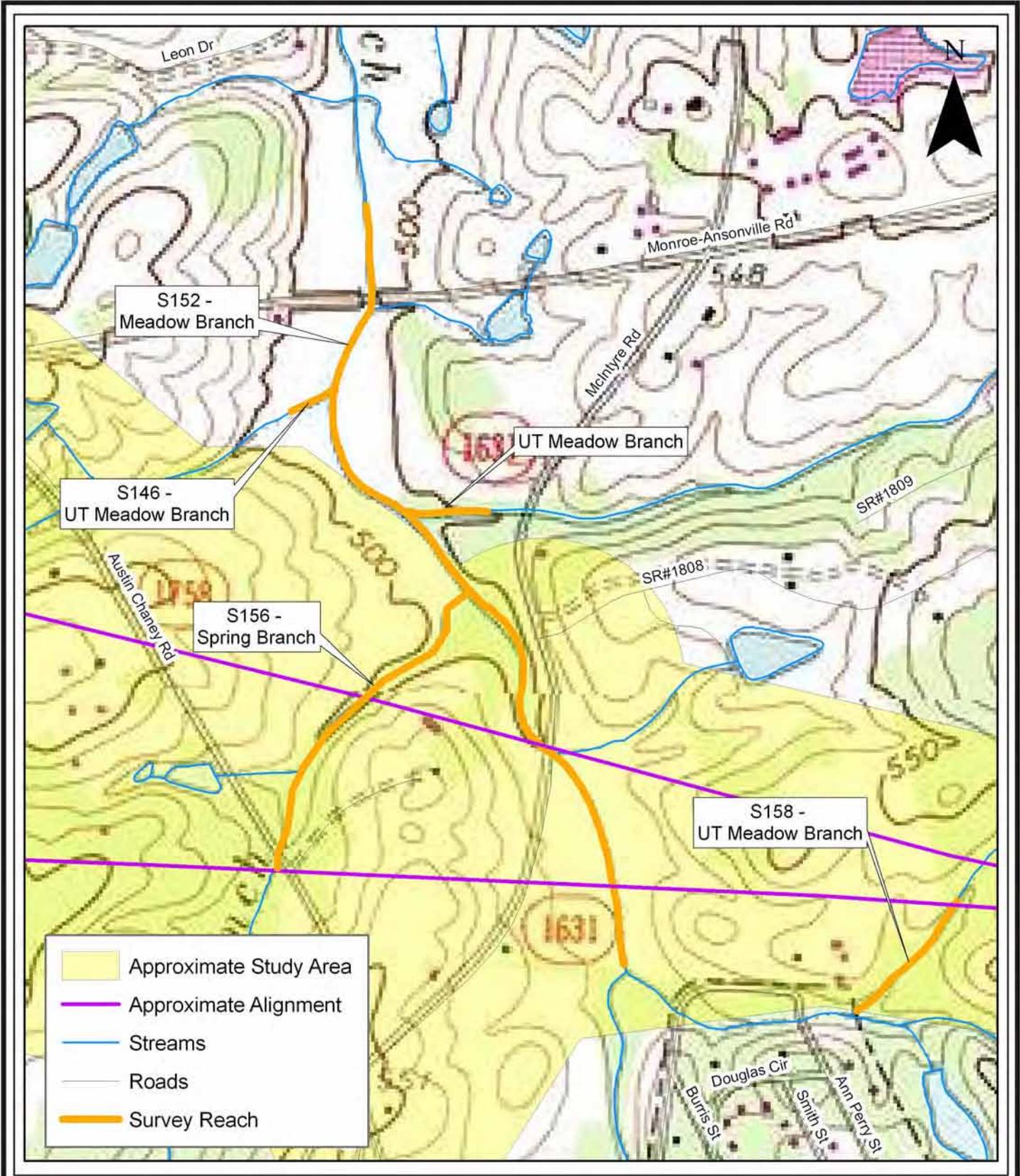
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Date: June 2009

Scale: 0 100 200 Meters

Job No.: 3247

Sheet
12



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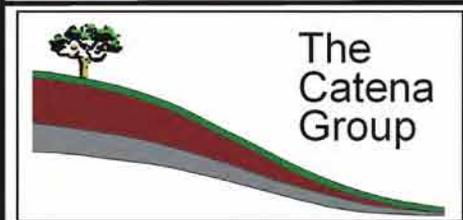
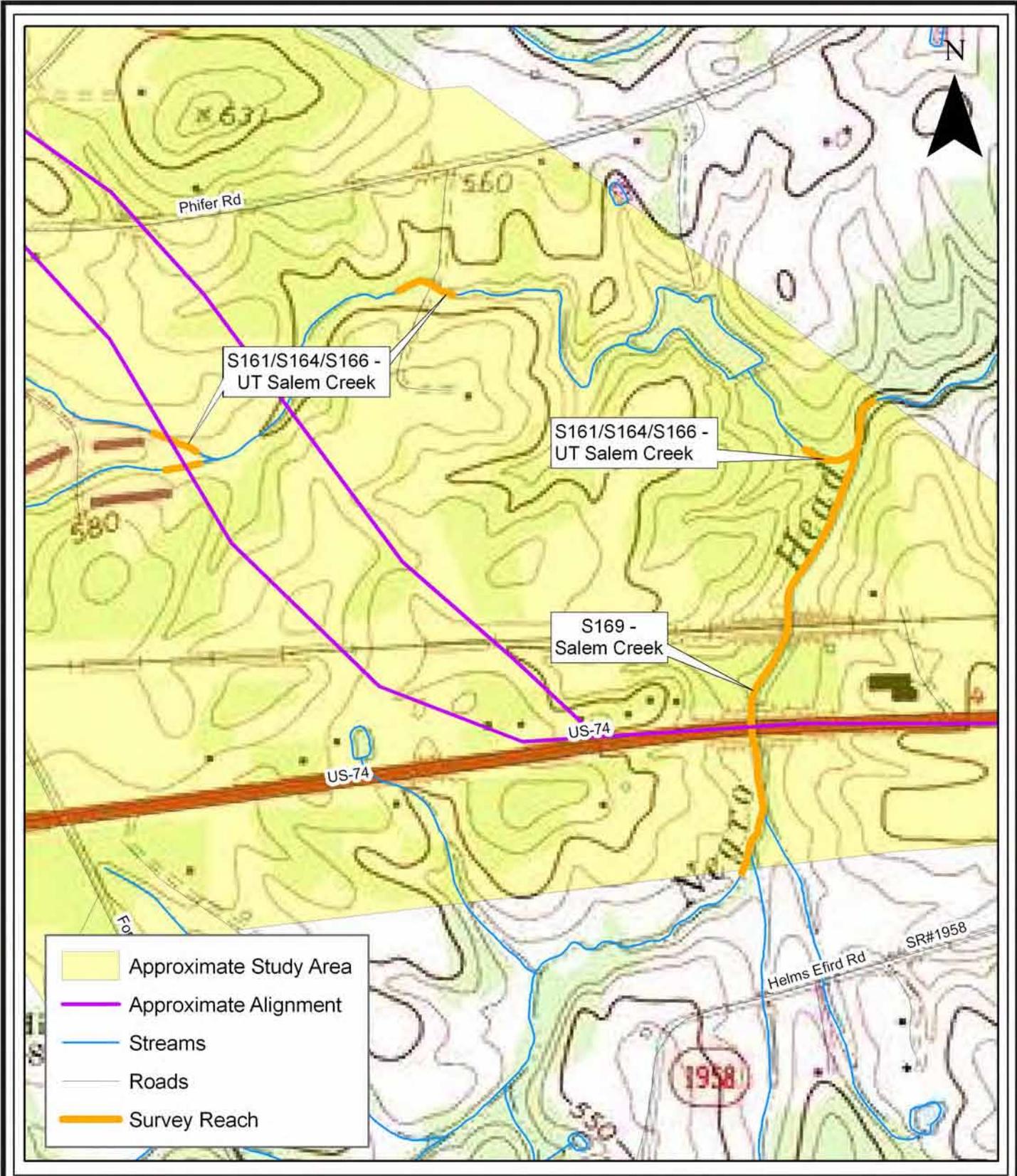
Mecklenburg and Union
 Counties, North Carolina

Date: June 2009

Scale: 0 80 160 Meters

Job No.: 3247

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13



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 (STIP R-3329 / R-2559)

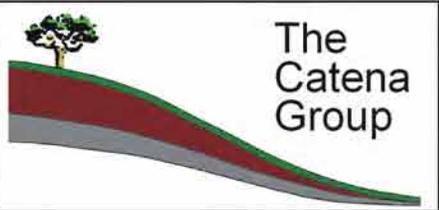
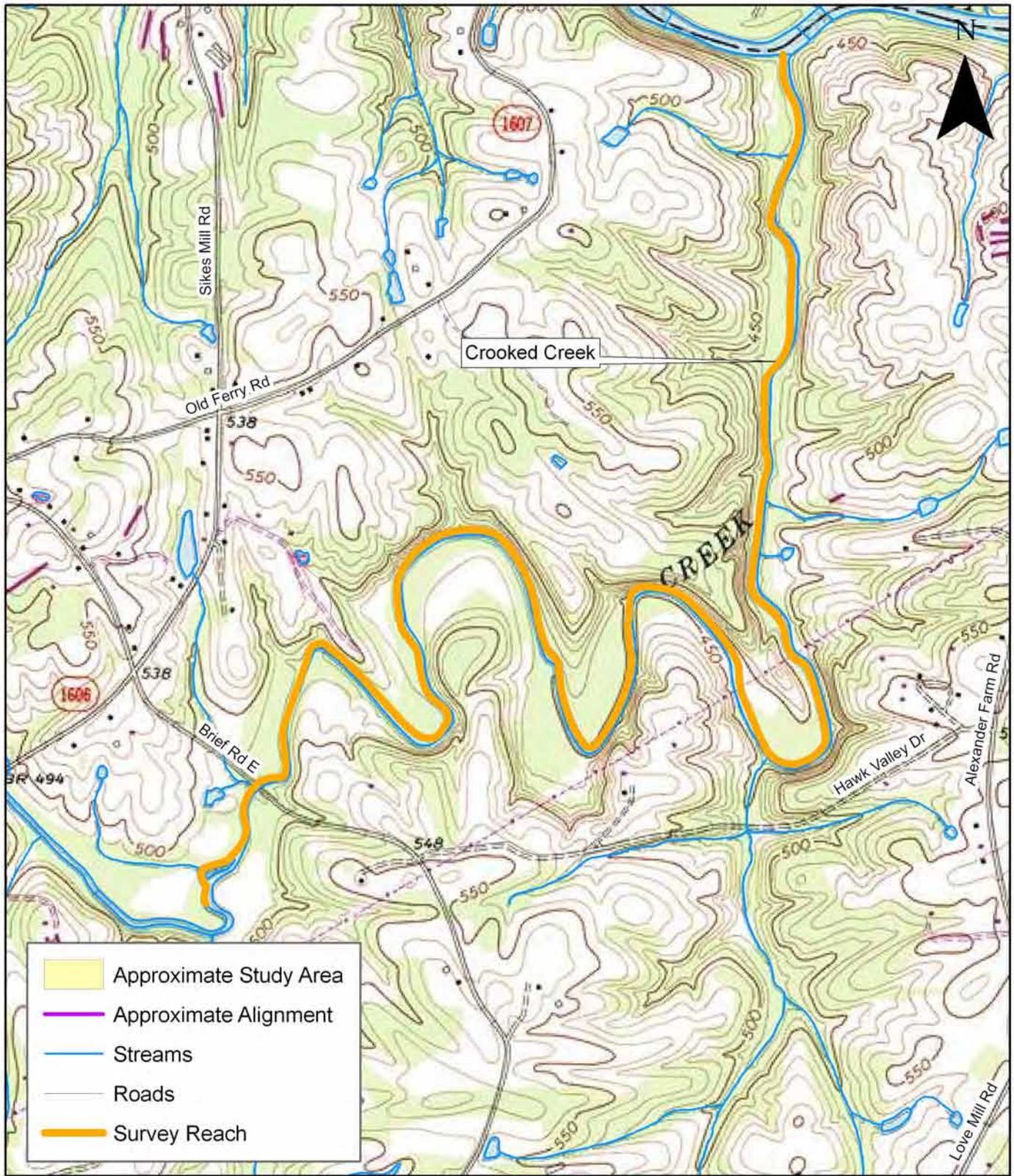
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 Counties, North Carolina

Date: June 2009

Scale: 0 95 190 Meters

Job No.: 3247

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Date:	June 2009
Scale:	0 150 300 Meters
Job No.:	3247

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