BIOLOGICAL ASSESSMENT

AN ASSESSMENT OF POTENTIAL EFFECTS TO FEDERALLY LISTED SPECIES

For

Complete 540 –
Triangle Expressway Southeast Extension
Wake, Johnston, & Harnett Counties

STIP Project Nos. R-2721, R-2828, and R-2829
State Project Nos. 6.401078, 6.401079, and 6.401080
Federal Aid Project Nos. STP-0540(19), STP-0540(20), and STP-0540(21)
WBS Nos. 37673.1.TA2, 35516.1.TA2, and 35517.1.TA1

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Glossary of Endangered Species Act Definitions:

Action Area – All areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. [50 CFR §402.02].

Cumulative effects - those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation. [50 CFR §402.02] This definition applies only to section 7 analyses and should not be confused with the broader use of this term in the National Environmental Policy Act or other environmental laws.

Discountable – extremely unlikely to occur.

Effects of the action - the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action. These effects are considered along with the environmental baseline and the predicted cumulative effects to determine the overall effects to the species for purposes of preparing a biological opinion on the proposed action. [50 CFR §402.02] The environmental baseline covers past and present impacts of all Federal actions within the action area. This includes the effects of existing Federal projects that have not yet come in for their section 7 consultation.

Insignificant - relate to the size of the impact and should never reach the scale where take occurs.

Interdependent action- An action that has no independent utility apart from the proposed action that is subject to consultation [50 CFR §402.02].

Interrelated action - An action that is part of a larger action, and that depends on the larger action for its justification [50 CFR §402.02].

Glossary of Freshwater Mussel Definitions:

Anterior – front or forward

Cardinal teeth – teeth located between the lateral teeth in Corbiculidae and Sphaeriidae

Dorsal – the top or back; in mussels, the hinge area

Gill – a thin plate-like paired structure within the mantel cavity, which serves as a respiratory organ in aquatic mollusks and in female unionids all of the gills or certain portion of the gills serve as the marsupium.

Glochidia – the bivalve larva of unionids which are generally parasitic on the gills of fish

Gravid – a female that has embryos in the marsupium

Hinge ligament – an elastic, elongate, corneous structure that unites the two valves dorsally along the hinge plate.

Marsupium – in unionids, a brood pouch for eggs and developing glochidia, formed by a restricted portion of the outer gill, the complete outer gill, or all four gills

Mantle – soft tissue enclosing the body of a mussel, the principal function of which is to secrete the shell. In some species of the Subfamily Lampsilinae, the posterior portion of the female mantle serves to attract host fish by mimicking the shape and movement of fish or crayfish.

Nacre – the interior iridescent, then layer of a mussel shell.

Naiad – formerly a tribe of Mollusca nearly equivalent taxonomically to the family Unionidae, often used as a synonym of unionid.

Periostracum – exterior or outside layer of the shell.

Posterior – hind or rear

Pseudocardinal teeth – triangular-shaped hinge teeth near the anterior -dorsal margin of the shell

Salvage area – the construction footprint plus an up- and down-stream buffer from which freshwater mussels will be removed prior to construction

Tachytitic – mussels which are short-term breeders; i.e., glochidia are found in the gills of the female only during the summer.

Valve – the right or left half of a mussel (or unionid) shell.

Ventral – the underside or bottom.

1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT), in cooperation with the Federal Highway Administration (FHWA), proposes transportation improvements to NC 540, a project known as the "Complete 540 – Triangle Expressway Southeast Extension" in Wake and Johnston Counties, North Carolina (Figure 1). The proposed roadway is a controlled-access toll road, approximately 27 miles in length.

The purpose of this Biological Assessment (BA) is to evaluate the potential effects of the Complete 540 project on federally listed and proposed species and designated critical habitat in accordance with Section 7 of the Endangered Species Act (ESA) (16 U.S.C. 1536 (c)). Section 7(a)(2) of the ESA (16 USC 1531-1544 and Section 1536) requires that each Federal agency shall, in consultation with the U.S. Fish & Wildlife Service (USFWS), ensure that any action authorized, funded, or carried out by such agency, is not likely to jeopardize the continued existence of an endangered or threatened species, or result in the destruction or adverse modification of critical habitat. Since the proposed project includes both funding by FHWA and approval by the U.S. Army Corps of Engineers (USACE) pursuant to the Clean Water Act (CWA), the project is subject to consultation under Section 7 of the ESA. This BA is provided to satisfy the action agencies' (FHWA and USACE) obligations under Section 7 of the Endangered Species Act of 1973 (ESA) (See Glossary on Page vi of this report). FHWA is the lead federal agency for NEPA and the ESA.

FHWA and NCDOT is evaluating the project under the National Environmental Policy Act, as amended (42 U.S.C. 4321, et seq.) (NEPA). This BA is primarily based upon information developed for the Complete 540 project, including the Aquatic Species Survey Report (Three Oaks Engineering [Three Oaks} 2017), Dwarf Wedgemussel (DWM) Viability Study (Three Oaks 2016), Qualitative Indirect and Cumulative Effects (ICE) report (H.W. Lochner [Lochner] 2014, planning horizon is 2035), Quantitative ICE report (Michael Baker Engineering [Baker Engineering] 2017a, 2017b, 2017c, 2017d, planning horizon is 2040), Draft Environmental Impact Statement (DEIS) (H.W. Lochner 2015), and analyses detailed in this report (Appendices C, D, and E). Note that the definitions for Indirect Effects and Cumulative Effects differs between NEPA and ESA.

1.1 Statutory Authority of Action

The proposed project is included in the NCDOT's *2016-2025 State Transportation Improvement Project* (STIP), project numbers R-2721 (NC 55 to US 401), R-2828 (US 401 to I-40), and R-2829 (I-40 to US/64/US 264 Bypass (I-495)) (Figure 3). NCDOT derives their statutory authority via North Carolina General Statutes (NCGS) 143B-345 and 346 and FHWA derives their statutory authority via 49 US Code (USC) 104.

1.2 Summary of Consultation History

In a letter dated February 17, 2011, from USFWS to NC Turnpike Authority (NCTA), the USFWS indicated that an updated Environmental Baseline on the DWM (*Alasmidonta heterodon*) population in Swift Creek would be needed to determine if the proposed action could potentially jeopardize the continued existence of this species. The USFWS suggested a three-tiered study to develop the updated baseline. Three Oaks, at the time The Catena Group (Catena), was contracted by (NCTA, through Lochner) to conduct this DWM Viability Study. The two reports produced as part of the study provide accounting of conservation measures implemented in Swift Creek to protect DWM, assess the effectiveness of those conservation measures regarding habitat and population stability, and assess the historic trends and current viability of the DWM population and its habitat in Swift Creek. The population trends of the other freshwater mussel species that occur in Swift Creek were also evaluated, including the Yellow Lance (*Elliptio lanceolata*), a species that has been officially proposed for federal listing and is also addressed in this BA. The DWM Viability Study determined that, while the DWM population in Swift Creek is under significant stress from urbanization in the watershed, declines appear to have leveled off and there is a chance the species could persist into the future if active management plans are implemented (Catena 2014, Three Oaks 2016).

In September 2013, NCDOT published the Draft Alternatives Development and Analysis Report for the Complete 540 project, including a list of recommended Detailed Study Alternatives. NCDOT decided to study all recommended alternatives in detail in the DEIS, which was completed in October 2015. The preferred alternative was selected in April 2016 (Figure 2), and the Final Environmental Impact Statement (FEIS) is anticipated in mid-2018.

A Qualitative ICE study was prepared by Lochner and finalized in December 2014. A Quantitative ICE were prepared for the FEIS. The first two parts of the study (Baker Engineering 2017a, Baker Engineering 2017b) were used to prepare the Memorandum on Water Quality Modeling Methodology and Results (WQ ICI), and Indirect and Cumulative Effects Memorandum (Baker Engineering 2017c, Baker Engineering 2017d).

2.0 PROJECT AND ACTION AREA DESCRIPTION

2.1 Project Description

The Complete 540 project is proposed to be a controlled-access toll road extending the existing Triangle Expressway from NC 55 Bypass in Apex to the US 64/US 264 Bypass (I-495) in Knightdale, a distance of approximately 27 miles. The project will occupy approximately 1,240 acres within the proposed right of way (ROW). The proposed action will improve mobility, reduce forecast traffic congestion on the existing roadway network, and improve system linkage within the project study area.

2.2 Avoidance and Minimization During Alternative Development

Consideration was given to the location of endangered species throughout the alternatives development and design process, based on the best available information regarding the known locations of the protected species populations. Specific consideration was provided to the DWM. As such, the DEIS states "all [design study alternatives] DSAs except those using the Red Corridor segment (Alternatives 6 and 7) cross Swift Creek below Lake Benson and therefore have the potential to directly affect the DWM. NCDOT is working with USFWS to develop feasible strategies to offset the project's effects on these species and will complete the Section 7 consultation process following the selection of the Preferred Alterative" (H.W. Lochner 2015). Yellow Lance had not been proposed listed at the time of alternative development.

2.3 Description of Action Area

The Action Area, as defined in 50 CFR 402.02, includes all areas to be affected directly or indirectly by a federal action and not merely the immediate area involved in the action, which for this project includes the land area within the Future Land Use Study Area (FLUSA) as defined in the DEIS, and the proposed freshwater mussel propagation facility (Yates Mill Aquatic Conservation Center) in Wake County, which is being developed as a conservation measure for this project (Section 4.5.2.2). Portions of Wake, Johnston, and Harnett Counties, North Carolina occur within the Action Area (Figure 1). The FLUSA component of the Action Area extends southward into northern Harnett County, and encompasses most of southern Wake County and a large portion of northern Johnston County (H.W. Lochner 2014). The Action Area includes the entire Swift Creek Watershed (SCW) below Lake Benson to allow for evaluation of potential effects on the DWM and Yellow Lance. The Action Area totals approximately 278,000 acres.

2.4 Federally Listed Species: Wake, Johnston, and Harnett Counties, NC

Based on the official USFWS species list by county (dated July 10, 2017 for Wake County, April 6, 2017 for Johnston County, and September 13, 2017 for Harnett County), the USFWS lists seven federally protected and one proposed species as occurring in Wake, Johnston, and/or Harnett Counties (Table 1). There is no designated critical habitat within the Action Area for the species listed in Table 1. However, on August 17, 2017, the National Marine Fisheries Service (NMFS) designated critical habitat for the Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the Neuse River from the confluence with the Pamlico Sound below New Bern, to the base of the Milburnie Dam, just east of Raleigh. The project alignment crosses the Neuse River within this critical habitat unit, and 16 river miles of the unit occurs within the FLUSA portion of the Action Area. This species is currently not on the official USFWS species list for either Johnston, or Wake Counties. The NMFS is the lead consultation agency for this species; thus, the Section 7 consultation with the NMFS will be handled separately from this consultation.

The USFWS is in varying stages of conducting Species Status Assessments (SSAs) on four of the aquatic species in Table 1, the Atlantic Pigtoe, Carolina Madtom, Green Floater, and Neuse River Waterdog, to determine if federal listing as endangered or threatened is warranted. These species are not addressed in this BA; however, Three Oaks has gathered baseline data for these species if they become formally listed during the development stages of this project. Additionally, there are current documented occurrences of Michaux's Sumac in the Action Area.

Table 1. Federally Listed Species; Wake, Johnston, and Harnett Counties, North Carolina

Scientific Name	Common Name	Status	County	Present in Action Area
Alasmidonta heterodon	Dwarf Wedgemussel	E	W, J	Yes
Elliptio lanceolate	Yellow Lance	Proposed	W, J	Yes
Fusconaia masoni	Atlantic Pigtoe	Petitioned	W, J, H	N/A
Haliaeetus leucocephalus	Bald Eagle	BGPA	W, J, H	N/A
Lasmigona subviridis	Green Floater	Petitioned	W, J	N/A
Lysimachia asperulaefolia	Rough-leaved Loosestrife	E	H	No
Necturus lewisi	Neuse River Waterdog	Petitioned	W, J	N/A
Notropis mekistocholas	Cape Fear Shiner	E	H	No*
Noturus furiosus	Carolina Madtom	Petitioned	W, J	N/A
Parvaspina steinstansana	Tar River Spinymussel	E	J	No
Picoides borealis	Red-cockaded Woodpecker	E	W, J, H	No
Rhus michauxii	Michaux's Sumac	E	W, J	Yes

Notes: BGPA – Bald and Golden Eagle Protection Act, T – Threatened, E – Endangered, W – Wake, J- Johnston, H – Harnett, N/A – Not Applicable at this time; * No longer present in subwatershed

The official species list for this project was based on potential federally listed species in all of Wake, Johnston, and Harnett Counties. The Action Area for the project is a smaller area than the counties' limits. Given this, the species on the official species list that are outside the Action Area and do not require ESA Section 7 consultation are noted as N/A. These species are addressed briefly in Section 9.0 with a "No Effect" determination.

The DWM, Yellow Lance, Michaux's Sumac, and Cape Fear Shiner are known to occur within some portion of the Action Area (Table 1) and the potential project related effects to these species are considered in this BA.

In addition, Table 1 lists four species that were petitioned for listing by the Center for Biological Diversity (CBD 2010). The petitioned species (Atlantic Pigtoe, Carolina Madtom, Green Floater, and Neuse River Waterdog) are also known to occur in watersheds within the Action Area (Table 1). While these species are currently not afforded protection under the ESA, and are thus not subject to Section 7, NCDOT and FHWA recognize that they do occur in the Action Area and may become federally protected during the life of this project, in which case Section 7 Consultation will be reinitiated. Thus, NCDOT has gathered information on these species during the environmental documentation phases of this project in the event they do become listed.

2.5 Habitat Conservation Plans In Action Area

There have been no Habitat Conservation Plans developed for any listed species within the Action Area.

2.6 Potential Effects of the Action

Effects of the action refer to the direct and indirect effects on the species and/or critical habitat, together with the effects of other activities that are interrelated or interdependent with the action, that will alter the environmental baseline. Direct effects are caused by the proposed action and generally occur at the same time and place as the project. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur [50 CFR 402.02]. These types of effects can include natural responses to the proposed action's direct effects, or can include human induced effects associated with the proposed action [50 CFR 402.02].

Interrelated actions are defined as actions that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Interrelated/Interdependent action areas include project-associated utility relocations, as well as construction borrow pits, haul roads, staging areas, and development patterns induced by the action.

Preliminary roadway designs for the Preferred Alternative are in progress at the time of this BA submittal, therefore, the proposed roadway used for planning purposes consists of a six-travel lane facility with 70-foot median. For areas where existing roads would cross the highway, various existing two and four-lane roads (e.g. Sunset Lake Road and Holly Springs Road) would be widened to be consistent with the adopted Metropolitan Transportation Plan. The areas of construction effects will encompass:

- The Complete 540 roadway footprint, including improvements along crossing roads
- Adjacent areas impacted for permanent fixtures (noise walls, ROW fences, etc.)
- Associated utility relocations (temporary as well as permanent)
- Haul/access roads
- Staging areas
- Borrow sites
- Other ground disturbing activities directly associated with the project.

Cumulative effects are those of future state or private activities, not involving federal activities, which are reasonably certain to occur within the Action Area of the proposed federal action. In addition to highway improvements, other infrastructure projects such as water and sewer service have the potential to stimulate land development and directly or indirectly result in effects within the Action Area. However, these other types of infrastructure will likely require some type of federal authorization, such as a CWA 404 permit, and would therefore, have their own ESA Section 7 consultation and not be considered a cumulative effect under ESA.

2.7 Conservation Measures

Conservation measures are those measures that facilitate conservation of the species and offer some level of protection by minimizing, or off-setting, project related effects. Conservation measures are included as part of the Action. These measures are discussed in Section 4.5 of this report.

2.8 Other Consultations in Action Area

Following are the relevant previous consultations under Section 7 of the ESA with USFWS for projects within the Complete 540 Action Area (as defined in Section 2.3):

- Bridge No. 72 on NC 210 over Swift Creek in Johnston County (TIP B-2647) was replaced in 2015 (Catena 2013). The findings of a Biological Evaluation were transmitted to the USFWS in a letter dated March 20, 2013.
- Bridge No. 147 on SR 1525 (Cornwallis Road) over Swift Creek in Johnston County (TIP B-4561) was replaced in 2013 (Catena 2012a). The findings of a BA were transmitted to the USFWS in a letter dated October 10, 2012.
- Clayton Bypass - the Clayton Bypass was a 10.7-mile highway connecting I-40 in Wake County and US-70 in Johnston County that opened in 2008. As a part of the Section 7 Consultation for this project, the Town of Garner, Wake County, and Johnston County separately entered into Memoranda of Understanding (MOUs) with NCDOT and USFWS. Each MOU was specific to the municipality/county, but they all were aimed at reducing the potential effects of the Clayton Bypass on the DWM. The Town of Garner agreed to limit development adjacent to Swift Creek and other important streams. Wake County and Johnston County also implemented development restrictions. Johnston County also created a Watershed Administrator position to implement watershed ordinances, which was funded by NCDOT. More details about these conservation efforts are in the DWM Viability Report (Three Oaks 2016).
- Dempsey E. Benton Water Treatment Plant (WTP) – The City of Raleigh operates the Dempsey E. Benton WTP, which opened May 12, 2010. Raleigh coordinated with the USFWS on terms and conditions for offsetting effects from the WTP to the DWM. These measures include monitoring outflows from the WTP, limiting maximum base withdrawal rate and frequency of the maximum withdrawal rate, water quality monitoring, managing Lake Benson Dam to prevent reductions in downstream flows, decommissioning two small wastewater treatment facilities, and purchasing greenway

corridors surrounding Lake Benson. More details about these conservation efforts are in the DWM Viability Report (Three Oaks 2016).

3.0 ENVIRONMENTAL BASELINE FOR DWM AND YELLOW LANCE

As noted in Section 2.4, the DWM and Yellow Lance are known to occur within a portion of the Action Area, specifically Swift Creek Watershed below Lake Benson and Middle Creek Watershed (outlined in Figure 3) and have the potential to be affected by the proposed action. The area within these watersheds (88,300 acres) is approximately 32 percent of the FLUSA portion of the Action Area. Due to the similarity in threats and location of the two species, DWM and Yellow Lance are analyzed collectively in this section.

3.1 Watershed Conditions Baseline

DWM and Yellow Lance are known to occur within two subbasins of the Upper Neuse River Basin, Middle Creek and Swift Creek, within the Action Area. The current, physical and chemical conditions of these watersheds are a primary factor that influence the population status of the respective species. The Upper Neuse River Basin (US Geological Survey hydrologic unit 03020201) covers an area of approximately 540,000 acres in Person, Orange, Durham, Granville, Franklin, Wake, Johnston, Wilson and Wayne Counties. The Upper Neuse River drains all of Raleigh, Hillsborough, Wake Forest, Garner, and portions of Durham, Cary, and many other municipalities. The headwaters of the Neuse River are the Eno, Flat, and Little Rivers in Person and Orange Counties, which flow southeast into Falls Lake in Durham and Granville Counties, a manmade reservoir covering more than 12,000 acres. Following in the southeasterly flow, the next major tributaries to the Neuse River are Crabtree Creek and Walnut Creek in Wake County and Swift Creek, Middle Creek, Black Creek, and Mill Creek in Johnston County. The Little River flows into the Neuse River in Wayne County. Downstream, the Neuse River flows through the Middle Neuse River Basin and continues toward Albemarle Pamlico Sound and the Atlantic Ocean. Baseline conditions of the Middle Creek and Swift Creek subbasins are discussed below.

3.1.1 Best Usage Classification

The North Carolina Department of Environmental Quality (NCDEQ) assigns a best usage classification to all waters of North Carolina. These classifications, which are the responsibility of the Division of Water Resources (NCDWR), provide a level of water quality protection to ensure that the designated usage of that water body is maintained. The minimum designation of Class C waters is defined as waters that are suitable for aquatic life propagation and survival, fishing, wildlife, secondary recreation and agriculture. Class C imposes a minimum standard of protection for all waters of North Carolina; they are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture, and other uses suitable for

Class C. Class B waters provide the same protection as Class C waters, plus primary recreation. Primary recreation is the use of waters for swimming or other activities involving contact with the water. Water Supply (WS) waters are protected for Class C uses and additionally are used as a source of drinking water or other uses of consumption. WS classifications are further categorized with a suffix of -I to -V, with -I being in undeveloped areas in public ownership and having a High Quality Waters supplemental classification and -V having the least amount of protection and often used by industry. A classification of WS-III, which is found in streams within the Action Area, have fewer restrictions than WS-I and WS-II streams and are found in low to moderately developed areas. Nutrient Sensitive Waters (NSW) is a supplemental classification intended for waters needing additional nutrient management due to being subject to excessive growth of microscopic or macroscopic vegetation. The entire Neuse River Basin is classified as NSW.

Table 2 lists the named streams in the Action Area within either the Middle Creek or Swift Creek subbasins and their Usage Classification and NCDWR Index number (#). Unnamed tributaries carry the classification of the receiving water body. Figure 3 shows the streams in the FLUSA.

3.1.2 Impaired 303(d) Listing

As mandated in Section 303(d) of the CWA by the US Environmental Protection Agency (EPA), states, territories, and authorized tribes are required to develop lists of impaired waters, which are defined as water bodies that do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. These water quality standards include designated uses, numeric and narrative criteria, and anti-degradation requirements as defined in 40 CFR 131. Failures to meet standards may be due to an individual pollutant, multiple pollutants, or unknown causes of impairment, originating from point and non-point sources and/or atmospheric deposition. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Load (TMDLs) limits of identified pollutants for these waters.

Table 2. Action Area Streams within Middle and Swift Creek Subbasins

Steam Name	Usage Classification	DWR Index #
Middle Creek (HUC# 0302020109)		
Basal Creek [(Bass Lake) (Mills Pond)]	B; NSW	27-43-15-3
Beaverdam Branch	C; NSW	27-43-15-13
Bells Lake	C; NSW	27-43-15-6
Buffalo Branch	C; NSW	27-43-15-11
Camp Branch	C; NSW	27-43-15-5
Cow Branch	C; NSW	27-43-15-14
Ditch Branch	C; NSW	27-43-15-10-2-1
Guffy Branch	C; NSW	27-43-15-10-2
Juniper Creek	C; NSW	27-43-15-10-1
Little Creek	C; NSW	27-43-15-10

Table 2. Action Area Streams within Middle and Swift Creek Subbasins (continued)

Steam Name	Usage Classification	DWR Index #
Middle Creek	C; NSW	27-43-15-(1)
Middle Creek (Sunset Lake)	B; NSW	27-43-15-(2)
Middle Creek	C; NSW	27-43-15-(4)
Mill Branch	C; NSW	27-43-15-12
Mills Branch	C; NSW	27-43-15-7
Rocky Branch	C; NSW	27-43-15-4.5
Shop Branch	C; NSW	27-43-15-15
Steep Hill Branch	C; NSW	27-43-15-16
Terrible Creek	C; NSW	27-43-15-8-(2)
Terrible Creek (Johnsons Pond)	B; NSW	27-43-15-8-(1)
Swift Creek (HUC# 0302020110)		
Buck Branch	WS-III; NSW	27-43-6-(1)
Cooper Branch	C; NSW	27-43-13
Dutchmans Creek	WS-III; NSW	27-43-4.5
Little Creek	C; NSW	27-43-12
Long Branch	WS-III; NSW	27-43-2.8
Lynn Branch [(Meadows Creek) (Lochmere Lake)]	WS-III; NSW	27-43-3
Macgregor Downs Lake	WS-III; NSW	27-43-2.2
Mahlers Creek	C; NSW	27-43-9
Neal Branch	C; NSW	27-43-10
Reedy Branch	WS-III; NSW	27-43-7-(1)
Reedy Branch (Little Branch)	C; NSW	27-43-14
Regency Park Lake	WS-III; NSW	27-43-2.5
Speight Branch	WS-III; NSW	27-43-3.5
Swift Creek (Lake Wheeler)	WS-III; NSW	27-43-(1)
Swift Creek (Lake Benson)	WS-III; NSW; CA	27-43-(5.5)
Swift Creek	C; NSW	27-43-(8)
Unnamed Tributary (UT) to Swift Creek (Yates Mill Pond)	WS-III; NSW	27-43-5-(1.5)
White Oak Creek (Austin Pond)	C; NSW	27-43-11
Woodys Lake	WS-III; NSW	27-43-4

The 303(d) Category 5 streams, which require a TMDL or TMDL alternative, in the Middle Creek and Swift Creek subbasins are listed in Table 3 along with details of the impairments. They are also shown in Figure 4. As of the writing of this report, the 2016 303(d) list has not been finalized, though a draft was submitted to the EPA. The draft 2016 303(d) list (NCDEQ 2017a), submitted by NCDEQ, did not propose changes to the streams listed below.

Table 3. Impaired (Category 5) Streams 2014 in Middle and Swift Creek Subbasins

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Middle Creek (HUC# 0302020109)				
Middle Creek	27-43-15-(1)b1	3 FW Miles	Fair Bioclassification	Ecological/Biological Integrity (Bio Int) Benthos (2008)
Middle Creek	27-43-15-(1)b2	1.6 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)
Middle Creek	27-43-15-(4)a1	4.5 FW Miles	Poor Bioclassification	Fish Community (2014)
Terrible Creek	27-43-15-8-(2)	7.8 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)

Table 3. Impaired (Category 5) Streams 2014 in Middle and Swift Creek Subbasins (continued)

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Swift Creek (HUC# 0302020110)				
Swift Creek	27-43-(1)d	2.4 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2008)
Swift Creek (Lake Benson)	27-43-(5.5)a	0.87 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2008)
UT to Swift Creek (Lake Benson)	27-43-(5.5)but7	2.7 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2014)
Swift Creek	27-43-(8)a	20.6 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)
Little Creek	27-43-12	11.4 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (1998)

Notes: FW – Freshwater Miles

3.1.3 Point Source Pollution

Point source discharge is defined as discharge that enters surface waters through a pipe, ditch, or other well-defined point of discharge. This includes municipal (city and county) and industrial wastewater treatment facilities, small domestic discharging treatment systems (schools, commercial offices, subdivisions and individual residents), and stormwater systems from large urban areas and industrial sites. The primary substances and compounds associated with point source discharge include nutrients, oxygen demanding wastes, and toxic substances such as chlorine, ammonia, and metals.

Under Section 301 of the CWA, discharge of pollutants into surface waters is prohibited without a permit by the EPA. Section 402 of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) permitting program, which delegates permitting authority to qualifying states. In North Carolina, NCDWR is responsible for permitting and enforcement of the NPDES program. Point source dischargers located throughout North Carolina are permitted through the NPDES program. All dischargers are required to register for a permit. NPDES dischargers are divided into two categories: individual and general. General permits are issued for specific activities, including non-contact cooling water discharges, petroleum-based groundwater remediation, sand dredging, seafood packaging, and domestic discharges from single family residences. Individual permits are issued on a case-by-case basis for activities not covered under general permits. Individual permits are divided into two classes: major and minor. Major discharges are permitted to discharge one million gallons per day (MGD) or greater. Minor discharges are permitted to discharge less than 1 MGD.

The NPDES Permitting Policy includes limits on various parameters, including, but not limited to chlorine (since October 2002), ammonia, fecal coliform, biological oxygen demand (BOD), dissolved oxygen (DO), flow, and temperature, for the existing facilities.

The FLUSA has 28 NPDES individual permitted discharges and 53 NPDES general permitted discharges (Figure 5). There are 15 individual permitted discharges and 13 general permitted discharges in the Middle Creek subbasin (Tables 4 and 5). There are 5 individual permitted discharges and 19 general permitted discharges in Swift Creek subbasin (Tables 4 and 5). Individual NPDES permits are issued on a case by case basis and are site specific. General permits, on the other hand, cover discharges with similar operations and types of discharges that are applicable state-wide. The requirements of a general permit are defined and known by the permittee. In general, an individual permit will take longer to be issued than a general permit (NCDEQ 2017b). Included in Table 5 are NPDES general permitted discharges.

Table 4. NPDES Individual Permitted Discharges within Middle and Swift Creek Subbasins

Permit	Facility	Receiving Stream	Flow (GPD)	Owner
Middle Creek (HUC# 0302020109)				
NC0064050	Apex WRF	Middle Creek	3,600,000	Town of Apex
NC0022217	Apex Terminal	Middle Creek	Not limited	Motiva Enterprises LL
NC0062740	Briarwood Farms WWTP	Middle Creek	40,000	Aqua NC, Inc.
NC0082996	Hollybrook WTP	Middle Creek	Not limited	Aqua NC, Inc.
NC0088862	Sunset Forest Subdivision Well #1	Basal Creek	Not limited	Aqua NC, Inc.
NC0086690	Stansted Well #2 (WTP)	Basal Creek	Not limited	Aqua NC, Inc.
NC0065102	South Cary WRF	Middle Creek	16,000,000	Town of Cary
NC0062715	Crooked Creek WWTP	Middle Creek	150,000	Aqua NC, Inc.
NC0061638	Amherst WWTP	Middle Creek	53,000	Carolina Water Service, Inc. of North Carolina
NC0066150	Brighton Forest WWTP	Middle Creek	117,000	Town of Fuquay-Varina
NC0066516	Terrible Creek WWTP	Terrible Creek	6,000,000	Town of Fuquay-Varina
NC0073679	Oak Hollow WTP	Middle Creek	Not limited	Carolina Water Service, Inc. of North Carolina
NC0087998	Rand Meadows Phase II	Juniper Branch	Not limited	Aqua NC, Inc.
NC0088714	Lassiter Farm Subdivision WTP	Ditch Branch	Not limited	Aqua NC, Inc.
NC0088889	Hopson Downs Subdivision Well #4	Basal Creek	Not limited	Aqua NC, Inc.
Swift Creek (HUC# 0302020110)				
NC0060526	Pope Industrial Park	Swift Creek	8,000	Pope Industrial Park II Ltd Partnership
NC0088285	Dempsey E Benton WTP	Swift Creek	Not limited	City of Raleigh Public Utilities Department
NC0055701	Nottingham WTP	Swift Creek	Not limited	Aqua NC, Inc.
NC0049034	Mount Auburn Training Center	White Oak Creek	2,400	Wake County
NC0025453	Little Creek WRF	Little Creek	2,500,000	Town of Clayton

WRF = Water Reclamation Facility, WTP = Water Treatment Plant, WWTP = Wastewater Treatment Plant

Table 5. NPDES General Permitted Discharges within Middle and Swift Creek Subbasins

Middle Creek (HUC# 0302020109)	
Permit	**Facility**
NCG070111	Johnson Concrete Co
NCG110047	Town of Apex
NCG070014	Potters Industries LLC
NCG050092	Lufkin Division of Cooper Ind
NCG030281	Tipper Tie Inc
NCG080166	Colonial Pipeline
NCG110117	Town of Cary South WWTP
NCG551522	9624 Fayetteville Rd
NCG140010	S.T. Wooten Corp
NCG070075	NC Products
NCG160036	Gelder & Associates Inc
NCG510527	Don Lees Gas
NCG140073	Southern Equipment Concrete
Swift Creek (HUC# 0302020110)	
NCG200446	Wise One Clayton Plant
NCG150055	Johnston County Airport
NCG160050	S.T. Wooten Corp Drug Store

Swift Creek (HUC# 0302020110)	
Permit	**Facility**
NCG070072	Oldcastle Precast Inc
NCG500360	Oldcastle Precast Inc
NCG551548	601 Maple Lane
NCG551532	815 Colonial Drive
NCG130026	Safety - Kleen Corporation
NCS000420	Town of Garner MS4
NCG080688	Wade H Vester Public Works
NCG140074	Ready Mixed Concrete Co
NCG210346	Pergo Inc
NCG030111	Morris & Associates
NCG060235	Domino's Pizza
NCG551048	Dockside Dolls Night Club
NCG100095	Raleigh Auto Parts Inc
NCD000024	White Oak Landing Phase III
NCG110080	Little Creek Water Reclamation
NCG200498	Source Recycling of Raleigh

3.1.4 Non-point Source Pollution

Non-point source (NPS) pollution refers to runoff that enters surface waters through stormwater or snowmelt. There are many types of land use activities that contribute to NPS pollution, including land development, construction activity, animal waste disposal, mining, agriculture, and forestry operations, as well as impervious surfaces such as roadways and parking lots. Various NPS management programs have been developed by several agencies to control specific types of NPS pollution (e.g. pesticide, urban, and construction related pollution). Each of these management plans develops Best Management Practices (BMPs) to control for a specific type of NPS pollution. For example, financial incentives to reduce agricultural NPS pollution are provided through North Carolina's Agriculture Cost Share Program, administered by the North Carolina Department of Agriculture and Consumer Service's Division of Soil and Water Conservation to protect water quality by installing BMPs on agricultural lands.

Land cover for the Neuse River subbasin portion of the FLUSA is shown in Table 6 (Figure 6) (Homer et al. 2015). Deciduous forest makes up the greatest percent of land cover in this portion of the FLUSA, followed closely by developed open space (such as lawns, parks, and golf courses). The effects of non-point pollution on aquatic species associated with human development and associated impervious surface area are discussed in Section 3.5.4.

Table 6. Land cover in the Neuse River subbasins of the FLUSA

Land Cover	Sum of Area (Acres)	Percent
Barren Land	1255.6	0.53
Cultivated Crops	22641.8	9.59
Deciduous Forest	42349.6	17.94
Developed, High Intensity	1296.8	0.55
Developed, Low Intensity	16301.3	6.91
Developed, Medium Intensity	5671.2	2.40
Developed, Open Space	38613.3	16.36
Emergent Herbaceous Wetlands	840.8	0.36
Evergreen Forest	25698.5	10.89
Hay/Pasture	25471.4	10.79
Herbaceous	19795.4	8.39
Mixed Forest	12858.4	5.45
Open Water	2830.4	1.20
Shrub/Scrub	5680.6	2.41
Woody Wetlands	14751.6	6.25
Total	236056.7	100.00

Note: While the same National Land Cover Data raw data was used in the Memorandum on Land Use Scenario – Methodology and Results (Quantitative ICE Assessment Memo #2), the Memorandum further modified the data as required for use in various models. Therefore, this data in Table 6 and ICE Memo #2 Table 4 does not exactly match.

3.1.5 Ecological Significance

The North Carolina Natural Heritage Program (NCNHP) maintains a database of rare plant and animal species, as well as significant natural areas, for the state. The NCNHP compiles the North Carolina Department of Natural and Cultural Resources priority list of "Natural Heritage Areas" as required by the Nature Preserves Act (NCGS 113A-164 of Article 9). Natural areas (sites) are inventoried and evaluated on the basis of rare plant and animal species, rare or high quality natural communities, and geologic features occurring in the particular site. NCNHP has revised its process for establishing conservation priorities (NCDENR 2015) for the more than 2,400 Natural Heritage Natural Areas (NHNA) that have been identified through field investigations. Each NHNA receives two significance ratings, which measure different values and assign a rating from 1 (exceptional) to 5 (general):

1. Element Collective Value rates each NHNA based on the number and rarity of all the elements it contains.
2. Element Representational Value rates each NHNA on its importance in protecting the best occurrences of individual elements.

The following sites are natural areas within the Swift and Middle Creek subbasins of the FLUSA (Figure 7, Table 7).

Table 7. Natural Heritage Natural Areas in the Neuse River subbasins of the FLUSA (NCNHP 2017)

Natural Heritage Natural Area	Representational Value	Collective Value
Neuse/Swift Creek Aquatic Habitat	N/A	C3 (High)
Yates Mill Pond	R1 (Exceptional)	C4 (Moderate)
Swift Creek Bluffs	R4 (Moderate)	C5 (General)
Swift Creek Magnolia Slopes	R5 (General)	C5 (General)
Hemlock Bluffs State Natural Area	R4 (Moderate)	C4 (Moderate)
Reedy Branch Floodplain	R3 (High)	C5 (General)
Middle Creek Bluffs and Floodplain	R2 (Very High)	C4 (Moderate)
Blue Pond Salamander Site	R5 (General)	C5 (General)
Middle Creek – Barber Bridge Floodplain	R5 (General)	C4 (Moderate)
Middle Creek Floodplain Knolls	R5 (General)	C5 (General)
Middle Creek Amphibolite Slope	R5 (General)	C5 (General)
Neuse/Middle Creek Aquatic Habitat	N/A	C3 (High)

In addition to DWM and Yellow Lance, the Swift and Middle Creek subbasins also support many other rare aquatic species. They are listed in Table 8, along with their state and federal status. Additionally, the aquatic habitats of Swift Creek and Middle Creek are considered to have a "High" Collective Value Rating. This rating sums the number of elements in a natural area, and the rarity of those elements, weighted by their degree of imperilment at both the global level (G-Rank) and state level (S-Rank). The imperilment scores are assigned to each extant element occurrence on a 10-point scale, based on their combination of G-Ranks and S-Ranks. The highest scores are given to elements that are considered imperiled at both the global (G1) and state (S1) levels with successively smaller scores given to elements that are considered more secure (G5S5) at both the global and state levels (NCDENR 2015).

Table 8. Non- Federally Protected Rare Aquatic Species in Swift and Middle Creek Subbasins

Scientific Name	Common Name	NC Status	Federal Status	Species Type
Alasmidonta undulata	Triangle Floater	T	~	Mussel
Cambarus davidi	Carolina Ladle Crayfish	SR	~	Crustacean
Elliptio fisheriana	Northern Lance	SR	~	Mussel
Elliptio marsupiobesa	Cape Fear Spike	SC	~	Mussel
Elliptio roanokensis	Roanoke Slabshell	T	~	Mussel
Fusconaia masoni	Atlantic Pigtoe	E	FSC, Petitioned	Mussel
Lampetra aepyptera	Least Brook Lamprey	T	~	Fish
Lampsilis radiata	Eastern Lampmussel	T	~	Mussel
Lasmigona subvirdis	Green Floater	E	FSC, Petitioned	Mussel
Necturus lewisi	Neuse River Waterdog	SC	FSC, Petitioned	Amphibian
Notropis volucellus	Mimic Shiner	SR	~	Fish
Noturus furiosus	Carolina Madtom	T	FSC, Petitioned	Fish
Orconectes carolinensis	North Carolina Spiny Crayfish	SC	~	Crustacean
Strophitus undulates	Creeper	T	~	Mussel
Villosa constricta	Notched Rainbow	SC	~	Mussel

Notes: E = Endangered, T = Threatened, FSC = Federal Species of Concern, SR = Significantly Rare, SC = Special Concern, Petitioned = Species petitioned by Center for Biological Diversity (CBD) for listing, ~ = no rating (NCNHP 2017)

3.2 Dwarf Wedgemussel (Alasmidonta heterodon) Species Baseline

Status: Endangered
Family: Unionidae
Listing: March 14, 1990
Critical Habitat: Critical Habitat has not been designated for DWM, however the CBD petitioned the USFWS in 2015 to do so (CBD 2015).

3.2.1 Species Characteristics

DWM was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortmann (1919) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900).

The specific epithet *heterodon* refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. DWM is generally small, with a shell length ranging between 25 mm and 38 mm. The largest specimen reported by Clarke (1981) was 56.5 mm long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark and nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. This species is considered to be a long-term brooder, with gravid females reportedly observed in the fall months. Like other freshwater mussels, this species' eggs are fertilized in the female as sperm are taken in through their siphons as they respire. The eggs develop within the female's gills into larvae (glochidia). The females later release the glochidia, which then attaches to the gills or fins of a specific host fish species. Based on anecdotal evidence, such as dates when gravid females are present or absent, it appears that release of glochidia occurs primarily in April in North Carolina (Michaelson and Neves 1995). Research has confirmed at least three potential fish host species for DWM to be the Tessellated darter (*Etheostoma olmstedi*), Johnny Darter (*E. nigrum*), and

Mottled Sculpin (*Cottus bairdii*) (Michaelson 1993). A more recent study determined that the Fantail Darter (*Etheostoma flabellare*) could also be a host for DWM in North Carolina (Levine et al. 2009). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

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).

3.2.2 Distribution and Habitat Requirements

The historic range of DWM was confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages in 11 states and 1 Canadian Province (USFWS 1993a). When the recovery plan for this species was written, DWM was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993a). Strayer et al. (1996) conducted range-wide assessments of remaining DWM populations and assigned a population status to each of the populations. The status rating is based on range size, number of individuals, and evidence of reproduction. Seven of the 20 populations assessed were considered "poor," and two others were considered "poor to fair" and "fair to poor," respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however, it is believed to have been extirpated from the main-stem of the Neuse River.

The most recent assessment (2013 5-Year Review) indicates that DWM is currently found in 16 major drainages, comprising approximately 75 "sites" (one site may have multiple occurrences) (USFWS 2013). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that many of the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the floods of 2005 are still being studied. Table 9 updates population status from Strayer et al. (1996) with data included in the 2013 5-Year Review (USFWS 2013), North Carolina Wildlife Resource Commission (NCWRC) data (NCWRC Unpublished Aquatics Species Database), Smith et al. (2015), and the DWM Viability Study (Three Oaks 2016).

The population in the Upper Tar River is not a large or dense population, but it is believed to be viable due to recent recruitment, the regular occurrence of individuals, and the connectivity to other occupied tributaries (USFWS 2013), and is considered the strongest population in North Carolina (Smith et al. 2015). DWM has been found in Cub Creek as recently as July 2015 and in

Shelton Creek as recently as July 2014. DWM was found in the main-stem of the Tar River in Granville County in July 2013 and August 2012. Also within the Tar River Basin, Fishing Creek supports a viable population of DWM, with evidence of recruitment, and connectivity of several tributaries that are known to contain DWM, including Shocco Creek, Rocky Swamp, and Maple Branch. In Shocco Creek, DWM has been found consistently in recent years, with a total of 18 live and two shells found between 2009 and 2014. One live individual and over 40 live individuals were found in Shocco Creek and Little Shocco Creek, respectively, in 2017 (Neil Medlin, RK&K, and Tyler Black, WRC, personal communication). DWM has been observed steadily in Maple Branch since 1997, with 3 live individuals observed in 2013, and one shell observed as recently as January 2014 (NCWRC Unpublished Aquatics Species Database).

There are several streams within the Neuse River Basin where DWM have been found; however, Swift Creek is the only one where recent records ($\leq$ 10 years) have been reported (Figure 8). It was found in Buffalo Creek in Johnston County in 1998 (one live, two shells), the Eno River in Orange County in 1995 (one valve), the Little River in Wake and Johnston Counties, beginning in 1989 and most recently in 2004 (five live, and two shells), Moccasin Creek in Johnston and Nash Counties, beginning in 1991 and most recently in 2004 (five live, three shells), and in Turkey Creek in Wilson and Nash Counties, beginning in 1991 and last seen in 1996 (total of 19 live, and 25 shells). It has not been found in any of these water bodies in subsequent survey efforts (NCWRC Unpublished Aquatics Species Database). The documented occurrences of DWM in Swift Creek are discussed in detail in the two-phase DWM Viability Study (Three Oaks 2016), which examined the environmental baseline of the Swift Creek DWM population by characterizing watershed conditions, summarizing conservation measures meant to protect DWM, and assessing historic trends and future viability of the DWM population and habitat conditions. The baseline status of the DWM in the Action Area is summarized in Section 3.4.

Table 9. DWM Population Densities at Study Streams 1996 and Follow-up Survey Data*

Stream	Number of study reaches	Density Index (no/m^2) 1996 (Strayer et al. 1996)	Post 1996 catch-per-unit-efforts and presence/absence
Connecticut River, NH/VT	9	0.03 (0.1-0.05)	Present. Additional populations found, some of which may exceed densities found in 1996. Farmington River population has been extirpated.
Ashuelot River, NH	7	0.04 (0.02-0.06)	Present. Density estimates of two locations sampled in 2004 and 2006 range from 0.31 to 1.257 (Nedeau 2006). Sample sites overlapped Strayer et al. (1996) sites. Additional subpopulation found downriver of surveyed area
Neversink River, NY	6	0.04 (0.02-0.06)	Present. Populations affected by 2005 floods. Status uncertain.
McIntosh Run, MD	5	0.03 (0.01-0.05)	Present. No change.
Aquia Creek, VA	8	0.007 (0.003-0.01)	No live individuals since 2003. Population believed to be in decline
Po River, VA	3	0.01 (0.003-0.03)	Present in very low numbers
Tar River/Shelton Creek, NC	5	0.03 (0.01-0.05)	Present. Most viable population in NC.
Crooked Creek, NC	2	0	Present? 1 shell found in 2000 survey, status unknown
Little River, NC	3	0.03 (0-0.06)	Absent. 0 found in 2004, or since.
Swift Creek, NC	2	0	Present. 3 individuals found in 2002, and 30 since 2002.
Turkey Creek, NC	3	0	Absent. 0 found in 2005.
Moccasin Creek, NC	3	0	Present? Population viability unknown, presence based only on relict shells.

Notes: * - The survey methods are not comparable; this table merely indicates whether a perceived change in the populations has been observed since the 1994 intensive surveys were undertaken.

DWM inhabits creeks and rivers of varying sizes (down to approximately two meters [6 ft] wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993a). In North Carolina, DWM often occurs within submerged root mats along stable streambanks (USFWS 2007a). Two general in-stream habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

3.3 Yellow Lance (Elliptio lanceolata) Species Baseline

Status: Proposed Threatened
Family: Unionidae
Proposed for Listing: April 5, 2017
Critical Habitat: To be identified at time of formal listing

Supporting documents mentioned in Section 1.0 and included in Appendix D consider effects to the DWM only because at the time of their development Yellow Lance was not listed. Yellow Lance was subsequently listed as proposed on April 5, 2017, occurs within the FLUSA, and is vulnerable to the same threats as DWM. Therefore, discussions regarding DWM in these cited documents would pertain to Yellow Lance.

3.3.1 Species Characteristics

The Yellow Lance was described from the Tar River at Tarboro, NC, in 1828 by I. Lea (Lea 1828). Johnson (1970) synonymized this species with 25 other named species of lance-shaped elliptio mussels into *Elliptio lanceolate* species complex. Genotypic and phenotypic analysis suggests that some of these formally described species are valid, including *Elliptio lanceolata* (Bogan et al. 2009). This species differs from other lanceolate Elliptios by having a "waxy" bright yellow periostracum that lacks rays. Some older specimens are brown towards the posterior end of the shell. The periostracum can also have brown growth rests. Yellow Lance have a distinct pallial line and adductor muscle scars. The posterior ridge is distinctly rounded and curves dorsally towards the posterior end. The nacre ranges from an iridescent blue on the posterior end, sometimes becoming white or salmon colored on the anterior end. The lateral teeth are long, with two on the left and one on the right. Each valve also has two pseudocardinal teeth; on the left valve one tooth is before the other with the posterior tooth tending to be vestigial, and on the right valve the two teeth are parallel and the more anterior one is vestigial (Adams et al 1990).

The Yellow Lance is a tachytictic (short-term) breeder, brooding young in early spring and releasing glochidia in early summer. Based on the pelagic, "net-like" glochidia the fish host species is speculated to be some type of minnow (USFWS 2017a). White Shiner and Pinewoods Shiner (*Lythrurus matuntinus*) were the most effective fish hosts for Yellow Lance in laboratory studies (Eads and Levine 2009).

3.3.2 Distribution and Habitat Requirements

The reported range of the Yellow Lance has changed several times over the years due to taxonomic uncertainty with regard to "true" Yellow Lance, and other "lanceolate Elliptio" species. The Yellow Lance is currently thought to be distributed in Atlantic Slope river basins from the Neuse River Basin in North Carolina north to the Rappahannock River in Virginia, with the exception of the Roanoke River Basin, as well as the Patuxent River Basin in Maryland and possibly the Potomac River Basin in Virginia and Maryland (USFWS 2017a). It is in considerable decline throughout its range; however, extant populations still occur in all historic river basins, except possibly the Potomac (USFWS 2017a). This species has been found in multiple physiographic provinces, from the foothills of the Appalachian Mountains, through the Piedmont and into the Coastal Plain, in small streams to large rivers, in substrates primarily consisting of clean sand, and occasionally gravel, with a high DO content (USFWS 2017a, Adams et al 1990). Alderman (2003) stated that no remaining populations appear below point source pollution or other nutrient-rich areas. Associate mussel species include Atlantic Pigtoe, Tar River Spinymussel, Yellow Lampmussel (*Lampsilis cariosa*), Notched Rainbow (*Villosa constricta*), Triangle Floater (*Alasmidonta undulata*), Paper Pondshell (*Utterbackia imbecillis*), Eastern Lampmussel (*Lampsilis radiata*), Creeper (*Strophitus undulatus*), and other Elliptio species (Adams et al 1990, Figure 9).

Yellow Lance has been found in four management units (MUs) within the Tar River basin – Upper/Middle Tar River, Lower Tar River, Sandy-Swift Creek, and Fish Creek. First located in the Tar River in 1966, Yellow Lance has been recorded as recently as 2016 in the Sandy-Swift Creek MU. In the 1980 and 1990s, hundreds of individuals were often located during surveys, whereas surveys in 2015 and 2016 located only a few dozen individuals.

There is one MU in the Neuse River basin in which the first Yellow Lance was found in 1991. The most Yellow Lance recorded during a survey occurred in Swift Creek in 1994 when 18 individuals were located. Intensive surveys of Swift Creek between 2014 and 2016 have located only one individual. Population trends in each of the river basins currently or historically supporting this species were provided in detail in the SSA prepared as part of the listing package for this species (USFWS 2017a). The baseline status of the Yellow Lance in the Action Area is summarized in Section 3.4.

3.4 Summary of DWM and Yellow Lance within Action Area

The Action Area (FLUSA) encompasses streams in the Neuse River Basin, including Neuse River, Swift Creek, Middle Creek, and tributaries to these streams as depicted in Figure 3. As DWM and Yellow Lance are known to occur in creeks and rivers of varying sizes (down to approximately 2 meters [6 ft] wide), perennial streams within the Action Area were evaluated for presence of these species. Existing mussel survey data within the Action Area were reviewed. Data sources consulted included the NCWRC Unpublished Aquatic Species Database, which was reviewed in November 2016, the NCNHP database (NCNHP 2017), reviewed in May 2017, Johnson (1970), and surveys conducted by Catena/Three Oaks. The 65 perennial streams crossed by the preferred alternative were evaluated for the presence of the DWM and Yellow Lance in 2010, 2011, 2012, 2015, 2016, and 2017. DWM was found in Swift Creek in 2010, 2011, 2012, 2015, and 2016 (Catena 2011, 2012b, 2012c, 2014 and Three Oaks 2016, respectively). Yellow lance was found in Lower Middle Creek in 2012, and in Swift Creek in

2010, 2011, 2012, and 2015 (Catena 2011, 2012b, 2012c, 2014 and Three Oaks 2016, respectively).

Additionally, perennial streams within the Action Area that do not directly cross the alignment were also surveyed for freshwater mussels. Neither the DWM nor the Yellow Lance was found in streams other than Swift Creek and Lower Middle Creek. The results of these surveys were provided in a report submitted to NCDOT in May 2017 (Three Oaks 2017).

The results of these evaluations indicate the DWM and Yellow Lance currently occupy portions of Swift Creek and the Yellow Lance currently occupies portions of Lower Middle Creek within the Action Area.

3.4.1 Distributions in Swift Creek

The DWM was first discovered in Swift Creek in 1991 (Alderman 1991). Between 1991 and 2016, a total of 54 live individuals and 12 relict shells have been found at 34 distinct sites over 21 stream miles, including six live individuals in 2016 (Three Oaks 2016, NCWRC Unpublished Aquatics Species Database). The lower 10 miles, however, are represented by only one individual, and the species has not been found in this 10-mile section since 1991. Additionally, two individuals have been recorded in Little Creek and one in White Oak Creek; both streams are tributaries to Swift Creek. A table listing all DWM records from the Swift/Middle Creek Watershed, including year and specific locations, is included in Appendix B. The distribution of DWM Element Occurrences (EO), as described by NCNHP, is shown in Figure 8.

The DWM Viability Study (Three Oaks 2016) provides further details on the history of mussel surveys and mussel fauna population trends in Swift Creek. The results of this study showed that there are several stressors to aquatic communities in the Swift Creek subbasin, directly and indirectly related to urbanization of the watershed. While mussel populations have declined since urbanization began, the decline appears to have leveled off, and there is some indication that mussel recruitment has increased within the past few years. So, while long-term viability is threatened, with active management and increased habitat protection, there is a chance of persistence into the future. Management recommendations that would help maintain a sustainable DWM population include in-stream habitat monitoring, population augmentation using captive propagation techniques, continued targeted water quality monitoring, and establishing a DWM focused stakeholder group in the lower SCW below Lake Benson. These management actions would also apply to the Yellow Lance population.

The Yellow Lance was first recorded in Swift Creek in 1991 (Three Oaks 2016, NCWRC Unpublished Aquatics Species Database). Population trend analysis performed for the Swift Creek DWM Viability Study demonstrates that the Yellow Lance was much more common in Swift Creek during the 1992-1996 period than in later years, and it has become extremely rare in the stream since that time (Three Oaks 2016). The species was last identified in Swift Creek in late 2015, and was not detected during 2016 and early 2017 surveys (Tim Savidge, personal communication).

3.4.2 Distributions in Middle Creek

Two DWM individuals were found in Middle Creek in 1992. Subsequent surveys, including extensive survey efforts undertaken for this project in 2010, 2011, 2012 and 2016, did not detect any live individuals; however, one relict shell was found in 2016 in the lower portion of Middle Creek below the Crantock Road crossing (Tim Savidge, Three Oaks, personal observations). This shell was found along with relict shells of other rare mussel species, including Yellow Lance, Atlantic Pigtoe and Notched Rainbow, all of which have become either extremely rare, or are no longer extant in Middle Creek. The shells were found within an area of the stream that had been recently exposed by an eroded bank, suggesting the shells may have been buried in sediments for many years (Tim Savidge, personal observations). The general consensus is that the DWM has been extirpated from Middle Creek (NC Scientific Council on Mollusks 2011).

The Yellow Lance was first reported from Middle Creek in 1992, and has been reported from three distinct locations in Lower Middle Creek (USFWS 2017a). As in Swift Creek, the Yellow Lance has become increasingly rare in Middle Creek, with the last observation of a live individual being 2012. Live individuals were not found during extensive surveys in 2016; however, as mentioned above, two relict shells were found. It appears that the shells had been recently exposed by an eroded bank, suggesting the shells may have been buried in sediments for many years (Tim Savidge, Three Oaks, personal observations).

3.5 General Threats to DWM and Yellow Lance

The aggregate effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (e.g., impoundments, channelization) have contributed to the decline of the DWM throughout its range. With the exception of the Neversink River population in New York, which had an estimated population of over 80,000 DWM individuals (Strayer et al. 1996), all of the other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpations from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes. Based on expert opinion of a North Carolina DWM (NC DWM) Work Group assembled by the USFWS Raleigh field office in 2012, the “Allee effect”, defined as a high risk of demographic extirpation due to low population abundance and lack of dispersal, was identified as the second highest threat behind “unsuitable physical habitat" to the Swift Creek DWM population (Smith et al. 2014). These threats are likely having a similar impact on the Yellow Lance population in Swift and Middle Creeks.

3.5.1 Sedimentation

Siltation resulting from substandard land-use practices associated with activities such as agriculture, forestry, and land development has been recognized as a major contributing factor to 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; Marking and Bills 1979). Sediment accumulations of less than 25 mm (one inch) have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the DWM because of accelerated sedimentation and erosion (Smith 1981).

3.5.2 Habitat Alteration

The impact of impoundments on freshwater mussels has been well documented (USFWS 1992a; Neves 1993). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia. 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 5.79 meters (19 feet) of muck (USFWS 1992b). Large portions of all river basins within the DWM range have been impounded. This is believed to be a major factor contributing to the decline of the species (Master 1986; USFWS 1993a).

3.5.3 Toxic Contaminants

Pollution in waterways is known to adversely affect aquatic organisms in a variety of ways. Choudri and Baawain (2016) summarize the adverse impacts to aquatic organisms from multiple types of pollutants. With regard to freshwater mussels, the presence of toxic contaminants has been shown to contribute to widespread declines of populations (Havlik and Marking 1987; Bogan 1993; Neves et al. 1997; Richter et al. 1997; Strayer et al. 2004; Henley et al. 2016). Toxic contaminants can produce lethal or sub-lethal responses to freshwater mussels. The NC DWM Work Group identified "low water quality due to contaminants" as the third most important threat to the Swift Creek population (Smith et al. 2014). The sensitivities of freshwater mussels to toxic contaminants is variable based on species, life stage (glochidium, juvenile, or adult), and environmental conditions, as well as concentration and exposure type (water column, sediments, etc.), frequency, and duration. Several studies have indicated that early life stages of freshwater mussels are among the most sensitive aquatic organisms to various inorganic toxicants such as copper (Jacobson et al. 1993; Jacobson et al. 1997; Milam et al.

2005; Wang et al. 2007a; Wang et al. 2007b), manganese and ammonia (NH3) (Archambault et al. 2017, Wade 1992; Augspurger et al. 2003; Bartsch et al. 2003; Newton et al. 2003; Wang et al. 2007a; Wang et al. 2007b; Grabarkiewicz and Davis 2008).

Anthropogenic sources of ammonia and copper in surface waters include sewage treatment effluent, industrial wastewater effluent, and runoff and ground water contamination from agriculture, lawn/turf management, livestock operations, roadways, and faulty septic systems. 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 discharges of chlorinated sewage effluent. Similarly, Gillis et al. (2014) found that mussels were absent for 7 km (4.3 miles) below a WWTP on the Grand River in Ontario, Canada. Water quality measurements taken as part of this study demonstrated that ammonia and nitrate concentrations, along with diel declines in oxygen, were associated with the extirpation of mussels in that 4.3-mile reach. Mussels returned to the river below a large tributary suggesting that the addition of the tributary improved water quality conditions to a level that supported mussels (Gillis et al. 2017).

Additionally, exposure to raw sewage can have numerous impacts on aquatic organisms, resulting in fish kills and damage to shellfish beds (USEPA 2011). On April 16, 2017, an estimated 250,000 gallons of raw sewage spilled from a ruptured pipe running adjacent to Swift Creek in Johnston County. Around 125,000 gallons made it directly to Swift Creek, while the other 100,000 gallons flowed into a wetland near the creek. The impacts to the aquatic fauna in Swift Creek have not been determined; however, numerous fish were killed in the wetland that received the raw sewage (News & Observer 2017).

Recent studies indicated that previous federal water quality criteria for many pollutants commonly found in wastewater discharges and stormwater runoff were likely not protective of freshwater mussels; nationwide regulations controlling the discharge or runoff of these pollutants are also not protective (Augspurger et al. 2003). The previous (1999) EPA-recommended ‘freshwater ammonia aquatic life ambient water quality’ criteria were based on the most sensitive endpoints known at the time: the acute criterion was based primarily on effects on salmonids (where present) or other fish, and the chronic criterion was based primarily on reproductive effects on the benthic invertebrate *Hyalella* or on survival and growth of fish early life stages (when present) (USEPA 2009). Research demonstrated that these standards were not protective of freshwater mussel species, which are some of the most sensitive aquatic organisms to ammonia. As a result, the EPA recently revised the freshwater ammonia aquatic life ambient water quality criteria (acute and chronic standards) to reflect freshwater mussel species sensitivity thresholds (USEPA 2013).

Ward et al. (2007) sampled for ammonia, copper and chlorine at five locations within, or draining to, the portion of Swift Creek occupied by DWM, and found that ammonia and chlorine levels rarely exceeded ecological screening values; however, copper levels exceeded ecological screening values for both acute and chronic exposure at all sites. Further discussion of this study, and results of water quality sampling targeting these compounds that were conducted as part of the DWM Viability Study are discussed in further detail in the Lower Swift Creek Water Quality Report (Three Oaks 2015), which is included in Appendix C.

When publishing the five year review for the Carolina Heelsplitter (*Lasmigona decorata*), another federally endangered freshwater mussel species that occurs in North Carolina, the USFWS stated that there were "currently no water quality standards, or monitoring requirements for ammonia, copper and phosphorus in North Carolina" (USFWS 2012).

The Goose Creek Site Specific Management Plan (NCDENR 2009), which was developed to provide protection for the Carolina Heelsplitter, requires that any direct or indirect discharge that may cause ammonia toxicity to the Carolina Heelsplitter implement measures to reduce ammonia inputs to achieve 0.5 milligrams per liter or less of total ammonia based on chronic toxicity defined in 15A NCAC 02B .0202 (NCAC 1998). This level of total ammonia is based on ambient water temperature equal to or greater than 25 degrees Celsius (NCDENR 2009).

While there are still no adopted standards or monitoring requirements for ammonia and phosphorus in North Carolina, standards have recently been developed for copper, as updated in the Triennial Review of Standards (North Carolina Register 2014). EPA water quality criteria and North Carolina water quality standards are discussed further in the Lower Swift Creek Water Quality Report (Three Oaks 2015).

In addition, studies indicate other toxicants present in wastewater effluent such as pharmaceuticals and personal care products (fluoxitine, estrogenic compounds, opiate derivatives etc.) cause a wide array of neurotoxicological (Gagné et al 2007a), reproductive (Bringolf et al. 2007; Gagné et al 2007b) and behavioral (Hazelton et al. 2013, Heltsley et al. 2006) impacts to freshwater mussels (de Solla et al. 2016).

Other sources of toxic contaminants in surface waters arise from highway and urban runoff. Gillis (2012) demonstrated that chronic exposure to a combination of WWTP effluent and highway runoff negatively affected freshwater mussel health and life span in urbanized watersheds; although, a specific cause was not identified, the assumption is that chronic exposure to multiple contaminants negatively effects health and longevity. Numerous pollutants have been identified in highway runoff, including various metals (lead, zinc, iron, copper, cadmium, etc.), sediment, pesticides, deicing salts, nutrients (nitrogen, phosphorus), and petroleum hydrocarbons (Gupta et al. 1981; Yousef et al. 1985; Davis et al. 2001; Gillis et al. 2014). The sources of these runoff constituents range from construction and maintenance activities to daily vehicular use. Hoffman et al. (1984) concluded that highway runoff can contribute up to 80 percent of the total pollutant loadings to receiving water bodies; identifying, among others, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), lead, and zinc. PAH compounds are largely derived from petroleum related sources (e.g., gasoline, oil) and are of major concern from transportation-related runoff to aquatic systems due to their potential acute and chronic (e.g., mutagenic and carcinogenic) toxic properties (Humphries 2006). The toxicity of highway runoff to aquatic ecosystems is poorly understood. A major reason for this poor understanding is a lack of studies focusing solely on highway runoff. Potential effects of highway runoff have often been inferred from studies conducted on urban runoff; however, the relative loadings of pollutants are often much greater in urban runoff, because of a larger drainage area and lower receiving water dilution ratios (Dupuis et al. 1985). The negative effects of urban runoff inputs on benthic macroinvertebrate communities have been well documented (Garie and McIntosh 1986; Jones and Clark 1987; Field and Pitt 1990). Lieb (1998) found the macroinvertebrate community of a headwater stream in Pennsylvania to be highly degraded by urban runoff via a detention pond. Improvements were observed at continual distances downstream from the discharge point; however, all sites examined were still impaired compared to a reference community.

The few studies that examined actual highway runoff show that some species demonstrate little sensitivity to highway runoff exposure, while others are much more sensitive (Dupuis et al. 1985). Maltby et al. (1995) found elevated levels of hydrocarbons and metals in both stream sediments and the water column below a heavily traveled British motorway. They demonstrated that the benthic amphipod (*Gammarus pulex*) experienced a decrease in survival when exposed to sediments contaminated with roadway runoff. However, this species showed no increase in mortality when exposed to water contaminated with roadway runoff. Most of these studies only measured acute toxicity to runoff and did not examine long-term effects.

The effects of highway runoff on freshwater bivalves have not been studied extensively. Augspurger (1992) compared sediment samples and soft tissues of three Eastern Elliptio (*Elliptio complanata*), a relatively common species upstream and downstream of the I-95 crossing of Swift Creek of the Tar River Basin in Nash County, North Carolina. The sediment samples, as well as the mussels, exhibited higher levels of aliphatic hydrocarbons, arsenic, lead, zinc, and other heavy metal contaminants in the downstream samples. Because of the small sample size, the effect on the health of these mussels was not studied. In another study, contaminant analysis of stream sediments showed an increase of PAHs and some metals downstream of road crossings, although there was no direct correlation found between increasing contaminant levels and decreasing mussel abundance at these crossings (Levine et al. 2005). The Eastern Elliptio was the only mussel species that was found in large enough numbers for statistically valid comparisons. The Eastern Elliptio is generally considered more tolerant of water quality degradation than many other mussel species. However, Humphries (2006) did show that mussels from streams with higher average daily traffic counts (ADTC) exhibited greater levels of genetic damage compared to mussels from streams with lower ADTC values. Additionally, laboratory data showed increasing DNA damage relative to increasing PAH concentration. Humphries

(2006) concluded that "PAHs are not likely contributing to acute toxicity of mussels in North Carolina streams, but the chronic, long-term pervasive effect of PAHs on native freshwater mussels remains uncertain." Further research is needed before the effects of highway runoff on sensitive mussel species such as the DWM and Yellow Lance can be determined.

While additional research is needed to document highway runoff effects on freshwater mussels generally, contamination of surface water from toxic spills along roadways is known to have significant impacts to aquatic communities. A toxic spill resulting from a tanker truck accident that was carrying Octocure 554 (a chemical liquid used in the rubber making process) killed several miles of mussel populations in the Clinch River near Cedar Bluff, Virginia (Richmond Times Dispatch 1998). The spill killed thousands of fish and mussels, including three federally protected species. The Clinch River contains one of the most diverse mussel faunas in the United States. The stretch of the river affected by the spill was one of the few remaining areas that contained a reproducing population of the endangered Tan Riffleshell (*Epioblasma florentina walkeri*), which has not been found in the river since. Presence of hazardous spill basins (HSBs) adjacent to crossings of waterways that support sensitive species provides the potential to avoid/ minimize major kills such as this.

3.5.4 Hydrologic Changes Due to Changes in Land Use

The SCW has experienced urbanization in recent years, as discussed in detail in Section 3.1. The correlation of increasing development within a watershed and decreasing water quality is well documented (Lenat et al. 1979; Garie and McIntosh 1986; Crawford and Lenat 1989; Lieb 1998), and is largely associated with increases in impervious surface area. These increases in impervious surface area can affect water quality in a variety of ways, particularly with regard to changes to stream flow, water temperature, total suspended sediment, and pollutant loadings.

Multiple studies have demonstrated that water quality and stream ecosystem degradation begins to occur in watersheds that have approximately ten percent coverage by impervious surfaces (Schueler 1994; Arnold and Gibbons 1996; Stewart et al. 2000). NCWRC recommendations for management of protected aquatic species watersheds are to limit imperviousness to 6 percent of the watershed (NCWRC 2002). The amount of impervious surface has increased in the SCW, constituting about 11 percent of the land area within Wake County (the more developed of the two counties). As a result, Wake County contributes about 4.29 inches/year of runoff (CDM 2003, Table 3-5). Of the precipitation that falls onto these impervious surfaces, an estimated 95 percent becomes runoff. Johnston County is less developed than Wake County. As of 2011, the county was approximately 3.6 percent urban development, while the portion in the SCW was approximately 8.6 percent. This is based on the National Land Cover Dataset (NLCD, Homer et al. 2015), and assuming all development is captured in the Low, Medium, and High Intensity Developed categories. The 2009 North Carolina Division of Water Quality (NCDWQ, now the North Carolina Division of Water Resources) Neuse River Basinwide Plan indicates the entire

SCW is 29.5 percent urbanized, with much of the growth occurring in the last 20 years. Increases in impervious surface area within a watershed can result in extremes (either high or low) in peak discharge, runoff volume, and base flow conditions.

3.5.4.1 Peak Discharge

Peak discharge is the maximum rate of stormwater flow expected from a storm event, measured in cubic feet per second (cfs). Peak discharge is often one metric used in analyzing effects from development and affects channel stability (or instability). Increases in peak discharge equates to higher velocity, which in turn increases the scouring effect (surface erodibility) of the runoff. Accordingly, sedimentation will increase as erosion rates increase. Increases of peak discharge rates, coupled with deforestation, have been shown to result in stream narrowing and incision and subsequent loss of ecosystem function (Sweeney et al. 2004). Shields et al. (1994) found that during base flows, incised streams contained fewer habitat types, particularly pool habitats, and lower fish species diversity than non-incised streams. Conversely, increases in peak discharge can also result in channel widening, as streambanks become susceptible to mass failure (Simon and Rinaldi 2006), which have been noted in a few areas in Swift Creek (Tim Savidge, Three Oaks, personal observations). As stream channels begin to become unstable, incision is typically the dominant result; however, once a critical threshold is passed, channel widening can occur rapidly (Shields et al. 1994). Harvey and Watson (1986) found that increases in channel cross- sectional area of up to 1,000% can occur within a few years. Increased peak discharges in areas of streams dominated by bedrock and boulder outcroppings intersecting the stream channel tend to widen the stream much more than deepening, as the energy gets dissipated horizontally. This appears to have occurred in a bedrock dominated area of Swift Creek adjacent to the Indian Overlook neighborhood (Tim Savidge, Three Oaks, personal observations).

3.5.4.2 Runoff Volume

Runoff volume is the amount of stormwater expected from a storm event, measured in acre-feet. Like peak discharge, runoff volume is another metric often used in determining effects of development, especially on the aquatic environment. For example, increases in the amount of runoff normally equates to increased sediment. While the two indicators are related, when analyzed separately, both are useful in assessing impacts to aquatic systems.

In a stable system, an increase in the volume may have little impact if velocity does not change, provided that measures to slow the increased velocity have been implemented. However, the increased runoff volume may have enough sediment to cause detrimental effects. Regardless, it is important to consider both the rate (peak discharge) and the amount (runoff volume) when assessing effects to aquatic systems. Again, sufficient stormwater controls accompanying future development activities in any given watershed are essential for conservation of sensitive aquatic species such as DWM and Yellow Lance.

3.5.4.3 Base Flow

Increases of impervious surface lead to decreases in infiltration and base flow (groundwater flow) within adjacent streams. This can result in the following:

- Less water to cover the stream bottom during periods of reduced base flow.
- Increases in water evaporation and temperature in widened streams as a result of reduced overhanging tree cover and increased exposure to sunlight, especially in areas with shallower water.
- Extension of the WWTP effluent "plume" further downstream, if base flow is reduced and WWTP discharge remains constant or increases, as it takes longer for the stream to dilute the nutrients and other toxins in the effluent.

Just as the road network in a watershed affects peak discharge, it also can lead to a reduction of base flow. While the total amount of water remains relatively constant, base flows decrease because the rapid runoff (increases the timing and volume of peak discharge) reduces the total amount of water that can infiltrate and be stored in the soil (Castro 2003).

The effects of lowered base flow as a result of changes in the landscape are further exacerbated by water withdrawals. Permitted and un-permitted water withdrawals for crop and turf/lawn irrigation further exacerbate this effect. In North Carolina, permits are required for water withdrawals of one million gallons per day or greater for agricultural uses (100,000 gallons per day for non-agricultural uses). Withdrawals less than this volume are not regulated, and are often unknown. Numerous small withdrawal operations have been observed in the Lower SCW (Tim Savidge, Three Oaks, personal observations).

In general, soils in the Piedmont portion of the Neuse River Basin are highly erodible and are underlain by fractured rock formations that have limited water storage capacity resulting in the streams that flow through them being naturally susceptible to periods of very low or even interrupted flow. Streams in this area tend to have low summer flows and limited ability to assimilate oxygen-consuming wastes (NCWRC 2005). In addition, the Upper SCW is close to the transitional area between the poorly drained soils of the Triassic basin and the moderately drained soils weathered from granitic rocks underlying the Lower SCW. As such, Swift Creek is even more susceptible to periods of interrupted flow, particularly in the upper reaches, which have almost no potential for sustained 7Q10 low flow discharge; 7Q10 is defined as the minimum average discharge for a consecutive seven-day period occurring, on average, once in ten years (Weaver 1998). The natural susceptibility of these watersheds to periods of very low to interrupted flow is further compounded by anthropogenic factors such as water withdrawals and urbanization.

Prolonged periods of drought have been shown to adversely impact mussel species (Johnson et al. 2001; Golladay et al. 2005; USFWS 2012), as mussels may face increased water temperatures and reduced DO concentrations (hypoxia, or eventually anoxia), increased predation, and emersion or stranding (Johnson et al. 2001). Thin-shelled species like DWM may be inherently more prone to the consequences of drought than thicker shelled species like *Elliptio* mussels. Prolonged drought has been identified as a major threat to the endangered Carolina Heelsplitter (USFWS 2012). Similarly, based on expert opinion of the NC DWM Work Group, drought ("unsuitable flow") was identified as one of the top three threats in all of the DWM populations in the Tar River Basin (Smith et al. 2015). Similarly, the SSA completed for the Yellow Lance identified insufficient water quantity associated with drought to be a major factor affecting the resiliency of the species in the Neuse River Basin.

While drought is recognized as a major threat for many mussel species, the actual low flow requirements of mussels is poorly understood. Johnson et al. (2001) and Golladay et al. (2005) assessed drought impacts on mussel assemblages in a number of streams in the Flint River Basin of southwestern Georgia. Flow rate, water temperature, water depth, and DO were monitored throughout the study and sites were classified as flowing or non-flowing during the drought period. Sites that ceased flowing during the drought had significant declines in the abundance of all mussel species, some of which are endangered, as well as declines in species richness. However, sites that maintained some flow during the drought had increases in stable species of mussels and no change in special concern or endangered species through the drought. Mortality of mussels at sites that ceased flowing was attributed to reductions in DO concentration, which was highly correlated with water velocity.

As part of the Section 7 Consultation for the Dempsey E. Benton WTP, a 60-year synthesized hydrologic time series was developed for Swift Creek using a ratio of the drainage area from the nearby, unregulated Middle Creek. The analysis concluded that Swift Creek historically experienced near zero and zero flow conditions (Entrix 2005). Minimum flow releases are now guaranteed as a result of conservation measures developed for that project (Section 1.3 of Entrix 2005).

3.5.5 Thermal Pollution

Concerns over effects of thermal pollution from urban runoff on aquatic systems have increased in recent years. Elevation of stream temperature can raise BOD, lower DO, and alter faunal composition (Poole et al. 2001, Roa-Espinosa et al. 2003). Typically, runoff from an impervious area will have a temperature similar to that of the impervious area. During the hot summer months, this could potentially make the stormwater runoff reach temperatures up to and above 90°F, which could be detrimental to aquatic life, such as freshwater mussels. Rising stream water temperatures have been shown to have lethal and sub-lethal effects on freshwater mussels during different life stages. Thermal stress on juvenile mussels was demonstrated to result in reduced burrowing capacity and inhibited byssal thread production, which may hamper their ability to escape predation or extreme high or low flows, as well as limit their attachment and dispersal capabilities (Archambault et al. 2013). The thermal tolerance of freshwater mussels "is controlled by multiple interacting and complex factors" (Pandolofo et al. 2012). For example, mussels are not only limited by their own thermal tolerances, but also by those of their host fish (Pandolofo et al. 2012). Pandolofo et al. (2010) suggested that freshwater mussels "already might be living close to their upper thermal tolerances in some systems".

Traditional structural stormwater controls, such as open storm-water detention ponds/basins that do not allow for infiltration, do not protect receiving water bodies against adverse temperature effects. Various stormwater BMPs have been shown to be effective in ameliorating temperature effects (NC State Cooperative Extension 2006a). For example, bioretention devices were shown to reduce runoff temperature by 5-10°F in Greensboro, NC (NC State Cooperative Extension 2006b). The loss of riparian buffers as well as peak discharge related channel widening can also contribute to stream temperature increases, by increasing sunlight exposure and decreasing water depth. Increases in the level of imperviousness within a watershed can result in unnatural widening of stream channels. This is due to increasing stormwater flows, that erode and widen stream channels, which in turn decreases the vegetative shading and leads to increases in water temperatures.

3.5.6 Invasive Species

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 DWM and Yellow Lance. 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 Widlak 1987; Alderman 1995). The Zebra Mussel, native to the drainage basins of the Black, Caspian, and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The zebra mussel is not currently known from any river supporting DWM or Yellow Lance populations.

3.5.7 Loss of Riparian Buffers

Loss of riparian buffers can lead to degradation of adjacent aquatic habitats. The role of forested riparian buffers in protecting aquatic habitats is well documented (NCWRC 2002). Riparian buffers provide many functions including pollutant reduction and filtration, a primary source of carbon for aquatic food webs, stream channel stability, and maintenance of water and air temperatures. Numerous studies have recommended a range of buffer widths needed to maintain these functions. Recommended widths vary greatly depending on the parameter or function evaluated. Wide contiguous buffers of 100-300 feet are recommended to adequately perform all functions (NCWRC 2002). The NCWRC recommends a minimum 200-foot native, forested buffer on perennial streams and a 100-foot forested buffer on intermittent streams in watersheds that support federally endangered and threatened aquatic species (NCWRC 2002). The USFWS often takes these NCWRC recommendations into consideration when addressing federally protected aquatic species in North Carolina.

3.5.8 Degradation Caused by All-Terrain Vehicle Use

Another human-related factor adversely impacting habitat of the DWM and Yellow Lance is recreational all-terrain vehicle (ATV) use. ATV tracks have been noted crossing streams as well as traveling stream channels throughout the SCW. In addition to directly running over mussels, ATVs destabilize stream banks and floodplains, causing sedimentation and buffer degradation. While there is no quantitative data available on ATV use, locally, this can have significant impacts. This was identified as a threat to the DWM population in Swift Creek (Smith et al. 2015).

3.6 Potential Effects of Roadway Projects on Freshwater Mussels and Habitat

Roadways have the potential to cause adverse effects to freshwater mussels and their habitat. In addition to direct impacts that occur during roadway construction, the roadway project can have indirect effects associated with the roadway post construction (operational effects, as well as indirect effects associated with project-induced development. While several threats are recognized (Section 3.5), potential roadway-related effects on freshwater mussels and habitat fall into three main categories, which are evaluated in detail in Section 4.0:

1. Physical effects (habitat degradation, direct mortality of individuals),
2. Water quality effects (chemical, temperature, and biological pollutants), and
3. Water quantity effects (changes in peak and base flows).

3.6.1 Physical Effects

Roadway construction can result in physical impacts to individual freshwater mussels as well as to their habitat. Physical effects associated with road construction include, but are not limited to, riparian land-clearing, physical loss of habitat (substrate fill), stream re-channelization, hydrologic modification, erosion associated with construction in the project corridor as well as within fill/borrow areas, and construction staging/access areas outside of the project corridor. The potential effects of these activities on aquatic species, especially freshwater mussels, include physical injury to individual mussels from substrate disturbance and/ or sediment deposition. Potential physical effects to mussel habitat include channel and stream bank scouring, channel erosion, and sedimentation, all of which reduces habitat suitability.

3.6.2 Water Quality Effects

Roadway construction can result in a variety of chemical and thermal water quality effects during construction as well as from induced land use changes post-construction. These effects include the addition of various chemical and thermal pollutants to waterways originating from the project construction and facility footprint, as well as and those pollutants originating from induced land use changes, particularly pollutants from commercial and/or residential developments (e.g., urban runoff, fertilizers, pesticides). Various parameters that serve as proxies for chemical and thermal water quality effects were modeled for a build vs. no-build scenario, including Impervious Surface, Total Suspended Solids (TSS) and Copper (Section 4.3).

3.6.3 Water Quantity Effects

Water quantity effects are temporary and permanent alteration of flows. These include construction impacts (temporary dewatering, causeway construction, channel restriction, etc.), which were qualitatively assessed in Section 4.1, as well as impacts from induced land use changes (increased runoff and storm flows, decreased infiltration and associated base flow). The amount of impervious surface levels in the subject watersheds was modeled as a proxy for water quantity effects associated with induced land use changes (Section 4.3.1).

4.0 EVALUATED EFFECTS OF PROPOSED ACTION ON DWM AND YELLOW LANCE

This section evaluates the direct and indirect effects of the project, together with the effects of other activities that are the interrelated and interdependent with the action on DWM and Yellow lance. We used the potential effects to the freshwater mussels and mussel habitat discussed above to frame the evaluated effects from the Complete 540 project. The project related impacts are presented in three categories:

1) Construction Effects
2) Operation Effects
3) Induced Land Use Effects

The modeled effects with and without the proposed project, more specifically Build vs. No-Build scenarios as presented in the ICE (Baker Engineering 2017 a-d), were used in the induced land use effects portion of this BA. The measures incorporated into this project to avoid or minimize effects to the DWM and Yellow Lance are included in this evaluation. The induced land use effect is considered a subset of the overall interrelated and interdependent activities associated with this action.

4.1 Construction Effects

Based on mussel survey data and habitat evaluations, DWM and/or Yellow Lance have been reported in portions of the following watersheds within the Action Area of the proposed project; Swift Creek, White Oak Creek, Little Creek and Middle Creek (Appendix B). The remaining portion of the Action Area outside of these watersheds does not contain DWM or Yellow Lance; Therefore, those watersheds are not included as a part of the effects analysis of these two species. The project alignment traverses a section of Swift Creek that is occupied by both species, as well as waterbodies that drain to habitat occupied by either, or both; therefore, there is the potential for roadway construction to affect the species. While there is the potential for construction related effects from any jurisdictional crossing within the watershed, the likelihood of such impacts generally declines the further the action is from occupied habitat. As such, the distance from each jurisdictional stream crossing to occupied habitat have been placed in four categories:

- 0.0 – 0.25 river miles (RM)
- >0.25 – 1.0 RM
- >1.0 – 2.0 RM
- >2.0 RM

Potential effects are even further reduced if the stream drains into an impoundment, prior to reaching occupied habitat, such as Austin Pond on White Oak Creek. The specific streams are noted in Table 10, and depicted in Figure 10. However, in certain instances sediment effects from construction sites can extend long distances. In 1997, a large plume of sediment in the Neuse River near New Bern was traced to a construction site along Crabtree Creek in Raleigh, over 180 miles upstream (Kays 2002). While this is an extreme example, it demonstrates the potential for project related sedimentation to have far reaching effects on the aquatic habitats downstream.

Table 10. Distances to Occupied Habitat from Verified Jurisdictional Streams

Stream Name	JD map ID	RM to occupied habitat	Stream Name	JD map ID	RM to occupied habitat
Buffalo Branch	SCT	4.181	UT to Swift Creek	SEW	1.902
Swift Creek	SDG	0.000	UT to Swift Creek	SEY	1.882
UT to Buffalo Branch	SCR	4.571	UT to Swift Creek	SFA	3.253
UT to Buffalo Branch	SCS	4.296	UT to Swift Creek	SFB	2.964
UT to Buffalo Branch	SCU	4.181	UT to Swift Creek	SFE	2.693
UT to Buffalo Branch	SCV	4.206	UT to Swift Creek	SFF	2.788
UT to Buffalo Branch	SCW	4.353	UT to Swift Creek	SFG	2.978

Table 10. Distances to Occupied Habitat from Verified Jurisdictional Streams (continued)

Stream Name	JD map ID	RM to occupied habitat
UT to Swift Creek	SCX	1.357
UT to Swift Creek	SCY	0.232
UT to Swift Creek	SCZ	1.382
UT to Swift Creek	SDA	0.983
UT to Swift Creek	SDB	1.164
UT to Swift Creek	SDC	1.172
UT to Swift Creek	SDD (1)	0.742
UT to Swift Creek	SDD (2)	0.792
UT to Swift Creek	SDE	0.742
UT to Swift Creek	SDF	0.252
UT to Swift Creek	SDH	0.000
UT to Swift Creek	SDI	0.294
UT to Swift Creek	SDJ	0.071
UT to Swift Creek	SDK	0.228
UT to Swift Creek	SDL	0.275
UT to Swift Creek	SDM	0.381
UT to Swift Creek	SDO	0.603
UT to Swift Creek	SDP	1.516
UT to Swift Creek	SDQ	1.076
UT to Swift Creek	SDT	1.006
UT to Swift Creek	SDV	0.276
UT to Swift Creek	SDW	0.684
UT to Swift Creek	SDX	1.278
UT to Swift Creek	SDY	1.173
UT to Swift Creek	SDZ	1.173
UT to Swift Creek	SEB	1.187
UT to Swift Creek	SEC	1.381
UT to Swift Creek	SEF	1.243
UT to Swift Creek	SEG	1.014
UT to Swift Creek	SEH	1.116
UT to Swift Creek	SEJ	1.131
UT to Swift Creek	SET	0.358

Stream Name	JD map ID	RM to occupied habitat
UT to Swift Creek	SFH	2.736
UT to Swift Creek	SFI	1.434
UT to Swift Creek	SFJ	3.856
UT to Swift Creek	SFK	3.721
UT to Swift Creek	SFL	1.511
UT to White Oak Creek	SED	2.860
UT to White Oak Creek	SFC	5.963
UT to White Oak Creek	SFD	6.059
UT to White Oak Creek	SFN	6.991
UT to White Oak Creek	SFP	6.834
UT to White Oak Creek	SFQ	6.989
UT to White Oak Creek	SFR	6.676
UT to White Oak Creek	SFS	7.195
UT to White Oak Creek	SFT	7.185
UT to White Oak Creek	SFU	6.032
UT to White Oak Creek	SFX	5.750
UT to White Oak Creek	SFY	7.174
UT to White Oak Creek	SFZ (1)	7.247
UT to White Oak Creek	SFZ (2)	7.141
UT to White Oak Creek	SGA	7.117
UT to White Oak Creek	SGC	7.698
UT to White Oak Creek	SGD	7.724
UT to White Oak Creek	SGE	7.854
UT to White Oak Creek	SGF	7.854
UT to White Oak Creek	SGG	7.930
UT to White Oak Creek	SGH	8.342
UT to White Oak Creek	SGI	7.306
UT to White Oak Creek	SHT	5.616
UT to White Oak Creek	SRQ	7.477
UT to White Oak Creek	SRR	7.623
White Oak Creek	SFV	5.872

Effects to the listed waterbodies will occur under three TIPs as shown on Figure 10. The projected construction duration of each TIP is approximately:

- R-2721 - 3.0 years
- R-2828 - 3.5 years
- R-2829 - 2.5 years

TIPs R-2721 and R-2828 are scheduled to be constructed first and concurrently such that they open to traffic at about the same time. TIP R-2829 is currently scheduled to follow the completion of R-2828 by about 3 to 4 years.

4.1.1 Stream Fill (Substrate (Habitat) Disturbance/Loss)

Highway construction within and around water bodies often results in the placement of fill into streams and adjacent floodplains. Two types of fill may occur, permanent and temporary. Permanent fills consist of bridge piers and abutments, culvert and pipe construction or extensions, and roadway fill slopes. Construction causeways and work bridges used for equipment access are examples of temporary fill. The specific effects to the streams within 0.25 RM of occupied habitat are as follows (Figure 11):

- Swift Creek (SDG) & SDH - As noted in Section 4.5.1, NCDOT has committed to avoiding any in-stream fill related impacts, be it permanent or temporary, at the crossing of Swift Creek
- Stream SDF & SCY – Based upon the preliminary design, the second bridge in the Swift Creek floodplain avoids the placement of permanent fill in the majority of (potentially the entire) stream channel, pending the final design. In a "worse-case scenario", total permanent impacts are not expected to exceed 180 feet. Temporary causeways may be required to construct this bridge and roadway; however, the extent of these temporary impacts will not be known until the final design. Efforts will be made to minimize impacts to the amount practicable; however, assuming a single work bridge in between the dual bridges, temporary impacts are not expected to exceed 70 feet.
- Stream SDJ – Stream SDJ is a roughly perpendicular crossing that will be placed in a box culvert. This is expected to result in permanent fill of 443 linear feet of stream channel.
- Stream SDK – Stream SDK is an intermittent stream that begins near the edge of a fill slope based on preliminary design. Impacts will be determined in final design, but are anticipated to be relatively minor.

The crossing of Swift Creek will not involve any permanent, or temporary fill into the channel; thus, there will be no anticipated habitat loss/disturbance associated with this crossing. However, given the close proximity of the bridge footprint to the stream channel, there is always a remote possibility that small amounts of fill (rip rap, bridge materials, etc.) could inadvertently fall into the channel. These unforeseen events are unlikely to occur, and if they do occur would result in minimal amounts of fill related effects; nevertheless, this potential is factored into the effect assessment and conservation measures to offset effects.

While none of the streams within 0.25 mile aside from Swift Creek are considered to be currently occupied by either DWM or Yellow Lance, there is a slight possibility that these species could expand their respective range into the lower sections of these tributaries in the future. Additionally, fish hosts of the two mussel species could potentially be present in these streams during construction and adverse effects to the fish hosts related to stream fill would in turn result in adverse effects to the mussels.

4.1.2 Fish Host Effects

There is the potential for fish infested with DWM or Yellow Lance glochidia to be present in streams while the crossing structures are being constructed. Lethal and sub-lethal effects to these fish resulting from construction, would in turn effect the attached mussel glochidia.

Mortality of individual fish can occur during construction in a variety of ways. Individuals can be crushed during pile driving, or causeway placement. Demersal species like darters are more inherently susceptible to this type of injury than pelagic species like shiners, as they have an affinity to occur near the stream bottom, and seek cover within the substrate when threatened, as opposed to shiners, which occur more in the water column and would swim away from the impact area.

Causeway construction may also strand individuals in areas that are dewatered, or congregate them into ponded areas where temperature and DO levels may impact their health and/or survival. Dispersal of host fish from the areas being affected by construction may increase their susceptibility to predation while they seek alternate habitats.

Acoustic, or noise impacts, can also occur to fish during pile driving and causeway placement. Underwater sound waves emitting from these actions can cause tissue damage to fish that can be lethal. There are several factors which affect the level of impact, including, frequency, sound pressure, acoustic impulse and distance from source (Caltrans Office of Environmental Engineering 2001). Anatomical and physiological traits of the fish species may also influence their susceptibility to sound impacts. For example, shiners and other ostariophysan fishes contain a series of small bones called Weberian Ossicles that connect the auditory system to the swim bladder, whereas, darters and other species in the Neotelostei clade do not have a close swim bladder-auditory system connection. Studies have shown that the level of inflation of the swim bladder greatly influenced hearing sensitivity of species with Weberian Ossicles, and had no significant effect on species without this structure (Moyle and Cech, 1988). The size of the fish also influences sensitivity to sound effects, as larger fish appear to be able to withstand a larger sound impulse than small sized fish (Caltrans Office of Environmental Engineering 2001, Yelverton et al. 1975). A further summary of the effects of acoustics on fish, including, bridge construction related effects, are provided in Caltrans Office of Environmental Engineering (2001) and references contained within.

Sub-lethal effects on host fish from construction activities can range from physiological stress (lower DO) associated with causeway de-watering, non-lethal tissue damage related to acoustic effects, and non-lethal effects to the fish sensory system, which may impact their ability to detect predators. All of these could in turn affect the ability of attached glochidia to successfully transform into juveniles.

Furthermore, in-stream fill of these tributaries may cause downstream impacts to the species by affecting stream stability and thus resulting in erosion/sedimentation, which could then impact occupied habitat.

4.1.3 Erosion/Sedimentation from Construction

The detrimental effects of erosion/sedimentation on freshwater mussels are discussed in Section 3.5.1. Excessive suspended solids in the water column, sedimentation, and turbidity result in reduced biodiversity as well as a decline in productivity at all trophic levels (Gilbert 1989). As discussed in Section 4.5.1, NCDOT is committing to using the Design Standards in Sensitive Watersheds [15A NCAC 04B .0124 (b) – (e)] throughout the project. These measures will minimize the potential for sedimentation/erosion related adverse effects to the DWM and Yellow Lance; however, they will not completely eliminate the potential. The amount of sedimentation/erosion that will result from project construction and the level to which it adversely effects the two species is difficult to predict and is dependent on several factors, such as the frequency and duration of rainfall events during construction that exceed the erosion control design devices, construction duration and adherence to proper maintenance of erosion control devices, and the promptness to respond and remediate erosion control failures.

4.1.4 Alteration of Flows/Channel Stability

Geomorphically stable stream channels and banks are essential for the survival and conservation of many freshwater mussel species, including DWM and Yellow Lance. Stream channel instability can result from bridge construction and culvert/pipe crossings. Natural stream stability is achieved when the stream exhibits a stable dimension, pattern, and profile such that over time, the channel features are maintained, and the channel neither aggrades, nor degrades. Channel instability occurs when scour results in degradation, or when sediment deposition leads to aggradation (Rosgen 1996). The placement of fill, such as bridge piers, culverts, pipes, and causeways, into streams can alter the normal flow pattern of a water body by reducing flow velocities upstream, increasing sedimentation and flow velocities downstream, and resulting in scour and erosion. Such effects are not anticipated in the mainstem of Swift Creek, as no permanent or temporary structures will be allowed within the channel or within 10 feet of the top of the banks. There are no other streams with the Action Area that are currently considered to be occupied by the DWM or Yellow Lance, and based upon the preliminary design and NCDOT stormwater design flow standards, little to no direct alteration of flows and/or channel stability associated with these structures are expected to occur within the occupied portion of Swift Creek.

4.1.5 Effects Associated with Borrow/Fill, Staging and Storage

The contractor may use areas within the Swift and Middle Creek watersheds for staging, storage, refueling, borrow pit, or spoil areas. Any of these areas that occur within the watershed of occupied habitat have the potential to result in direct effects to the DWM and Yellow Lance. In general, the locations of borrow pits and spoil areas will be excluded from stream buffer areas per existing buffer regulations and local ordinances (Section 4.3). However, areas outside of the buffers still have the potential to affect water quality, and in turn freshwater mussels, through sedimentation, erosion, and introduction of toxic compounds into streams via stormwater channels, ditches, and overland runoff or through losses during the hauling process. The extent and magnitude of these effects is dependent upon distance to occupied habitat, as well as soils and topography which influence transport of sediment and toxicants to occupied habitat. The potential for these effects to occur can be minimized by developing measures to control sedimentation, erosion, and introduction of toxic compounds from entering streams in these areas.

4.2 Operational Effects

Operational effects include effects that arise from maintenance and daily vehicular use of the facility once it is in operation, as well as natural responses over time to the proposed action's construction effects that occur post-construction.

4.2.1 Alteration of Flows/Channel Stability

As noted in Section 4.1.4, geomorphically stable stream channels and banks are essential for the survival and conservation of many freshwater mussel species, including DWM and Yellow Lance. Once construction is completed, stream channel instability can occur as over time streams adjust to the channel alterations from construction, which could eventually impact occupied habitat and/or host fish species. The constructed project road network within a watershed can be a factor affecting channel stability as it contributes to changing of the timing and volume of peak flows, intercepting subsurface water, and decreasing the time for overland runoff to reach the stream channel. The specific factors that influence the potential for the crossing structures outside of the defined area of construction related effects to adversely affect occupied habitats as a result of destabilization of the stream channel include, but are not limited to:

- design of the structure
- distance of crossing structure to occupied habitat
- watershed size
- stream gradient and characteristics (i.e. presence of natural grade control (bedrock outcropping, etc.)

- low gradient pools, or beaver dams and other structures that may attenuate flow velocity, as well as conditions and changes to the watershed including development and road network.

As a result, even though a watershed receives the same amount of precipitation, water is transported through the system much more quickly, thus resulting in higher peak discharges and resultant increases in stream power.

This increased stream power can more effectively erode the streambed and banks (Castro 2003). While any crossing structure (bridges, culverts, pipes, etc.) can lead to channel instability, in the past, culverts have been particularly problematic. Culverts have often lead to channel instability by constricting the flow, which increases the erosional forces. Historically, the design of culverts only accounted for the passing of water, and not bed materials, sediment, and woody debris. As such, significant problems at culverts have occurred including "(1) plugging due to large wood transport, (2) sediment deposition at the inlet due to the backwater effect, and (3) high velocity flows exiting the culvert resulting in channel scour" (Castro 2003). Channel instability associated with a culvert crossing is not static, rather they can be far reaching and effect the channel, and in turn the aquatic community, for considerable distances both upstream and downstream, as "streams are linear systems that move mass and energy along the channel primarily in upstream/downstream directions and through the floodplain in all directions" (Castro 2003).

4.2.2 Roadway Runoff

Numerous pollutants have been identified in highway runoff, including various metals (e.g., lead, zinc, iron), sediment, pesticides, deicing salts, nutrients (nitrogen, phosphorus), and petroleum hydrocarbons (see Section 3.5.3 for details on how these pollutants effect freshwater mussels). In addition, thermal effects to DWM and Yellow Lance can also occur from highway runoff. The respective populations are expected to experience localized increased exposure to roadway runoff originating from the 77 crossings draining to occupied habitat along the 540 alignment, as well as increased roadway runoff originating from the existing roadway network due to induced increases in traffic volumes (Section 4.3.1). In some areas there may actually be a reduced exposure to roadway runoff from induced decreases of traffic volumes (Section 4.3.1). NCDOT has committed to eliminating deck drainage directly into any waterbody within the Action Area, as well as a commitment to match the post-discharge to the pre-construction conditions. These actions will reduce the potential for adverse effects from roadway runoff.

4.2.3 Toxic Spills

Roadway construction can also affect the aquatic environment by increasing the potential for toxic spills from vehicular accidents once the facility is in operation. As evidenced from the

Clinch River in Virginia (Section 3.5.3), toxic spills resulting from traffic accidents can be devastating to mussel populations. The type (i.e. commercial truck, etc.) and volume of traffic affect the potential for toxic spills to occur. The locations where there is the highest potential for hazardous spills to impact the DWM and Yellow Lance are at the crossing of Swift Creek and tributaries within 0.25 mile, though any spill within the watershed has the potential to affect these species. There is no way to accurately predict when and where toxic spills will occur. The Texas Department of Transportation and the FHWA commissioned a study that evaluated roadway hazardous material spill incidents associated with transportation on Texas highways. The study found that between 2002–2006, more than 900 hazardous material spills of varying volumes were recorded in the state, and it was speculated that rainy/wet roadway conditions may be a factor in the frequency of spills. The results were used to develop design guidelines and parameters to reduce the risk of exposure to travelers and individuals responsible for spill cleanup (Thompson et al. 2011).

One way to lessen the adverse effects of toxic spills to water resources is the construction of HSB(s) along roadway stream crossings, which are designed to contain hazardous materials in the event of an accidental spill. During “normal operation, stormwater runoff flows unimpeded through the basin. In the event of a spill, the outlet control structure is can be closed, preventing discharge from the basin. HSBs may be shaped like a pond or a channel. Sluice gates or sand bags are typically used to block the basin outlet. Some HSBs are marked by a sign with instructions to personnel on how to contain a spill. The HSB outlet control structure may be designed to provide detention in some applications. One measure of a successful HSB application is the ease with which someone could locate and close the outlet device during an emergency. In addition, the HSB should allow access for appropriate maintenance equipment.

The NCDOT guidelines require HSBs to be provided at stream crossings on highways functionally classified as a rural or urban arterial, and;

- The stream (1) is identified as an Outstanding Resource Water (ORW) or a WS-I water supply, or
- The stream (1) crossing is within 1/2 mile of the critical area (2) of a water supply source classified as WS-II, WS-III and WS-IV.
    - For the purpose of these guidelines, Stream (1) is defined as those depicted as blue lines on 7-1/2 minute (1:24000 scale) United States Geological Survey (USGS) quadrangles.
    - Critical area (2) is defined as extending 1/2 mile from the normal pool elevation of a reservoir; or 1/2 mile upstream of, and draining to an intake.

While none of these situations apply, NCDOT can also require basins be built for other circumstances, such as the presence of sensitive aquatic species. As mentioned in Section 4.5.1, to minimize the potential for adverse effects to the DWM and Yellow Lance from toxic spills, NCDOT is committing to installing one to two HSB(s) within the immediate vicinity/floodplain of the crossing of Swift Creek, the ultimate location(s) to be determined during final design.

4.3 Induced Land Development

Roadway construction can influence land use and result in development that would not occur without the road (induced development). While land development itself does not affect freshwater mussels and their habitat, increases in sediment loads and various pollutants, alterations in flow regime (base flow and peak discharge), and loss of riparian buffers are consequences of development that lead to water quality degradation. How these consequences of land development affect water quality and ultimately freshwater mussels is discussed in Section 3.5.4 of this report.

Baker Engineering (2017) completed a Quantitative Indirect and Cumulative Effects (ICE) Report of the Complete 540 Project using a methodology to forecast land use changes between the base year of 2011 and design year 2040. This Quantitative ICE report utilized much of the information in the Qualitative ICE Report (H.W. Lochner 2014). As was projected in the Qualitative ICE Report and confirmed and quantified in the Quantitative ICE Report, the introduction of a high-speed, controlled-access roadway into the FLUSA would provide a faster and more direct route to employment and commercial centers in the region. Further, the primary changes in land development from the No-Build to Build are higher land use densities, more commercial and industrial development, and a greater mix of uses in the areas surrounding the interchanges. Though this pattern is captured in the model results, it is noted: "Without the project, there would be both less development overall and lower densities of development in the FLUSA. However, there does not appear to be a more sprawled development pattern in the FLUSA in the Build scenario, and the relative increase in development in the Swift Creek water supply watershed is miniscule," (Baker Engineering 2017d).

The predictive watershed model utilized in the analysis and documented in the Quantitative ICE Report (Baker Engineering 2017c) was run twice for each land use scenario to estimate a range of potential induced and cumulative effects to the water quality study area. For both model runs, the process described in Quantitative ICE Memo #2 (Baker Engineering, 2017b) was used to calculate land cover in the water quality study area. The first, more-conservative model run, produced an "upper limit" of percent impervious coverage for each HUC in the study area. The second model run used the observed percent impervious coverage by land cover type in the Baseline condition to estimate the "lower limit" of impervious coverage for the 2010, 2040 No-Build, and 2040 Build scenarios. This approach could produce some under-estimation of impervious surface percentages; therefore, Model Run 2 provides a low-end-of-range estimate, and Model Run 1 provides a high-end-of-range estimate. These results are provided as ranges in Table 11.

Table 11. Percent Increases from 2010 Baseline to 2040 No-Build and from 2040 No-Build to 2040 Build

Watershed	Impervious Surface (%)			TSS (MT/yr/ac)			Copper (g/yr/ac)		
	Baseline	Baseline to No-Build % increase	No-Build to Build % increase	Baseline	Baseline to No-Build % increase	No-Build to Build % increase	Baseline	Baseline to No-Build % increase	No-Build to Build % increase
White Oak Creek	4-10	5-18	≤1	0.08	26-38	≤1	0.69-0.70	26-38	1
Piney Grove Cemetery-Swift Creek	4-7	5-12	≤1	0.20	18-20	3-4	1.36-1.40	18-20	3-4
Little Creek (Lower)	4-9	7-22	≤1	0.11	21-27	≤1	0.74	21-27	≤1
Mahlers-Swift Creek	5-14	10-29	≤1-6	0.26	88-94	≤1	2.27-2.29	88-94	≤1
Reed Branch	4-12	7-22	≤1	0.17	18-20	2	1.17	34-38	2
Middle Creek (Lower)	3-8	5-14	≤1	0.33-0.34	34-38	3	2.26-2.34	29-30	3

The Quantitative ICE Assessment Memo #4 (Baker Engineering 2017d) addressed a more detailed NEPA-based analysis of induced effects to the six subwatersheds in which DWM and Yellow Lance are currently extent; White Oak Creek (Lower), Piney Grove Cemetery-Swift Creek, Mahlers-Swift Creek, Reed Branch, Little Creek (Lower), and Middle Creek (Lower) (Figures 8 and 9). Three factors were chosen to quantify induced land use effects for this BA; impervious surface, total suspended solids (TSS), and copper. These factors were chosen as they either directly or indirectly can be correlated with, or serve as surrogates for, threats to mussel species discussed in Section 3.5.3.

Stream flow and nitrogen were also evaluated in the Quantitative ICE memos (Baker Engineering 2017a, 2017b, 2017c, and 2017d). For stream flow, any changes will be a direct correlation to impervious surface effects. As there are opportunities to temper this correlation via various stormwater control measures, it was decided that impervious surface effects would be the most appropriate parameter to consider. Nitrogen was not included directly in this evaluation because of the difficulty of using this parameter as an indicator of stream health. Nitrogen toxicity on mussels is related to a multitude of factors, and the amount of nitrogen in and of itself does not necessarily equate to an effect.

As discussed in the DWM Viability Study (Three Oaks 2016) and the ICE Memoranda and Water Quality Assessment (Baker Engineering 2017a, 2017b, 2017c, and 2017d), there are a number of development restrictions in place within the Action Area, such as Neuse Buffer Rules and designated Environmentally Sensitive Areas (ESAs), that would lessen some of the potential for project induced development. However, the DWM Viability Study (Three Oaks 2016) notes there are several areas that drain into Swift Creek that are exempt from the current ESA, such as some properties in the I-40/NC-42 interchange area. For example, the Golden Corral property was exempt as it was approved prior to the adoption of the ESA regulations. However, the Wal-

Mart property was not exempt, and various stormwater BMPs were incorporated into site development.

4.3.1 Induced Impervious Surface Effects

Impervious surface was chosen as one of the three factors since it directly relates to loss of pervious surfaces and indirectly to water flow in receiving surface waters, and is used as a proxy to represent anticipated indirect physical habitat effects (channel instability, channel scour, etc.), indirect water quality effects (thermal pollution) and indirect water quantity effects (changes in peak and base flows). The percentage increase in five of the six watersheds from the 2040 No-Build to Build is less than or equal to 1 percent, with the exception being the Mahlers-Swift Creek watershed, where the range is less than or equal to 1 to 6 percent. In the least impactful scenario, there would be a 10 percent increase from the Baseline to the No-Build. In accordance with this scenario, then the percent increase from No-Build to Build would also be the least impactful scenario, with an increase of less than or equal to 1 percent over the Baseline to No-Build total. Accordingly, in the most impactful scenario, construction of the Complete 540 project (2040 Build Scenario) would increase the percent impervious by up to 6 percent above the 29 percent increase (No-Build) that would be expected without the project. In all the other watersheds, similar scenarios are forecast with regard to increasing amounts of imperviousness from the baseline conditions to 2040; however, in those instances, the increases in impervious surface attributable to Complete 540 would be less than or equal to 1 percent.

4.3.2 Induced TSS Effects

TSS was chosen as one of the three factors as a proxy to represent anticipated indirect water quality and physical habitat effects since it directly relates to sedimentation, which degrades water quality and habitat suitability. As shown in Table 11, the percentage increase in three of the six watersheds from the 2040 No-Build to Build is less than or equal to 1 percent. In the other three, the highest potential increase is the Piney Grove Cemetery-Swift Creek watershed, where there is a 3 to 4 percent increase attributable to Complete 540, followed by 3 percent in Middle Creek and 2 percent in Reed Branch. However, Piney Grove Cemetery-Swift Creek watershed, along with the Reed Branch watershed, is where the least amount of percent increase from Baseline to No-Build (18-20% for each) is anticipated.

4.3.3 Induced Copper Effects

Copper was chosen as one of the three factors as a proxy to represent anticipated indirect water quality effects since it is generally considered to be the most toxic of the contaminants to freshwater mussels, is found in runoff directly relatable to increased development, and has been addressed in the Lower Swift Creek Water Quality Report (Three Oaks 2015). Because the transport method for copper is directly related to TSS, the same percent increases in the six watersheds that were noted for TSS are also reflected for copper. The percentage increase in three of the six watersheds from the 2040 No-Build to Build is less than or equal to 1 percent, with the highest potential increase being the Piney Grove Cemetery-Swift Creek watershed. In this watershed, there is a 3 to 4 percent increase attributable to Complete 540, followed by 3 percent in Middle Creek and 2 percent in Reed Branch.

4.3.4 Induced Roadway Runoff Effects

Induced changes in land use also has the potential to affect traffic patterns on the existing road network within the action area of roadway construction projects, which in turn result in changes of pollutant concentration of roadway runoff exposure within occupied habitats. Increased traffic volumes on the road networks traversing the watersheds could potentially affect the associated aquatic communities, including freshwater mussels, by causing water quality degradation via an increase in runoff contaminants attributable to the additional traffic. Increased traffic volumes may also result in the need for widening and improvements to existing roads that occur within the Swift and Lower Middle Creek watersheds, further increasing runoff from both construction and increased stormwater flows from the additional impervious surface. Widening of existing roadways could also result in increased exposure to thermal pollutants due to a larger impervious footprint of the respective roadways. Decreases in traffic volume could have a potential localized beneficial effect by decreasing concentrations of toxicants originating from roadway runoff, and/or toxic spills along roadways.

Induced effects from roadway runoff fall into two categories; 1) increases/decreases in roadway runoff due to changes in traffic patterns on the existing roadway network within occupied watersheds, and 2) roadway runoff originating from project crossings of waters within occupied watersheds.

The forecasted traffic levels indicate that the induced growth effects of the proposed project will likely add to the total volume of traffic in Wake and Johnston Counties and to the total vehicle miles traveled and vehicle hours traveled. Roads that connect to Complete 540 will likely see some increases in traffic, mostly in the immediate vicinity of interchanges. The traffic analysis (HNTB 2017) of FLUSA-Level traffic conditions showed that while total Daily and PM Peak Vehicle Miles Traveled (VMT)/Vehicle Hours Traveled (VHT) slightly increased with Complete 540 in place, the congested Daily and PM Peak VMT/VHT, average Daily and PM Peak speeds, and Daily and PM Peak congested roadway mileage all improved in the Build condition. Additionally, the volume-to-capacity comparisons showed that all areas with a Level of Service of “E” or worse had Triangle Regional Model daily volume-to-capacity ratios within the same threshold in the model runs both Future-Year Build conditions (No-Build and Build). This indicates that these issues would exist with or without the project.

There are multiple crossings of water bodies within the Swift and Middle Creek watersheds all of which eventually drain to habitat occupied by DWM and/or Yellow Lance; thus, there is potential for occupied habitat to be exposed to various toxicants originating from these crossings. Numerous factors influence the potential for these toxicants to reach occupied habitats:

- traffic volumes
- distance of crossing structure to occupied habitat
- watershed size
- stream gradient and characteristics (i.e. presence of natural low gradient pools, or beaver dams and other structures that may attenuate transport of toxins, etc.)
- toxin attributes that affect exposure pathways (i.e. bound to sediment).

The magnitude of the effects associated with roadway runoff originating from a specific crossing is dependent on the transport mechanisms described above, coupled with the amounts of toxicants entering occupied habitat via other pathways (other tributaries, atmospheric deposition, run off from adjacent land use, ground water inputs, etc.).

4.4 Conclusions of Effects – DWM and Yellow Lance

The project will incorporate measures to avoid and minimize potential adverse effects. However, the project is still likely to have unavoidable direct and indirect effects to DWM and Yellow lance mussel populations in the action area.

4.4.1 Construction Effects

The construction of Complete 540 has the potential to have the following construction related effects on the DWM and Yellow Lance.

4.4.1.1 Habitat Loss/Disturbance

As discussed in Section 4.5.1, the crossing of Swift Creek will not involve any permanent, or temporary fill into the channel; thus, there will be no anticipated habitat loss/disturbance associated with this crossing. However, as stated in Section 4.2.1, unforeseen events may result in minimal amounts of fill entering Swift Creek and are factored into the assessment of effects and conservation measures to offset effects (See Preconstruction Survey and Potential Mussel Relocation Section 4.5.2.1).

There will be multiple crossings of streams within Swift Creek and Lower Middle watersheds that will result in the both the permanent and temporary loss (fill and realignment) of stream channel. Impacts to the tributaries that are within 0.25 mile of occupied habitat of Swift Creek could result in a maximum of 180 and 433 linear feet, respectively, of permanent stream channel fill. Additionally, temporary habitat disturbance/losses in Stream SDF is anticipated as a result of fill associated with the use of temporary causeways during construction, the final amount of which will be determined during final design, but will not exceed 70 linear feet.

The permanent and temporary steam impacts associated with the construction of Complete 540 may have long-lived effects on the DWM and Yellow Lance's ability to colonize these areas in the future.

4.4.1.2 Fish Host Effects

As discussed in Section 4.1.2, project construction has the potential to result in lethal and non-lethal effects to fish hosts, including being crushed by construction materials, stranding in dewatered areas, physiological stress, and increased susceptibility to predation from dispersal, as well as acoustic related impacts. The completion of Complete 540 will result in some of the longest water conveyances (culvert and pipe) throughout the Swift Creek and Middle Creek watersheds. Such lengthy structures have proven to be an impediment to fish migration and passage. Further, it is not unusual for step pools to form at the outlet of these structures, further inhibiting passage. So while neither DWM or Yellow Lance occupied habitat is extent outside of the mainstems of Swift and Middle Creeks, construction of Complete 540 could prevent or adversely affect the passage of fish hosts into unoccupied portions of the watershed. Determining if fish carrying DWM or Yellow Lance glochidia are present in streams that will be impacted would be very difficult, and require intensive fish sampling and examination. If host fish were determined to occur within these streams, such an analysis may also have more of an adverse impact on DWM and Yellow Lance glochidia than the actual effects associated with construction. Therefore, these effects are not readily quantifiable.

4.4.1.3 Sedimentation/Erosion From Stream Crossing Construction

As discussed in Section 4.5.1, NCDOT is committing to using the Design Standards in Sensitive Watersheds [15A NCAC 04B .0124 (b) – (e)] throughout the project, which will reduce the potential for adverse effects; however, these effects cannot be entirely eliminated. Numerous factors influence the extent and magnitude of these types of impacts, making it difficult to quantifiably predict (See Section 4.1.3). As such, some level of direct sedimentation/erosion related adverse effects to the DWM and Yellow Lance are anticipated to occur as a result of project construction.

4.4.1.4 Alteration of Flows/Channel Stability

As stated in Section 4.1.4, the crossing of Swift Creek will span the channel and not involve any fill (permanent, or temporary) in the stream; thus, alterations of flow and channel stability are not expected to occur in this location. In addition, based upon the preliminary design and NCDOT stormwater design flow standards, direct alteration of flows and/or channel stability associated with constructing the other crossings are anticipated to be minimal and are not expected to extend into the occupied portion of Swift Creek.

4.4.1.5 Effects Associated with Borrow/Fill, Staging, and Storage Sites

Other potential direct effects associated with project construction are sedimentation/erosion and introduction of toxic compounds originating from borrow/spoil, staging, equipment storage, and refueling areas, entering Swift Creek or Lower Middle Creek via unregulated stormwater channels, ditches, and overland runoff. At this time, the locations of potential borrow/spoil sites, staging areas, equipment storage areas, and refueling areas have not been chosen. As noted in the Conservation Measures (Section 4.5.1), NCDOT will strongly discourage the contractor from choosing borrow/waste site locations, staging areas, equipment storage areas, and refueling areas within 0.25 mile of Swift Creek. However, if the contractor opts to pursue borrow or waste sites in these locations, the NCDOT Division Environmental Officer will coordinate with the NCTA and the USFWS during the approval process of any borrow or waste sites. In addition, NCDOT standard guidance for borrow/fill sites provide another layer of environmental protection for waterbodies. These sites will also be reviewed prior to project permitting through interagency merger meetings.

Staging sites are required to be identified by the Contractor and discussed with NCDOT and USFWS (as well as all the regulatory agencies in the merger process) prior to permitting, and as such will be subject to the same regulations and guidance as the rest of the project.

As such, if any borrow/fill sites are within Swift Creek or Middle Creek watersheds, existing regulations and the commitment of NCDOT to adopt measures to avoid/minimize the potential for adverse effects in non-regulated areas within the respective watersheds, make it extremely unlikely (discountable) that these types of project-related direct effects will occur.

4.4.2 Operational Effects

Operational effects as described in Section 4.2 may occur in the waterbodies listed in Table 10. These effects generally diminish the further they occur from occupied habitat.

4.4.2.1 Alteration of Flow/Channel Stability

Once the project has been constructed, it is anticipated some streams will continue to alter their existing flow/channel stability as the seek equilibrium from construction impacts. In addition, the road network that evolves due to Complete 540 will affect flow/channel stability as it contributes to the change of the timing and volume of peak flows, intercepting subsurface water, and decreasing overland flow. However, given the predicted growth in the area regardless of the project (No Build), the extent and magnitude of this type of effect is difficult to predict, and can be minimized with adequate design and proper installation and maintenance. It is also possible that building Complete 540 will actually result in fewer roadways that would have otherwise been constructed. As such, indirect effects to DWM and Yellow Lance from the alteration of flow/channel stability are likely immeasurable.

4.4.2.2 Roadway Runoff

There are multiple streams that will be impacted due to the project that drain to occupied portions of Swift Creek and/or Lower Middle Creek. These new sources of roadway runoff coupled with increased traffic volumes on some of the existing roads within the respective watersheds may result in a localized increase of the respective DWM and Yellow Lance population's exposure to roadway derived pollutants. However, there may also be localized reductions in exposure to toxicants in other areas within the respective populations as a result of decreased traffic volumes along other roads within the Action Area that drain to occupied habitat. As such, while it is likely that construction of the Complete 540 will likely lead to slightly more exposure of freshwater mussels to roadway runoff than the No-Build scenario, there isn't existing data to determine if this potential increase would pass a threshold to which would adversely impact the mussels.

4.4.2.3 Toxic Spills

As discussed in Section 4.2.3 there is the potential for adverse effects to occur to the DWM and Yellow Lance as a result of toxic spills once the facility is in operation, with the potential for impacts increasing the closer they occur to Swift Creek. There is no way to accurately predict where and when toxic spills associated with the facility will occur; however, such an event is likely to occur during the lifetime of the facility. According to the US Department of Transportation (USDOT), there were 639 reported transportation related incidents involving hazardous materials in North Carolina in 1996 (USDOT 1996). It is even harder to predict the magnitude of the impacts to DWM and Yellow Lance if such a spill were to occur along the facility. The construction of a HSB(s) at the crossing of Swift Creek will help to minimize the potential for this type of adverse impact to occur in the future.

4.4.3 Induced Land Development Effects

As discussed in Section 4.3, both the ICE Memoranda and Water Quality Assessment (Baker Engineering 2017a, 2017b, 2017c, and 2017d) analyses, as well as the Qualitative ICE Report (H.W. Lochner 2014), forecast continued increases in developed land and associated water quality degradation in the Swift Creek and Middle Creek watersheds in both the 2040 No-Build and Build scenarios. Except for the Mahlers-Swift Creek subwatershed, all the subwatersheds occupied by or draining to habitat occupied by DWM and Yellow Lance increased in percentage of imperviousness, which is attributable to the 2040 Build Scenario, by less than or equal to 1 percent. In the Mahlers-Swift Creek subwatershed, the percent increase of imperviousness may be as high as 6 percent. Additionally, increases of 3 to 4 percent of TSS and copper associated with the 2040 Build Scenario are projected in the Piney Grove Cemetery-Swift Creek subwatershed; followed by 3 percent in the Lower Middle Creek; 2 percent in Reedy Creek; and less than or equal to 1 percent in White Oak Creek, Little Creek Lower and Mahlers-Swift Creek subwatersheds, respectively.

Induced changes in land use may also result in changes of roadway runoff exposure within occupied habitats. Increased traffic volumes on the road networks traversing the watersheds could potentially affect the associated aquatic communities, including freshwater mussels, by causing water quality degradation via an increase in runoff contaminants attributable to the additional traffic. Decreases in traffic volume could have a potential localized beneficial effect by decreasing concentrations of toxicants originating from roadway runoff, and/or toxic spills along roadways.

4.4.4 Cumulative Effects

As detailed above, the proposed Complete 540 is expected to directly and indirectly result in adverse effects to the DWM and Yellow Lance through the construction and operation of the proposed facility, as well as through induced land use effects. Cumulative effects under the ESA are those effects of future state or private activities not involving federal activities that are reasonably certain to occur within the action area of an action subject to consultation. Under NEPA, cumulative effects are the incremental environmental impact or effect of the proposed action, together with impacts of past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. As noted, the cumulative analysis for the DEIS was performed using the NEPA definition. We used the broader, more conservative, NEPA cumulative assessment as the biases for this ESA cumulative analysis. The reasoning for this is due to the difficulty predicting which of the future development will require federal authorization, such as a CWA 404 permit, and would not be considered a cumulative effect under the ESA for this action. Therefore, the potential cumulative effects discussed in this BA, as defined per ESA, are overestimated since the ICE Report (Baker Engineering 2017a-d) included the effects of future federal actions as well as non-federal actions. We are making the assumption that some of the future activities discussed would have a Federal nexus and/or are already considered as induced development for the project (interrelated/interdependent activities).

Future state and private activities, including federal actions, are reasonably certain to occur within the Swift Creek and Middle Creek watersheds (Baker Engineering 2017d) and will continue to impact the DWM and Yellow Lance. However, as indicated above, most all of which are expected to occur with or without (Build vs. No-Build) the proposed action. The projected growth in the project Action Area is anticipated to result in additional (cumulative) effects to the DWM and Yellow Lance.

State and local regulations in the Swift and Middle Creek watersheds aim to reduce the cumulative effect of development on water quality in these sensitive watersheds. These regulations include the *Swift Creek Land Management Plan*, the Neuse River Riparian Buffer Rules, the Neuse River Basin Stormwater Rules, protections agreed on during the consultation process for the Clayton Bypass project, and protections agreed on during the development of the Dempsey E. Benton WTP. These regulations and protections are discussed in detail in the DWM Viability Study (Three Oaks 2016). While the effectiveness of these plans has not been fully evaluated due to the short period of time in which they have been in effect, these plans provide more stringent restrictions to development than what would otherwise have been enforced by other state and federal regulations.

Other adverse effects to the DWM and Yellow Lance populations in the Action Area have occurred in the past and will continue to occur. These types of effects are difficult to identify or quantify, but may include sedimentation/erosion impacts from agricultural and residential land use; water quality effects from agricultural and residential sources (e.g., fertilizers, pesticides); small-scale littering into the river; and impacts from recreational uses of the river (e.g., fisherman stepping on individual mussels, using mussels as bait, and the riding of ATVs in occupied areas of the streams). These activities could adversely affect individual mussels or habitat. Potential effects are expected to be localized and small.

Table 11 reports the potential range of effects to the three indicator factors analyzed, however, further quantifying the ultimate effect the changes to the factors may have on the DWM and Yellow Lance is not plausible. Given the projected growth in the watershed with or without the Complete 540 project, the viability of both the DWM and Yellow Lance in these watersheds is uncertain. As detailed in the DWM Viability Study (Three Oaks 2016), aggressive management of the remaining populations, particularly through captive propagation and thereby providing the potential to augment the existing populations if conditions so warrant in the future, is considered to be the best practice to allow these populations to survive.

The combined effect of past and future actions addressed above may lead to adverse effects to the DWM and Yellow Lance. Improved land-use practices, development controls, and protection of habitat could provide beneficial effects that would help offset adverse cumulative effects. The proposed conservation measures, particularly the propagation facility, will help to alleviate some of the cumulative effects affecting these two species (See Section 4.5 – Project Conservation Measures).

4.4.5 Biological Conclusion

As summarized in Section 4.0, construction of the Complete 540 Project is expected to result in unavoidable adverse effects to both the DWM and the Yellow Lance. Therefore, the proposed action **"May Affect, Likely to Adversely Affect"** the DWM and Yellow Lance. Incorporation of conservation measures into the project will offset some of those effects (Section 4.5).

4.5 Project Conservation Measures

The following measures are being implemented by NCDOT to avoid/minimize and offset potential effects from construction activities to DWM and Yellow Lance. These conservation measures fall into two general categories:

1) measures to avoid/minimize effects
2) measures to help offset anticipated effects

4.5.1 Conservation Measures to Avoid/Minimize Effects to DWM and Yellow Lance

Various measures have been incorporated into the project to avoid and minimize adverse effects to the DWM and Yellow Lance.

4.5.1.1 Erosion Control Measures

For projects that occur in watersheds that contain protected aquatic species, NCDOT develops erosion control measures that exceed the standard BMPs, incorporating the Design Standards in Sensitive Watersheds [15A NCAC 04B .0124 (b) – (e)], regardless of the NCDWR stream classification. For this project, NCDOT will require Design Standards in Sensitive Watersheds throughout the entire project.

The areas within the SCW and Lower Middle Creek will be identified as “Environmentally Sensitive Areas” on the Sedimentation and Erosion Control Plans. By definition, the Environmentally Sensitive Areas will be identified as a 50-foot (15.2-meter) buffer zone on both sides of the stream measured from top of streambank. Within the identified 50-foot (15.2-meter) Environmentally Sensitive Areas, the following shall apply:

1. The Contractor may perform clearing operations, but not grubbing operations until immediately prior to beginning grading operations.
2. Once grading operations begin in identified Environmentally Sensitive Areas, work shall progress in a continuous manner until complete.
3. Erosion control devices shall be installed immediately following the clearing operation.
4. “Seeding and Mulching” shall be performed on the areas disturbed by construction immediately following final grade establishment.
5. Seeding and mulching shall be done in stages on cut and fill slopes that are greater than 20 feet (6.1 meters) in height measured along the slope, or greater than 2 acres (0.81 hectare) in area, whichever is less.

All sedimentation and erosion control measures will be appropriately maintained following NCDOT standards, to ensure proper function of the measures

4.5.1.2 Bridge Deck Drainage

The design for all bridges within the SCW and Middle Creek will eliminate deck drains into the water bodies they cross.

4.5.1.3 Agency Coordination

NCDOT will invite representatives from USFWS and NCWRC (as well as other agency personnel) to the preconstruction meeting for the Complete 540 project, as well as to preconstruction meetings associated with installation of structures within 0.25 mile of the Swift Creek crossing to ensure compliance with special project commitments.

4.5.1.4 Construction Practices

NCDOT will strongly discourage the contractor from choosing borrow/waste site locations, staging areas, equipment storage areas, and refueling areas within 0.25 mile of Swift Creek by putting such language in the project commitments. However, if the contractor opts to pursue borrow or waste sites in these locations, the NCDOT Division Environmental Officer will coordinate with the NCTA and the USFWS during the approval process of any borrow or waste sites. Note that the contractor must follow provisions in the Standard Specifications for Roads and Structures (January 2012) for borrow excavation (Section 230) and disposal of waste and debris (Section 802).

4.5.1.5 Stream Crossing Review

During the development of the alternatives for the project, an interagency field review was held to review stream crossings and determine if the minimum required structure type should be altered to avoid/minimize environmental effects. Within SCW, three crossings (Figure 12) were identified as particularly high-value that warranted larger structures (Table 12) to minimize direct effects.

Table 12. Stream and Wetland Crossings within the Swift Creek Watershed with Larger Proposed Structures Than Hydraulically Required.

Stream ID (as noted in NRTR)	Stream Crossing	Meeting Result	Reduction of Impacts
SDF, SCY, WDV	UT to Swift Creek	3@7x5 reinforced concrete box culvert (RCBC) replaced with bridges	Streams 1,495 lf Wetlands 4.39 ac *Buffers 2.95 ac
SDV, SDW, WEC	UT to Swift Creek	3@9x5 RCBC replaced with bridges	Streams 1,619 lf Wetlands 8.62 ac Buffers 4.49 ac
SEW, WFN	UT to Swift Creek	Quad bridges extended	Streams 39 lf Wetlands 5.56 ac Buffers 0.12 ac

Notes: * - 50 ft buffers measured from top of bank on either side of stream (Neuse Riparian Buffers)

4.5.1.6 Bridging of Swift Creek

The bridge that crosses Swift Creek will not have any part of the structure in the stream channel or within 10 feet of the top of either bank. Further, no permanent structures or temporary structures required to build the bridge will be placed within Swift Creek. All permanent and temporary structures will be designed and installed such that they should not result in bank instability or cause significant sediment to runoff into Swift Creek.

4.5.1.7 Hazardous Spill Basins (HSBs)

NCDOT will require construction of permanent HSB(s) on the crossing of Swift Creek. NCDOT will also require that final design attempt to direct road runoff through a HSB before being discharged to the Swift Creek tributaries (SCY, SDF, SDH, SDJ and SDK as labeled in NRTR) that are within 0.25 mile of Swift Creek. The basin(s) will be designed to contain a spill from a typical tanker truck that may have otherwise flowed directly into these water bodies. NCDOT will implement their standard protocols for upkeep and use of these basin(s).

4.5.2 Conservation Measures to Offset Effects to DWM and Yellow Lance

The following conservation measures will be undertaken by NCDOT to partially offset unavoidable project related effects to the DWM and Yellow Lance.

4.5.2.1 Preconstruction Survey and Potential Mussel Relocation

NCDOT will conduct preconstruction surveys (just prior to construction) at the Swift Creek crossing (Stream SDG) and remove mussels from a defined area (salvage area) and relocate them to appropriate habitat within Swift Creek outside of the salvage area (relocation site), or if deemed appropriate after coordination with the USFWS and NCWRC, DWM and Yellow Lance individuals may be taken into captivity to use as brood stock for propagation efforts (See Section 4.5.2.2). The pre-construction survey will be incorporated into a relocation plan that will be developed in coordination with USFWS. NCDOT and Three Oaks have successfully relocated other federally protected freshwater mussel species from other project footprints. Preconstruction survey will be incorporated into a Mussel Relocation Plan, which will identify the salvage area and be developed in coordination with USFWS and NCWRC.

4.5.2.2 Propagation Facility

Captive propagation of freshwater mussels is becoming an increasingly useful tool in the management and restoration of freshwater mussel populations. The Allee effect (high risk of demographic extirpation due to low population abundance and lack of dispersal) has been recognized as one of the major limiting factors of DWM and Yellow Lance population viability in Swift Creek. Whether the cause for the Allee effect in Swift Creek is due to past or ongoing anthropogenic factors is unclear. If the Allee effect is operating in Swift Creek causing unsustainable recruitment for the DWM and Yellow Lance populations, the release of propagated individuals might increase population viability given the apparent leveling off in population declines for some of the other mussel species.

As concluded in Smith et al. (2015) and discussed in detail in the DWM Viability Study (Three Oaks 2016), population augmentation through captive propagation is an essential component of management strategies to ensure DWM persistence in North Carolina, including the Swift and Middle Creek populations. Numerous imperiled freshwater mussel species have been successfully propagated and released into the wild for various projects in the United States, such as the Aquatic Fauna Restoration Project in the Cheoah River in Western North Carolina. This is an on-going cooperative effort between NCWRC, USFWS, and other private entities that has successfully propagated and released several freshwater mussels, including Appalachian Elktoe (*Alasmidonta ravenelaina*), which is federally listed, Slippershell Mussel (*Alasmidonta viridis*), Wavy-rayed Lampmussel (*Lampsilis fasciola*) and Rainbow (*Villosa iris*), as well as several native fish species and a federally threatened fish species, the Spotfin Chub (*Erimonax monachus*), into a nine-mile reach of the river (Fraley et al. 2017). The Appalachian Elktoe and Slippershell Mussel are closely related to the DWM. To date there have not been any DWM population augmentation or re-introduction efforts using captive propagation. However, the species has successfully been propagated from two different source populations, the Po River of the York River Basin in Virginia and Moccasin Creek of the Neuse River Basin in North Carolina (Beck and Neves 2001). There were 1,191 juveniles produced from two gravid females collected from Moccasin Creek; however, they were not released back into the creek due to logistical reasons regarding the State’s species augmentation/re-introduction policy at that time (Beck and Neves 2001). A number of the partners involved in the Cheoah River project will be an integral part of the proposed propagation facility.

Lastly, as stated in the DWM Viability report, the Dwarf Wedgemussel Workgroup for North Carolina concluded that propagation/augmentation was the highest priority management action for the Swift Creek population.

The long-term maintenance of captive held “ark” populations is a vital conservation strategy for critically imperiled mussels (Rachael Hoch, personal communication). Thus, in addition to augmenting the Swift Creek DWM population, developing the propagation facility will allow for the establishment of an “ark” population of the DWM for the Neuse River Basin, and in the future one for the Tar/Pamlico River Basin, to maintain the genetic stock.

An ongoing commitment by several entities in developing the Yates Mill Aquatic Conservation Center (YMACC) has been underway simultaneous to the development of the Complete 540 project. USFWS and NCDOT have been in coordination regarding the logistics (e.g., location, costs, maintenance) of developing a propagation facility in the Raleigh area as part of a conservation measure to help offset anticipated effects to the Swift Creek DWM and Yellow Lance population resulting from the construction of the Complete 540 project.

NCDOT has agreed to provide funding to be utilized for the retrofit and upgrade of the existing research facility in the A.E. Finley Center, at the Historic Yates Mill County Park, owned by Wake County and leased and operated by North Carolina State University (NCSU), for the purpose of research and propagation of DWM, Yellow Lance, and other aquatic species. The goal of the YMACC is to promote the long-term survival of rare aquatic species in streams throughout North Carolina by producing juveniles for reintroduction. Wake County will be provided with approximately $2 million in funding for the construction of the retrofit and upgrade to the existing research facility in the A.E. Finley Center. Wake County will oversee and manage the construction of the new YMACC. In addition, approximately $3 million in funding will be provided to NCWRC to support the North Carolina Non-Game Aquatic Species Program. These funds will be earmarked for NCSU to provide a facility manager and an assistant at the YMACC to oversee the propagation research, outreach, and other expenses needed to operate and maintain the facility for 5 years.

The responsibility of NCDOT for the propagation facility project is strictly to provide the initial funding. NCDOT is not responsible for the construction, management, or success of the facility or its propagation goals. NCDOT has committed to provide funding and will be entering into a funding agreement with Wake County for construction of the YMACC. NCDOT will enter into a separate funding agreement with NCWRC for operation of the North Carolina Non-Game Aquatic Species Program. These funding agreements are being prepared and will be in place prior to permitting for Complete 540 project.

4.5.3 DWM Viability Study

NCDOT in cooperation with the USFWS commissioned the DWM Viability Study to update the baseline conditions for the DWM. The specific purpose of the DWM Viability Study was threefold:

- Characterize existing conditions of the SCW
- Summarize conservation measures that have been implemented to protect DWM in the SCW
- Assess historic trends and future viability of the DWM population and habitat conditions

The results of this study provide critical information to assist in making decisions on how to best manage and conserve the SCW DWM population.

5.0 ENVIRONMENTAL BASELINE FOR MICHAUX'S SUMAC

As noted in Section 2.4, the Michaux's Sumac is known from the Action Area and has the potential to be impacted by the proposed action.

5.1 *Michaux's Sumac (Rhus michauxii)*

Status: Endangered
Family: Anacardiaceae
Listed: September 28, 1989
Critical Habitat: Not designated

5.1.1 Species Characteristics

Michaux's Sumac is a rhizomatous shrub that grows 0.2 to 1.0 meter (7.9 to 39 inches [in]) in height. Although it is usually dioecious, monoecious individuals have been reported in some populations (USFWS 1993b). The entire plant is densely pubescent. The narrowly winged or wingless rachis supports 9 to 13 sessile, oblong to oblong-lanceolate leaflets that are each 4 to 9 centimeters (1.5 to 3.5 in) long, 2 to 5 centimeters wide, and acute to acuminate (USFWS 1993b, NatureServe 2016). The bases of the leaflets are rounded, and their edges are simply or doubly serrate. Flowering occurs in June and the small flowers are borne in a terminal, erect, dense cluster, with each one being four- to five-parted and greenish-yellow to white (USFWS 1993b). The fruit is a red, densely short-pubescent drupe, 5 to 6 millimeters broad, and is visible on female plants from August to October (USFWS 1993b). Michaux's Sumac can generally be distinguished from other species in the genus due to its small stature, dense pubescence, and evenly serrate leaflets. Michaux's Sumac, also called false poison sumac, is quite harmless compared to poison sumacs of superficial resemblance.

Little information is available on the population biology and reproductive requirements of Michaux's Sumac. Most of the surviving populations appear to contain plants of only one sex and therefore reproduce only vegetatively, if at all (USFWS 1993b). Due to the rhizomatous nature of the species, this may mean that the single-sex populations may be clones of one or a few individuals. Limited genetic variation within populations may also contribute to the observed low rates of seed production; seed viability has also been shown to be extremely low (USFWS 2014).

5.1.2 Distribution and Habitat Requirements

Michaux's Sumac was originally described from "Mecklenburg County, North Carolina" as *Rhus pumula* by André Michaux in 1803, but later changed to *R. michauxii* by Sargent in 1895, to correct Michaux's use of a homonym (pullus) and to honor its discoverer (Barden and Matthews 2004). Historically, Michaux's Sumac has been documented in Davie, Durham, Franklin, Hoke, Johnston, Lincoln, Mecklenburg, Moore, Orange, Richmond, Robeson, Scotland, Wake, and Wilson Counties in North Carolina; Florence, Kershaw, and Oconee Counties in South Carolina; Columbia, Elbert, Gwinnett, Muscogee, Newton, and Rabun Counties in Georgia; and Alachua County, Florida (USFWS 1993b). Many of these populations have been extirpated. As of 2014, there are 43 populations range-wide (USFWS 2014). The NCNHP currently lists 33 extant populations in NC known from Cumberland, Davie, Durham, Franklin, Hoke, Mecklenburg, Moore, Nash, Richmond, Robeson, Scotland, and Wake Counties (NCNHP 2017). Four extant occurrences are known in Georgia (from Newton, Elbert, Henry, and Fulton Counties) and six in Virginia (from Brunswick, Dinwiddie, and Nottoway Counties, none of which were known at the time of listing). All previously known populations in South Carolina and Florida are currently considered extinct (USFWS 2014).

Michaux's Sumac grows in sandy or rocky open woods on sandy or sandy loam soils with low cation exchange capacities and appears to depend upon some form of disturbance to maintain the open quality of its habitat (USFWS 1993b, Dale Suiter, personal communication.). Michaux's Sumac can occur on circumneutral soils, loamy swales, or on clayey soils derived from mafic rocks, depending on the physiographic province where it occurs (NatureServe 2016). Most extant populations can be found on open disturbed areas, such as railroad, road, and utility rights-of-way that are periodically maintained and/or managed for the species.

Not much is known about the population dynamics of Michaux's Sumac. Fire or some other forms of disturbance, such as mowing or hand clearing (outside the normal flowering and fruiting time), appears to be essential for maintaining the open habitat preferred by Michaux's Sumac (USFWS 1993b). Without periodic disturbance, this type of habitat is overgrown by woody vegetation. As this overgrowth occurs, Michaux's Sumac begins to decline due to its intolerance of shade. The current distribution of Michaux's Sumac demonstrates its dependence on disturbance. Of the remaining populations, most are located in areas that receive significant disturbance through periodic clearing or maintenance by fire.

5.1.3 Presence in Action Area

The NCNHP records indicated two known occurrences of Michaux's Sumac within the FLUSA and one historical occurrence just outside of the FLUSA (Figure 13).

1. <u>Element Occurrence (EO) # 16/ EO ID: 8079</u>
   This approximately 0.41 acre site is in Wake County along Barwell Road in the northeast corner of the FLUSA. The City of Raleigh owns approximately 12.9 acres on the south side of Walnut Creek off of Barwell Road, which is managed by the Public Utilities Department. The City's Public Utilities Department and the City's Parks, Recreation and Cultural Resources Department have been working with the USFWS to conduct periodic monitoring and develop management recommendations since 2008 (Dale Suiter, personal communication). The site was monitored in 2014 and 115 stems were reported, an increase from previous monitoring years where 40-50 stems were reported (Dale Suiter USFWS, personal communication). In addition, a protective covenant was developed for this population as a requirement for a 2007 CWA Section 404 permit authorization issued by the U.S. Army Corps of Engineers, Wilmington District, Action ID SAW 200620349, associated with the development of an apartment complex (Legacy Oaks), that prohibits activities in this area without coordination with the USFWS Raleigh Field Office (US Army Corps of Engineers 2007).
2. <u>EO# 53/ EO ID: 3172</u>
   This site is part of the Longleaf Restoration Area of the Harris Research Tract in the Cape Fear River Basin. This EO was an experimental planting that began in 2001 (Blank et al. 2002). The site has not been burned regularly, and the plants observed in 2009 were on the decline. The site is 3.86 acres.
3. <u>EO# 70/ EO ID: 25384</u>
   This 0.48-acre site is in Wake County along Turnipseed Road and is just outside of the northeast FLUSA boundary, but is included in this assessment as the FLUSA boundary was set with some fluctuation and due to the proximity to this population, it was deemed prudent to consider it. This EO was first observed in 2007, last observed in 2011, and last surveyed in 2012. This EO is listed as historical, but this seems to be in error, as it was last observed in 2011. As this population is near a powerline

corridor, it may have been negatively impacted by maintenance or downed powerlines.

Species surveys were conducted within the project alignment and vicinity in 2013 by Mulkey Engineers and Consultants (NCDOT 2014) and 2017 by HDR Engineering (NCDOT 2017). At the time of the surveys in 2013, the Project Study Area (PSA) included several detailed study alternatives and was therefore much larger than the final selected alternative, but much smaller than the FLUSA. Surveys were performed again in 2017 in the selected alternative corridor; methodologies and results are included in the report (NCDOT 2017). These surveys followed established USFWS protocol. The surveys did not locate any Michaux's Sumac within the project alignment.

During the alternative selection process, there were 17 alternatives detailed in the Draft EIS (H.W. Lochner 2015) that totaled 9,327 acres when excluding the selected corridor. Surveys of these alternatives did not locate any Michaux's Sumac.

Additionally, there have been ten NCDOT projects, seven bridge replacements and three roadway improvements, just in the past five years within the Complete 540 project FLUSA that have required Michaux's Sumac surveys, none of which found any individuals.

Based on the results of these surveys and the NCNHP natural heritage database search, there are no known documented occurrences of Michaux's Sumac within the proposed project alignment.

5.1.4 General Threats to Michaux's Sumac

Michaux's Sumac is threatened by fire suppression and ecological succession (competition/shading by woody species) that occurs in areas not managed on a regular basis, either through periodic burns, or mechanically managed, to mimic historic land usage. Additionally, forested populations are threatened by timber; and utility rights of way populations are threatened by herbicide use, ground disturbing activities, and mowing during critical growth periods. Multiple observations also suggest that limited seed production continues to be a problem for most populations (Dale Suiter, personal communication).

The greatest threat to Michaux's Sumac comes from the loss/degradation or modification of habitat from activities such as development (residential, commercial, or industrial), highway construction and improvement, and intensive and/or untimely maintenance of existing utility and roadside rights of way (USFWS 1993b). Other threats include low genetic diversity within the existing populations and hybridization with other species of *Rhus*.

5.1.5 Roadway-Related Threats to Michaux's Sumac

Roadway projects can result in direct and indirect effects. These potential effects are discussed within their respective sections below.

5.1.5.1 Construction Effects

Construction related effects associated with roadway projects include, but are not limited to, land clearing and loss, degradation, and/or modification of habitat in the project corridor, in fill/borrow/spoil areas, and in construction staging/access areas outside of the project corridor. These effects can also occur from utility relocation and intensive maintenance of roadside and utility ROWs. Intensive maintenance includes herbicidal treatments, mowing, and ground disturbing activities, particularly during critical growth periods of the species.

5.1.5.2 Operational Effects

Operation effects are associated with maintenance and daily vehicular use of the facility post construction.

5.1.5.3 Induced Land Use Effects

Induced land use change as a result of roadway construction have the potential to indirectly effect Michaux's Sumac. This induced growth and development with limited or no proper planning programs along with unchecked development controls, has the potential to degrade suitable habitat for endangered plant species as a result of a proposed action.

5.1.5.4 Potential Cumulative Effects

Cumulative effects are those effects of future state or private activities, not involving federal activities, which are reasonably certain to occur within the Action Area of the proposed federal action [50 CFR 402.02]. Cumulative effects within an action area may include foreseeable infrastructure projects independent of the federal action, such as water and sewer service expansion, which have the potential to stimulate land development and associated roadway improvements. Other small-scale adverse effects to plant species may also occur within the project Action Area. Though difficult to predict or quantify, other potential cumulative effects may also include mismanagement of the species or its habitat by private landowners (i.e. poor conservation maintenance or herbicide use); habitat degradation caused by traffic accidents occurring within roadside populations; private harvesting of the species for medicinal or otherwise personal use; or habitat impairment caused by emergency repair efforts within utility ROW.

6.0 EVALUATED EFFECTS OF PROPOSED ACTION ON MICHAUX'S SUMAC

Potential effects to the Michaux's Sumac and Michaux's Sumac habitat discussed in Section 5.0 were evaluated with regard to this project. To determine the project effects on Michaux's Sumac, effects with and without the proposed project (2040 Build vs. No-Build scenarios) were evaluated. The types of direct, indirect, and cumulative effects that were specifically evaluated for this project are discussed below.

6.1 Construction Effects

Based upon plant surveys completed in 2017, Michaux's Sumac does not occur in the project footprint. Therefore, no effects are anticipated as a result of the construction aspects of the project.

6.2 Operational Effects

As stated in Section 5.1.3, Michaux's Sumac does not occur in the project alignment. Highly maintained interstate facilities such as the Complete 540 project generally do not contain habitat that is suitable for Michaux's Sumac; thus it is very unlikely that populations of this species would become established in the project ROW after construction is completed. As such maintenance activities associated with the operation of the facility are not expected to impact this species.

6.3 Induced Land Development Effects

The ICE Quantitative Memoranda (Baker Engineering 2017a-d) divided the 287,658-acre FLUSA into 16 land use categories and modeled the change in each category between the 2040 No-Build to Build scenarios (Table 13).

Table 13. Projected FLUSA Land Use in Build and No-Build Scenarios (Baker Engineering 2017a-d)

Land Use Category	Build (ac)	No Build (ac)	Acreage Change
Low Density Mixed Urban	12,248	11,518	-730
Medium Density Mixed Urban	5,293	5,251	-42
High Density Mixed Urban	11,009	10,706	-303
Low Density Residential	52,287	59,989	7,702
Medium Density Residential	100,494	92,431	-8,063
High Density Residential	2,028	2,014	-14
Turf/Golf	816	833	17
Hay/Pasture	2,336	2,434	98
Cropland	22,027	22,627	600
Forest	57,287	57,620	333
Mixed Forest	530	577	47
Deciduous Forest	139	151	12
Wetland	9,782	10,134	352
Emergent Wetland	7	6	-1
Bare Rock	50	51	1
Water	2,324	2,317	-7

As noted in Section 5.1.2, habitat for Michaux sumac is open sections of forests or lightly-maintained areas such as roadside shoulders or utility corridors. As such, there are no land use categories that well represent Michaux sumac habitat. Further, while there may be loss of habitat from the Forested land use categories, there may be an increase in habitat through creation of roadside margins and utility corridors associated with development land use categories.

For existing populations, there is currently no active management plan providing protection for EO# 16/ EO ID: 8079. However, it is along and within a NCDOT right-of-way. There is no plan to widen and/or improve this roadway. In the event that the road requires widening in the future, avoidance, minimization and protective measures will need to be considered during the project development and agency coordination phases. Therefore, induced land use effects resulting from the Complete 540 project to this population are not anticipated.

EO# 53/ EO ID: 3172 is part of the Longleaf Restoration Area of the Harris Research Tract in the Cape Fear River Basin. This tract is in private ownership and within an easement. Therefore, induced land use effects from the Complete 540 project to this population are not anticipated.

While changes in land use associated with the proposed project have the potential to affect the amount of suitable habitat for this species within the FLUSA portion of the Action Area (losses, or gains), the likelihood of adverse effects to unknown populations of this species are very low. Considering the overall change in land use, the Build Scenario results in just over 1,400 more acres of development than the No-Build. The 1,400 acres is approximately 0.5% of the 278,000 acre FLUSA portion of the Action Area. A very small percentage of the 1,400 acres is likely to contain potentially suitable habitat for this species, as the habitat requirements are very specific.

Further, while there is small percentage of hypothetically suitable habitat for this species, it is very unlikely that these areas currently support the species for the following reasons:

1) As detailed in Section 5.1.3, there have been numerous surveys within the FLUSA portion of the Action Area and there are only three known populations. The three known populations total approximately 4.75 acres of the 278,000 acre FLUSA.
2) The species is rare with a fragmented distribution; thus, there are few populations to serve as seed sources to colonize these areas.
3) The majority of suitable habitat that remains on the landscape is generally associated with periodically maintained roadside and utility corridors and thus more likely to have been detected in targeted surveys. Further, by occurring in more visible areas that are subject to higher human traffic, they are very likely to have been identified by random observation.
4) Given that this species has been federally protected since 1989 and the relatively large amount of growth within the FLUSA portion of the Action Area, infrastructure projects associated with this growth will have required Michaux's Sumac surveys which reduces the likelihood there are unknown populations.
5) Given the number of individuals familiar with Michaux's Sumac who work and live within the Action Area, it is a reasonable assumption that any unknown populations would have been identified.

6.4 Conclusion of Effects – Michaux's Sumac

6.4.1 Construction Effects

Based on NCNHP (2017) Natural Heritage EO data, as well as project study area surveys (NCDOT 2017), Michaux's Sumac does not occur within the proposed project alignment, ROW, or clearing limits. As such, construction effects to Michaux's Sumac are not anticipated.

6.4.2 Operational Effects

Based on this analysis, operational effects to the Michaux's Sumac are not anticipated.

6.4.3 Induced Land Development Effects

Based on this analysis, induced land development effects to the Michaux's Sumac are extremely unlikely to occur (discountable).

6.4.4 Biological Conclusion

The project is not anticipated to have direct or indirect effects to Michaux's Sumac. Therefore, we concluded that the project **"May Affect, Not Likely to Adversely Affect"** this species based on discountable effects.

7.0 ENVIRONMENTAL BASELINE FOR CAPE FEAR SHINER

A portion of the southern extent of the FLUSA component of the Action Area encompasses the Neills Creek (also shown as Neals Creek) subwatershed of the Cape Fear River Basin. The Cape Fear Shiner is known from Neills Creek downstream of the FLUSA boundary; thus potential effects to this species were evaluated.

7.1 Watershed Conditions Baseline

Neills Creek is referred to here as the Buies Creek-Cape Fear River subwatershed (HUC# 0303000405). This subwatershed is starts in southeast Wake County and flows south into northeastern Harnett County. The baseline conditions of this subwatershed are presented in the following sections.

7.1.1 Best Usage Classification

Table 14 lists the streams in the Action Area within the Upper Cape Fear River subbasin along with their Usage Classification and NCDWR Index number. These streams are depicted in Figure 3.

Table 14. FLUSA Streams within the Buies Creek-Cape Fear River Subwatershed

Steam Name	Usage Classification	DWR Index #
Buies Creek-Cape Fear River (HUC# 0303000405)		
Kenneth Creek	C	18-16-1-(1)
Neills Creek (Neals Creek)	C	18-16-(0.3)

7.1.2 Impaired 303(d) Listing

The 303(d) Category 5 streams in the Buies Creek-Cape Fear River subwatershed portion of the FLUSA are listed in Table 15 along with details of the impairments, as shown in Figure 4.

Table 15. Buies Creek-Cape Fear River Subwatershed Impaired (Category 5) Streams 2014.

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Buies Creek-Cape Fear River (HUC# 0303000405)				
Kenneth Creek	18-16-1-(2)	3.88 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (1998)
Kenneth Creek	18-16-1-(2)	3.88 FW Miles	Exceeding Criteria	pH (2012)
Kenneth Creek	18-16-1-(2)	3.88 FW Miles	Exceeding Criteria	Dissolved Oxygen (2014)
Neills Creek (Neals Creek)	18-16-(0.3)	2.65 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2006)
Neills Creek (Neals Creek)	18-16-(0.7)a	1.98 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2006)

7.1.3 Point Source Pollution

There are no individual permitted discharges and three general permitted discharges in Buies Creek subwatershed (Table 16, Figure 5).

Table 16. NPDES General Permitted Discharges within Buies Creek-Cape Fear River Subwatershed

Stream	Permit	Facility
Buies Creek-Cape Fear River (HUC# 0303000405)		
Neills Creek (Neals Creek)	NCS000504	Town of Fuquay Varina MS4
Neills Creek (Neals Creek)	NCG050003	Tyco Electronics Corp
Neills Creek (Neals Creek)	NCG050340	National Foam Inc

7.1.4 Non-Point Source Pollution

Land cover for the Buies Creek-Cape Fear River subwatershed portions of the FLUSA is in Table 17 (Figure 6). Cultivated crops make up the greatest percent (18.63%) of land cover in this portion of the FLUSA, followed by herbaceous (13.62%), and evergreen forest (12.05%), with development area making up approximately 24.84% of the subwatershed (when high, medium, and low intensity and open space categories are combined). The effects of non-point pollution on aquatic species associated with human development and associated impervious surface area are discussed in Section 3.5.4

Table 17. Land Cover in the Buies Creek-Cape Fear Subwatershed

Land Cover	Sum of Area (Acres)	Percentage
Barren Land	16.1	0.11
Cultivated Crops	2681.1	18.63
Deciduous Forest	1597.0	11.10
Developed, High Intensity	66.6	0.46
Developed, Low Intensity	1408.8	9.79
Developed, Medium Intensity	381.6	2.65
Developed, Open Space	1717.5	11.94
Emergent Herbaceuous Wetlands	73.3	0.51
Evergreen Forest	1734.1	12.05

Table 17. Land Cover in the Buies Creek-Cape Fear Subwatershed (continued)

Land Cover	Sum of Area (Acres)	Percentage
Hay/Pasture	750.2	5.21
Herbaceous	1959.8	13.62
Mixed Forest	891.9	6.20
Open Water	83.1	0.58
Shrub/Scrub	620.6	4.31
Woody Wetlands	406.5	2.83
Grand Total	**14388.0**	**100.00**

7.1.5 Ecological Significance

See Section 3.1.5 for more detail about the Natural Heritage Natural Areas. Within the Buies Creek-Cape Fear River Subwatershed, there are no designated NHNAs.

7.2 Cape Fear Shiner (Notropis mekistocholas)

Status: Endangered
Family: Cyprinidae
Listed: September 26, 1987
Critical Habitat: Designated, see Section 7.2.5

7.2.1 Species Characteristics

The Cape Fear Shiner is a small, moderately stocky Cyprinid described by Snelson (1971). The fish's body is flushed pale silvery yellow, with a black band running along the side. The fins are yellowish and somewhat pointed. The upper lip is black, and the lower lip bears a thin black bar along its margin.

The Cape Fear Shiner is distinguished from other *Notropis* by having an elongated alimentary tract with two convolutions crossing the intestinal bulb. This is believed to be an adaptation for herbivorous feeding, although the species is known to be omnivorous based on gut content analysis (Snelson 1971, USFWS 1988). This adaptation is believed to be useful in that when insectivorous fish populations are high and animal material is correspondingly low, the Cape Fear Shiner is able to thrive by shifting to herbivorous feeding habits (USFWS 2011).

The Cape Fear Shiner is usually found in low numbers in schools with other shiner species such as Highfin Shiner *(Notropis altipinnis)*, Swallowtail Shiner *(Notropis procne)*, White Shiner *(Luxilus albeolus)*, Sandbar Shiner (*Notropis scepticus)*, Spottail Shiner *(Notropis hudsonius)*, Comely Shiner (*Notropis amoenus)*, Satinfin Shiner (*Cyprinella analostana)*, and Whitefin Shiner (*Cyprinella nivea*) (Pottern 2009).

7.2.2 Distribution and Habitat Requirements

The Cape Fear Shiner is most often found in rocky pools, runs, and riffles with substrates containing gravel, cobble, and/or boulder components. These areas are typical of streams in the Carolina Slatebelt and Raleigh Belt with wide, shallow sections, an open forest canopy, and abundant American Water Willow (*Justicia americana*), Riverweed (*Podostemum* sp.), stream mosses (*Fontinalis* sp.), and filamentous algae. The species may be found in lower-gradient sections of rivers with sand dominated substrate, but usually only in low numbers, presumably as they move between more rocky sections (Pottern 2009). Gravel substrate has been shown to be important for Cape Fear Shiner in feeding and spawning (USFWS 2011). In comparing shiner density with substrate type, Howard (2003) found low shiner density in areas with less gravel availability.

Endemic to the upper Cape Fear River Basin in the Central Piedmont region of North Carolina, Cape Fear Shiner occupies the tributaries and main-stems of the Cape Fear, Deep, Haw and Rocky Rivers in Chatham, Harnett, Lee, Moore, and Randolph counties. Specifically, the current known range extends from SR 1545 (Chicken Bridge Rd) of the Haw River in Chatham County and from Coleridge Dam on the Deep River in Randolph County downstream to Erwin on the main-stem Cape Fear River. Including major tributaries such as the Rocky River, this is a range of approximately 135 river miles (Pottern 2009). The lower five miles of the Rocky River and the Deep River between High Falls and Coleridge area are known to have the highest densities of the minnow. The species is known to occupy tributaries to these main-stem rivers, but is typically only found within two miles of the confluence (Pottern 2009).

What is known of the historical and current distribution of the Cape Fear Shiner was reviewed and summarized by Pottern (2009), as shown in Table 18.

Additionally, NCNHP has developed a database of Cape Fear Shiner occurrences, which it used to estimate the following viability rankings (or probability of persistence) (USFWS 2011).

- <u>Deep River, stretching from High Falls Dam (Moore County) to Lockville Dam (Lee County), and Rocky River below the hydroelectric dam (Chatham County) = Excellent</u>. This group of Cape Fear shiners is likely to persist for at least 20-30 years.
- <u>Deep River, above High Falls Dam (Randolph and Moore Counties) = Good/Fair</u>. This group of shiners may or may not persist in its current condition.
- <u>Haw River (Chatham County) = Fair/Poor</u>. This group of Cape Fear shiners may be at risk of extirpation in the foreseeable future; however, restoration is deemed feasible/plausible.
- <u>Upper Cape Fear River, from Buckhorn Dam (Lee County) through Harnett County = Fair/Poor</u>. This group of Cape Fear shiners may be at risk of extirpation in the foreseeable future; however, restoration is deemed feasible/plausible.

- <u>Upper Rocky River, south of Siler City to the hydroelectric dam (Chatham County) = Possibly Extirpated</u>. There is evidence that this group of shiners may no longer exist.

Table 18. Cape Fear Shiner Relative Abundance* by River Segment

River Segment	Miles	1949-1983	1984-1986	1987-2006	2007-present
Haw River, Saxapahaw to Bynum Dam	17.4	None	None	Rare	Rare
Haw River, Bynum Dam to Jordan Lake	4.7	Rare	None	Rare	None
Haw River/ Roberson Creek to Jordan Lake Pool	4.9	Uncommon	None	None	None
Rocky River, Siler City to Rocky River Hydro	16.0	Common	Rare	None	None
Rocky River, Rocky River Hydro to Deep River	5.5	Common	Common	Common	Common
Deep River, Randleman to Coleridge Dam	21.6	None	None	None	None
Deep River, Coleridge to Highfalls Dam	18.9	None	Rare	Uncommon	Rare
Deep River, Highfalls to Carbonton	21.9	None	Rare	Uncommon	Common
Deep River, Carbonton to Rocky River	22.0	None	Uncommon	Uncommon	Uncommon
Deep River, Rocky River to Lockville Dam	3.5	None	Common	Common	Common
Deep River, Lockville Dam to US-1	0.3	None	Uncommon	Uncommon	Common
Cape Fear-Deep Haw confluence to Buckhorn Dam	12.7	None	None	None	None
Cape Fear River, Buckhorn to Lillington	14.0	Uncommon	Rare	None	None
Cape Fear River, Lillington to Erwin	11.5	None	None	None	Rare

Notes: * Rare= average1-4 collected, Uncommon=average 4-16 collected, Common=average 16+ collected

7.2.3 General Threats to Species

General threats to the Cape Fear Shiner are similar to those described for the DWM and Yellow Lance (Section 3.5). More specifically, three main conservation threats for the Cape Fear Shiner have been identified: (1) alteration of flow regimes; (2) pollution from anthropogenic sources; and (3) introduction of non-native predators (USFWS 2011). Additionally, the restricted range and small population sizes make this species vulnerable to catastrophic events (USFWS 1988). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes.

Habitat alteration resulting from multiple dam construction projects in the Cape Fear system is likely the most significant factor that contributed to the species decline (USFWS 1988). Upper Cape Fear River Basin dams alter flows and sediment transport and impound key habitat elements critical to the Cape Fear Shiner. These impoundments fragment the species’ population and limit genetic exchange, which can increase vulnerability to catastrophic events (USFWS 2011).

Water quality has been identified by Howard (2003) to be a limiting factor for Cape Fear Shiner. Caged shiners in the Haw River saw significant reduction in survival and growth, which was associated with higher concentrations of metals (cadmium, copper, zinc, mercury, lead) and organic contaminants (PAH, PCB, DDT, chlordane) in tested tissues as well as in Haw River water and sediments. Sedimentation resulting from poor agricultural practices or construction projects threatens habitat by smothering key rocky substrates or submerged aquatic vegetation areas.

New predator species introductions could negatively affect the Cape Fear Shiner. Hewitt et al. (2009) noted introductions of Roanoke Bass (*Ambloplites cavifrons*) and Flathead Catfish (*Pylodictis olivaris*) into the upper Cape Fear River Basin could result in a decline of the Cape Fear Shiner within its range.

7.2.4 Roadway Related Threats to Cape Fear Shiner

Roadway related threats on the Cape Fear Shiner are similar to those described for the DWM and Yellow Lance (Section 3.6).

7.2.5 Designated Critical Habitat

In accordance with Section 4 of the ESA, Critical Habitat for listed species consists of:

(1) The specific areas within the geographical area occupied by the species at the time it is listed, in which are found those physical or biological features (constituent elements) that are:
    a. essential to the conservation of the species, and
    b. which may require special management considerations or protection
(2) Specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of Section 4 of the Act, upon a determination by the Secretary that such areas are "essential for the conservation of the species."

On 25 September 1987, USFWS listed the Cape Fear Shiner as an endangered species under the Endangered Species Act. Critical habitat designation provided at that time (CFR Vol. 52 No. 186) consists of the following:

- Approximately 4.1 miles of the Rocky River, from NC State Highway 902 Bridge downstream to Chatham County Road 1010 Bridge (Chatham County).
- Approximately 0.5 river mile of Bear Creek, from Chatham County Road 2156 Bridge downstream to the Rocky River in Chatham County. From there the critical habitat area flows downstream approximately 4.2 river miles along the Rocky River (Chatham County). At the confluence of the Rocky and Deep Rivers, the critical habitat area extends downstream approximately 2.6 river miles on the Deep River. It ends at a location 0.3 river mile below the U.S. Geological Survey Gauging Station in Moncure, NC in Chatham County.
- Approximately 1.5 river miles of Fork Creek, flowing from a point 0.1 river mile upstream of Randolph County Road 2873 Bridge and downstream to where the creek meets the Deep River (Randolph County). From there, the critical habitat area extends

downstream approximately 4.1 river miles along the Deep River in Randolph and Moore Counties to a point 2.5 river miles below Moore County Road 1456 Bridge.

Since the listing of the species, the area of known occupied habitat for the Cape Fear Shiner has significantly expanded through restoration activities such as the removal of the Carbonton Dam on the Deep River and updated survey efforts (Catena 2006a, 2006b, 2007, 2009, 2010).

7.2.6 Presence in Action Area

The NCNHP database was searched for known populations, or EOs, within the Action Area. The NCNHP records indicated one historical occurrence of Cape Fear Shiner (EO ID# 23981) within the extreme southern portion of the FLUSA within the Neills Creek subwatershed (Figure 14).

8.0 EVALUATED EFFECTS OF PROPOSED ACTION ON CAPE FEAR SHINER

As detailed in Section 7.2.2, the Cape Fear Shiner occurs only within the Cape Fear River Basin. Given that the Complete 540 alignment occurs within the Neuse River Basin, there will be no Construction related, or Operation related effects to this species. Therefore, it was determined that the only potential effects would be indirect in the form of water quality and habitat effects associated with induced land development.

8.1 Induced Land Development

As discussed in Section 4.3, roadway construction can influence land use and result in development that would not occur without the road (induced development). While land development itself does not affect aquatic species like the Cape Fear Shiner and its habitat, increases in sediment loads and various pollutants, alterations in flow regime (base flow and peak discharge), and loss of riparian buffers are consequences of development that lead to water quality degradation. How these consequences of land development affect water quality and ultimately freshwater mussels, as well as fish species like the Cape Fear Shiner, is discussed in Section 3.5.4 of this report.

Baker Engineering (2017a-d) completed a Quantitative Indirect and Cumulative Effects (ICE) Report of the Complete 540 Project using a methodology to forecast land use changes between the base year of 2011 and design year 2040. This Quantitative ICE report utilized much of the information in the Qualitative ICE Report (H.W. Lochner 2014). As was projected in the Qualitative ICE Report and confirmed and quantified in the Quantitative ICE Report, the introduction of a high-speed, controlled-access roadway into the FLUSA would provide a faster and more direct route to employment and commercial centers in the region. Further, the primary changes in land development from the No-Build to Build are higher land use densities, more commercial and industrial development, and a greater mix of uses in the areas surrounding the interchanges. Though this pattern is captured in the model results, it is noted: "Without the project, there would be both less development overall and lower densities of development in the FLUSA".

However, for all parameters modeled in the ICE in the Cape Fear watershed, the change from No-Build to Build is equal to or less than 1%, except for total phosphorous in Hector Creek Watershed, which is 2%. As such, induced land development attributable to the construction of Complete 540 is insignificant.

8.1.1 Conclusion of Effects – Cape Fear Shiner

The project will have no construction or operation related effects in the Cape Fear Watershed. Induced land development effects will be insignificant. While a portion of the Neills Creek subwatershed occur within the FLUSA, the species has not been found in Neills Creek since it was first observed in December 1986 despite numerous targeted surveys (USFWS 2017b, NCWRC Unpublished Aquatics Species Database) and is considered to no longer occur in the subwatershed. Therefore, it is concluded that the project **"May Affect, Not Likley to Adversely Affect"** the Cape Fear Shiner. Furthermore, since project induced land development effects in the Cape Fear Watershed are anticipated to be insignificant, the project will not prohibit the watershed to become occupied in the future through natural recolonization, or active reintroduction.

9.0 FEDERALLY LISTED SPECIES NOT WITHIN ACTION AREA

The official species list for this project was based on federally listed species potential in all of Wake, Johnston, and Harnett Counties. The Action Area for the project is a smaller area than those counties' limits. Given this, some of the species on the official species list are outside the Action Area and the project will have no effect on those species. This section discusses the characteristics and current status of the other six federally protected species (Table 1) throughout their ranges.

9.1 Bald Eagle (Haliaeetus leucocephalus)

Bald Eagle is no longer federally listed under the ESA. While Bald Eagle is still afforded protection under the Bald and Golden Eagle Protection Act, Section 7 consultation is not required.

9.2 Rough-leaved Loosestrife (Lysimachia asperulaefolia)

Status: Endangered
Family: Primulaceae
Listed: June 12, 1987

Critical Habitat: Not designated

9.2.1 Species Characteristics

This perennial herb, which has slender stems, grows from a rhizome to a height of 12 to 24 inches. The whorled leaves encircle the stem at intervals below the showy yellow flowers, and usually occur in threes or fours. Flowers are borne in terminal racemes of five petaled flowers. Flowering occurs between late May and early June. Fruits are present from July through October.

9.2.2 Distribution and Habitat Requirements

Rough-leaved Loosestrife, endemic to the Coastal Plain and Sandhills of North and South Carolina, occurs in the ecotones or edges between longleaf pine uplands and pond pine pocosins (areas of dense shrub and vine growth usually on a wet, peaty, poorly drained soil), on moist to seasonally saturated sands and on shallow organic soils overlaying sand. It has also been found to occur on deep peat in the low shrub community of large Carolina bays (shallow, elliptical, poorly drained depressions of unknown origins). It occurs in fire maintained areas and is rarely associated with hardwood stands; acidic soils are preferred (USFWS 1995). In North Carolina, Rough-leaved Loosestrife is known to occur in Beaufort, Bladen, Brunswick, Carteret, Cumberland, Harnett, Hoke, New Hanover, Onslow, Pamlico, Pender, Richmond and Scotland counties. The Richmond County population is thought to be extirpated.

9.2.3 General Threats to Species

Threats to this species include urban development, conversion of land to agriculture and silviculture, associated drainage, and fire suppression, which reduce this species' habitat.

9.2.4 Presence in Action Area

The southern limits of the FLUSA extend into northern Harnett County, where this species is known to occur. This portion of Harnett County is within the Piedmont Physiographic Province. The NCNHP database was searched for known populations, or EOs, within the Action Area and none were found. Occurrences of this species within Harnett County are in the very southern portion of the county in the Sandhills region (Figure 15).

9.2.5 Conclusion of Effects – Rough-leaved Loosestrife

Since there will be no direct or indirect effects in any areas known to support Rough-leaved Loosestrife and the lack of EO records within or near the FLUSA, the project will have **"No Effect"** on this species.

9.3 Tar River Spinymussel (Parvaspina steinstansana)

Status: Endangered
Family: Unionidae
Listed: July 29, 1985
Critical Habitat: Not designated

9.3.1 Species Characteristics

The TSM grows to a maximum length of 60 millimeters. Short spines are arranged in a radial row anterior to the posterior ridge on one valve and symmetrical to the other valve. The shell is generally smooth in texture with as many as 12 spines that project perpendicularly from the surface and curve slightly ventrally. However, adult specimens tend to lose their spines as they mature (USFWS 1992a). The smooth, orange-brown to dark brown periostracum may be rayed in younger individuals. The shell is significantly thicker toward the anterior end, and the nacre is usually pink in this area. The posterior end of the shell is thinner with an iridescent bluish white color. Two or more linear ridges, originating within the beak cavity and extending to the ventral margin, can be found on the interior surface of the shell. The distance between these ridges widens toward the ventral margin. Johnson and Clarke (1983) provide additional descriptive material.

9.3.2 Distribution and Habitat Requirements

Previously this mussel was believed to be endemic to the Tar River system and probably ranged throughout most of the Tar River Drainage Basin before the area was settled during the 1700s (NC Scientific Council on Mollusks 2011). Historically, the TSM was collected in the Tar River from near Louisburg in Franklin County to Falkland in Pitt County (approximately 78 river miles). By the mid-1960s, its known range had been reduced to the main channel of the Tar River from Spring Hope in Nash County to Falkland in Pitt County (Shelley 1972, Clarke 1983). By the early 1980s, its range in the Tar River was restricted to only 12 miles of the river in Edgecombe County (Clarke 1983). The species was last observed (two individuals) in the river in 2001 within an extensive sandbar habitat in Edgecombe County (NCWRC Unpublished Aquatics Species Database). It is currently found in three streams, Shocco, Sandy/Swift and Fishing/Little Fishing creeks in the Tar River Basin (NCWRC Unpublished Aquatics Species Database). In 1998, the species was found in Johnston County in the Little River, a tributary to the Neuse River. Only a few individuals have been found in the Little River in subsequent years (unpublished data, NCWRC Aquatics Database). This species was last observed September 2011 in the Little River site (NCNHP 2017).

9.3.3 General Threats to Species

Threats to TSM are similar to those described in Section 3.5 for the DWM and Yellow Lance.

9.3.4 Presence in Action Area

TSM has not been found in the Action Area (Figure 16).

9.3.5 Conclusion of Effects – Tar Spinymussel

TSM has not been found in the Action Area (Figure 16); therefore, it can be concluded that project construction will have **"No Effect"** on this species.

9.4 Red-cockaded Woodpecker (Picoides borealis)

Status: Endangered
Family: Picidae
Listed: October 13, 1970
Critical Habitat: Not designated

9.4.1 Species Characteristics

The Red-cockaded Woodpecker (RCW) is a small bird measuring about 7 inches in length. Identifiable by its white cheek patch and black and white barred back, the males have a few red feathers, or "cockade." These red feathers usually remain hidden underneath black feathers between the black crown and white cheek patch unless the male is disturbed or excited. Female RCWs lack the red cockade. Juvenile males have a red 'patch' in the center of their black crown. This patch disappears during the fall of their first year at which time their 'red-cockades' appear (USFWS 2003).

9.4.2 Distribution and Habitat

RCWs were once considered common throughout the longleaf pine ecosystem, which covered approximately 90 million acres before European settlement. Historical population estimates are 1 to 1.6 million "groups," the family unit of RCWs. The birds inhabited the open pine forests of the southeast from New Jersey, Maryland, and Virginia to Florida, west to Texas and north to portions of Oklahoma, Missouri, Tennessee and Kentucky. The longleaf pine ecosystem initially disappeared from much of its original range because of early (1700's) European settlement, widespread commercial timber harvesting and the naval stores/turpentine industry (1800's). Early to mid-1900 commercial tree farming, urbanization and agriculture contributed to further declines. Much of the current habitat is also very different in quality from historical pine forests in which RCWs evolved. Today, many southern pine forests are young and an absence of fire has created a dense pine/hardwood forest (USFWS 2003).

For nesting and roosting habitat, RCWs need open stands of pine containing trees 60 years old and older, depending on species of pine. RCWs need live, large older pines in which to excavate their cavities. Longleaf pines (*Pinus palustris*) are preferred, but other species of southern pine are also acceptable. Dense stands (stands that are primarily hardwoods, or that have a dense hardwood understory) are avoided. Foraging habitat is provided in pine and pine hardwood stands 30 years old or older with foraging preference for pine trees 10 inches or larger in diameter. In good, moderately-stocked, pine habitat, sufficient foraging substrate can be provided on 80 to 125 acres (USFWS 2003).

Roosting cavities are excavated in living pines, and usually in those that are infected with a fungus known as red-heart disease. The aggregate of cavity trees is called a cluster and may include 1 to 20 or more cavity trees on 3 to 60 acres. The average cluster is about 10 acres. Completed cavities that are being actively used have numerous, small resin wells which exude sap. The birds keep the sap flowing as a cavity defense mechanism against rat snakes and other tree climbing predators (USFWS 2003).

Hardwood mid-story encroachment results in cluster abandonment; therefore, it is critical that hardwood mid-story be controlled. Prescribed burning is the most efficient and ecologically beneficial method to accomplish hardwood mid-story control. (USFWS 2003)

9.4.3 General Threats to Species

The loss of suitable habitat has caused the number of RCWs to decline by approximately 99 percent since the time of European settlement. The primary habitat of the RCW, the longleaf pine ecosystem, has been reduced to 3 percent of its original expanse. Many RCW populations were stabilized during the 1990s due to management based on new understanding of RCW biology and population dynamics. However, there are still populations in decline and small populations throughout the species' current range are still in danger of extirpation (USFWS 2003).

9.4.4 Presence in Action Area

To determine presence of the species within the Action Area, the NCNHP database was searched for EOs, suitable habitat was evaluated, and presence/absence surveys were conducted. Species surveys were conducted within the project alignment and vicinity by Mulkey Engineers and Consultants in May 2014 (Mark Mickley, personal communication).

The NCNHP records indicate one known occurrence (EO ID: 15047) of RCW within the Action Area (Figure 17). The record was first and last observed in 1977 in the Lake Myra area and is considered historic. There are several other historical EOs in the vicinity. The closest current EOs are approximately 12 miles outside of the FLUSA: one west in Chatham County on Jordan

Lake (John Hammond, personal communication); and one east in Johnston County west of Smithfield (NCNHP 2017).

9.4.5 Conclusion of Effects - Red-cockaded Woodpecker

Based on the (EO ID: 15047) being considered historical, and the results of the surveys within the project alignment, it appears that the RCW no longer occurs within the Action Area. It can be concluded that the project will have **"No Effect"** on this species.

10.0 DETERMINATION OF EFFECTS

FHWA has made the following determinations for federally listed and proposed species under the ESA for the Complete 540 project (Table 19).

Table 19. Determination of Effects On Federally Listed Species

Scientific Name	Common Name	Status	County	Present in Action Area	Determination of Effect
Alasmidonta heterodon	Dwarf Wedgemussel	E	W, J	Yes	LAA
Elliptio lanceolata	Yellow Lance	Proposed	W, J	Yes	LAA
Lysimachia asperulaefolia	Rough-leaved Loosestrife	E	H	No	No Effect
Notropis mekistocholas	Cape Fear Shiner	E	H	No*	NLAA
Parvaspina steinstansana	Tar River Spinymussel	E	J	No	No Effect
Picoides borealis	Red-cockaded Woodpecker	E	W, J, H	No	No Effect
Rhus michauxii	Michaux's Sumac	E	W, J	Yes	NLAA

Notes: T – Threatened, E – Endangered, W – Wake, J- Johnston, H – Harnett, LAA –Likely to Adversely Affect; NLAA –Not Likely to Adversely Affect; * No longer present in Neills Watershed

FHWA has determined that the project will likely adversely affect the Dwarf Wedgemussel and the Yellow Lance mussel. FHWA has determined the project may affect but is not likely to adversely affect the Cape Fear Shiner and Michaux's Sumac based on insignificant and discountable effects.

FHWA is consulting with the National Marine Fisheries Service regarding the Atlantic Sturgeon and Atlantic Sturgeon critical habitat for the Complete 540 project. The biological assessment for the Atlantic sturgeon and designated critical is contained in a separate document.

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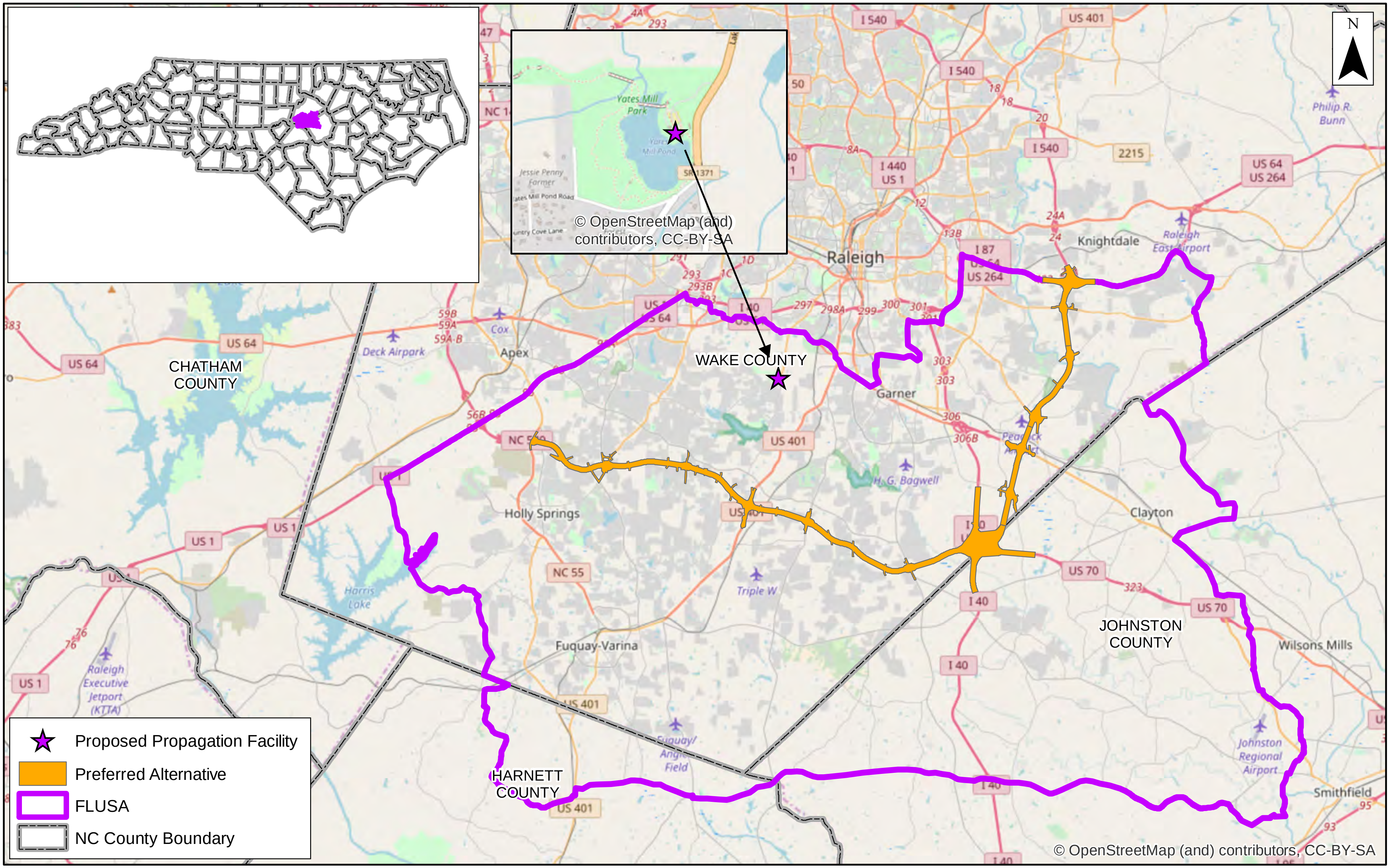
Appendix A - Figures



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

Future Land Use Study Area / Action Area and Preferred Alternative

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017

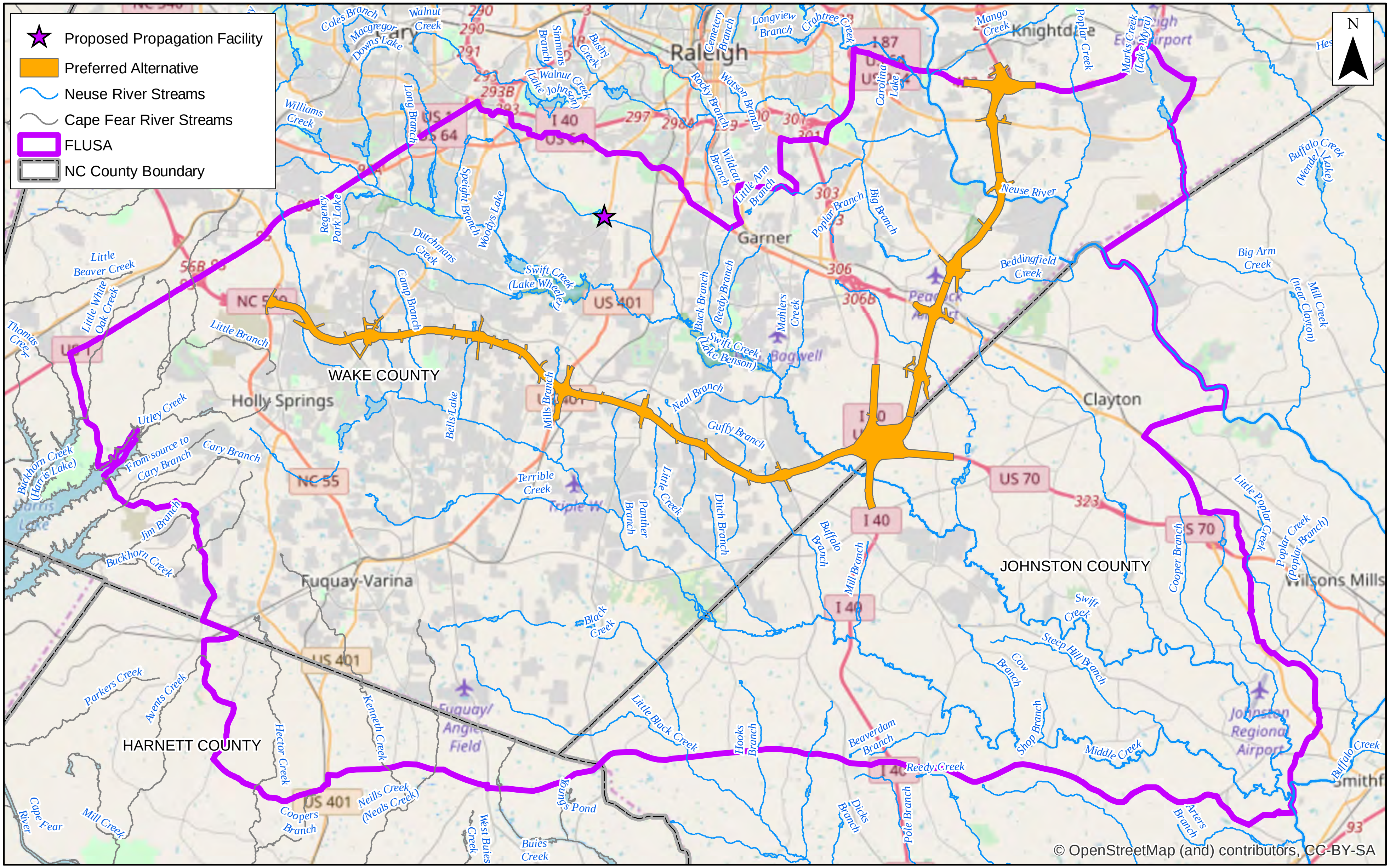
Scale: 0 1.5 3 Miles

Job No.: 1200

Drawn By: NMS

Checked By: KMS

Figure 1



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

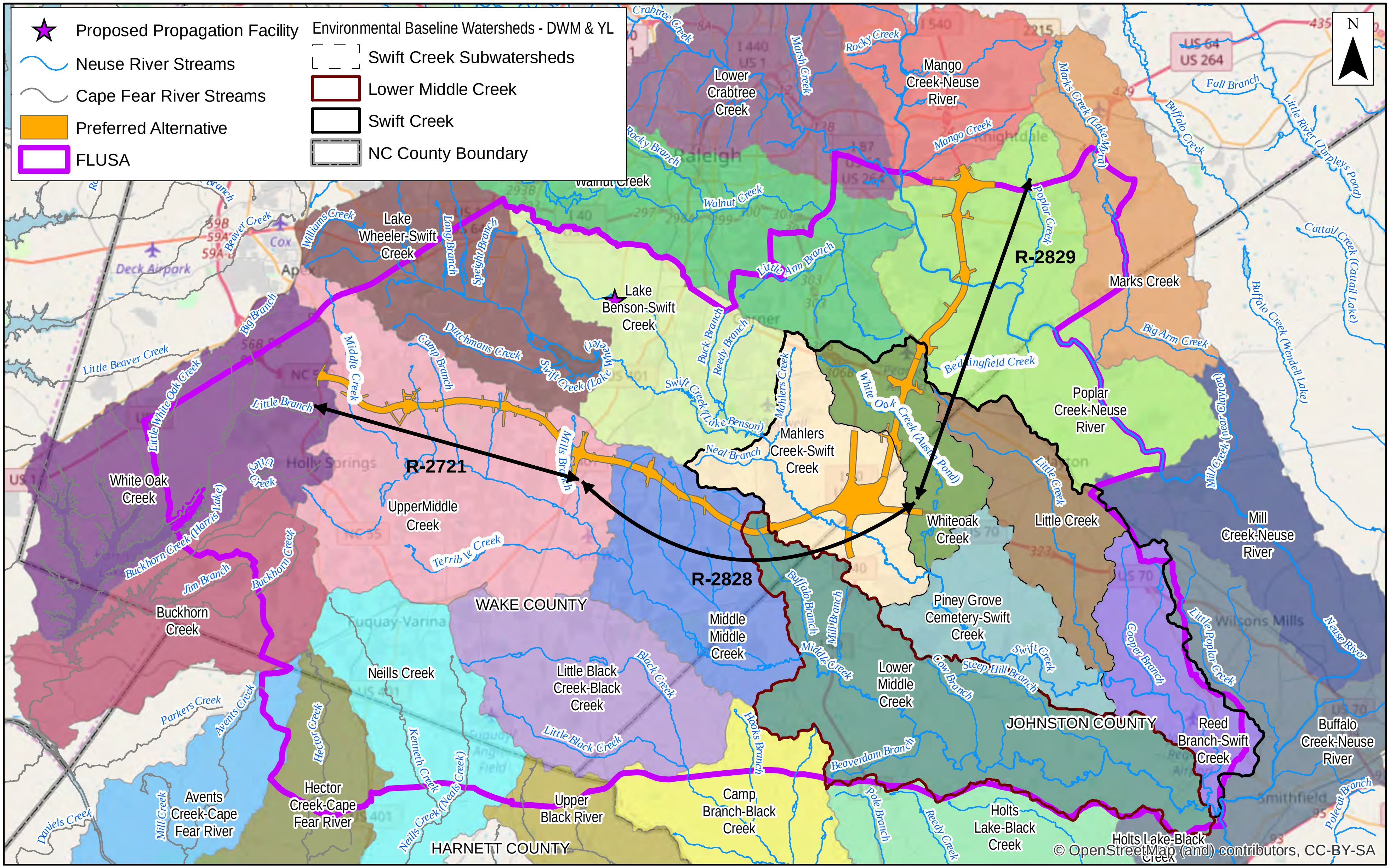
Preferred Alternative
Detailed Study Alternative No. 2

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure

2



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

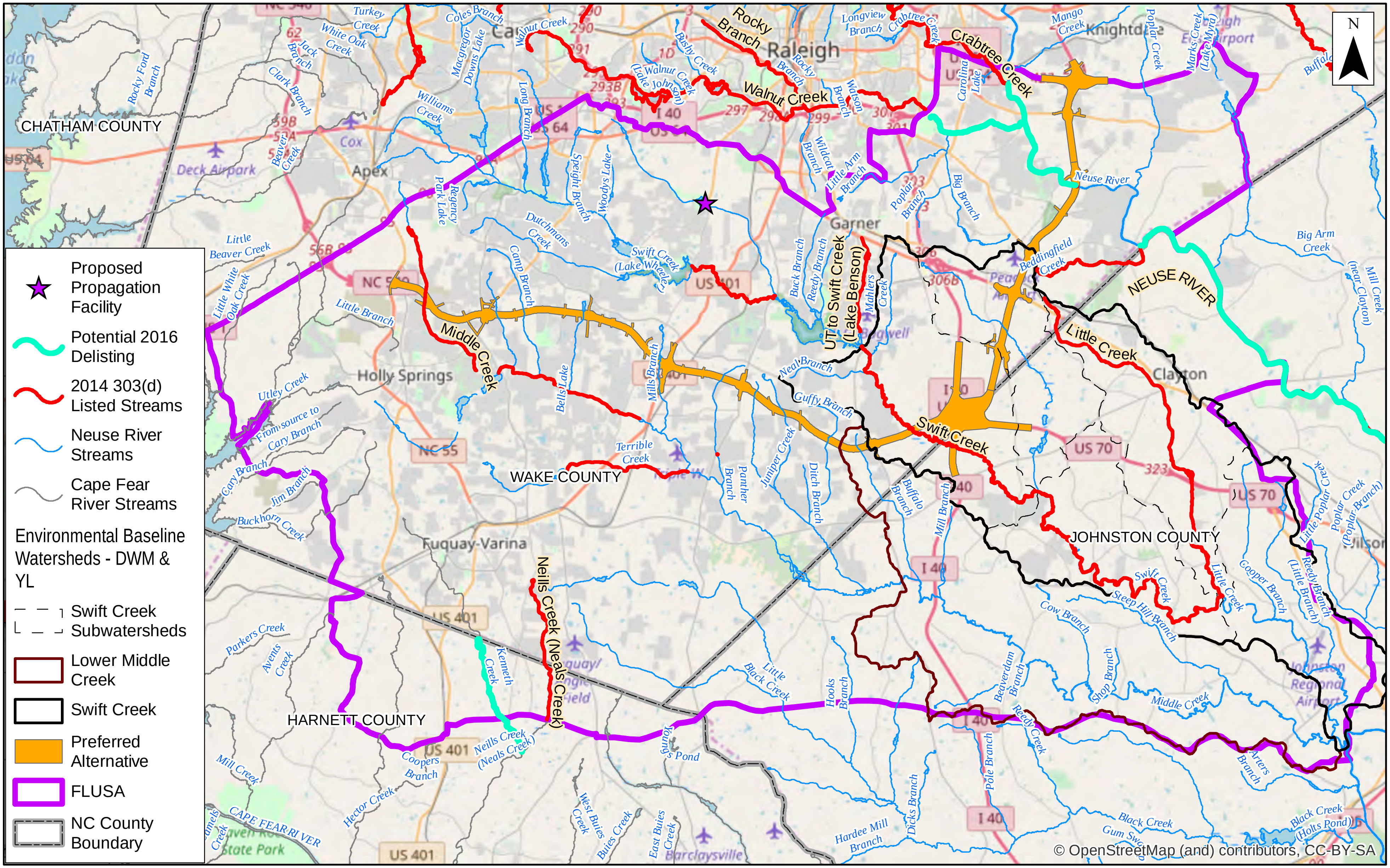
Future Land Use Study Area Streams and 12-digit Subwatersheds

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure

3



Prepared For:

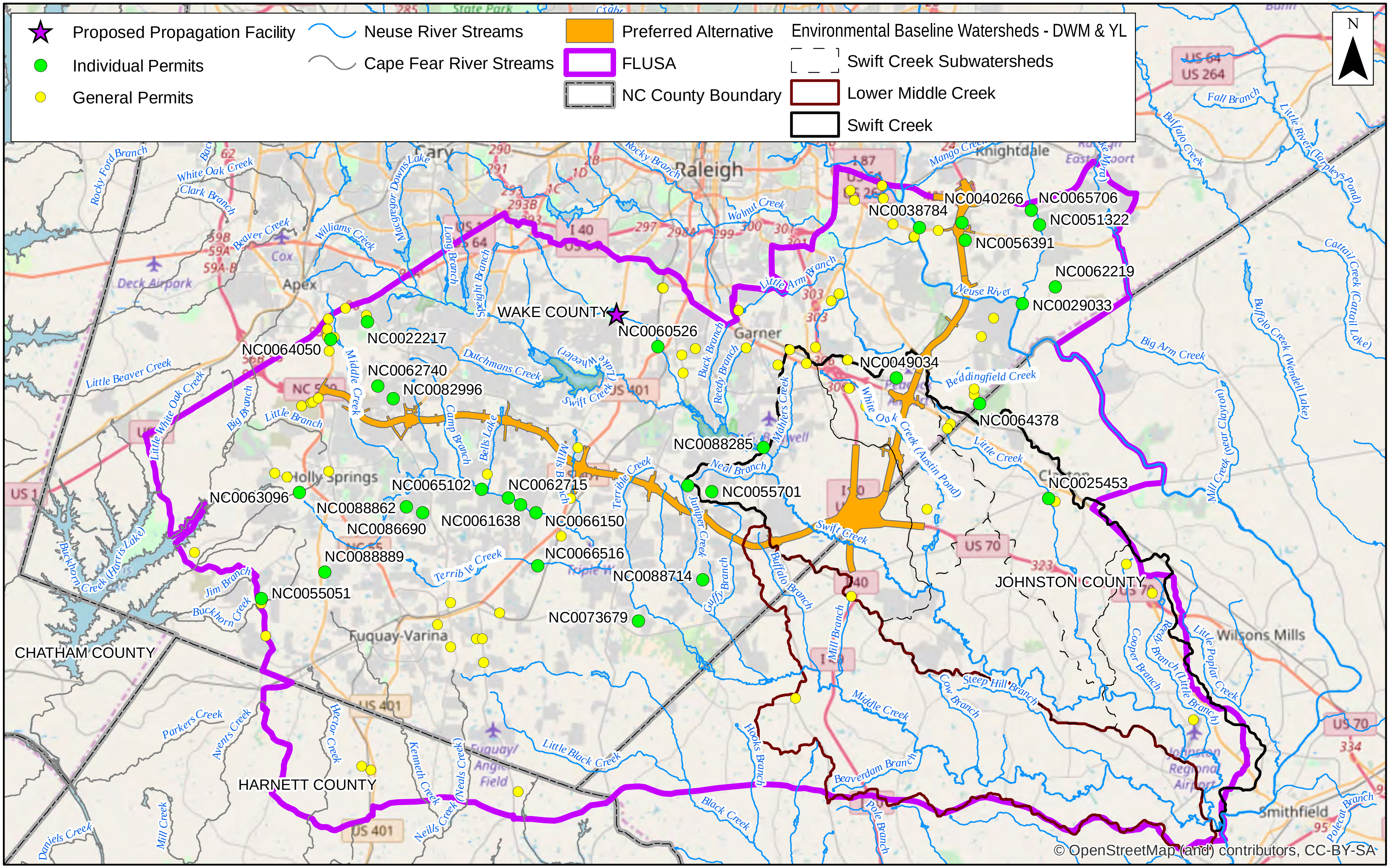
Complete 540 Triangle Expressway Southeast Extension

North Carolina Department of Environmental Quality
303(d) Impaired Streams

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure 4



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Complete 540 Triangle Expressway Southeast Extension

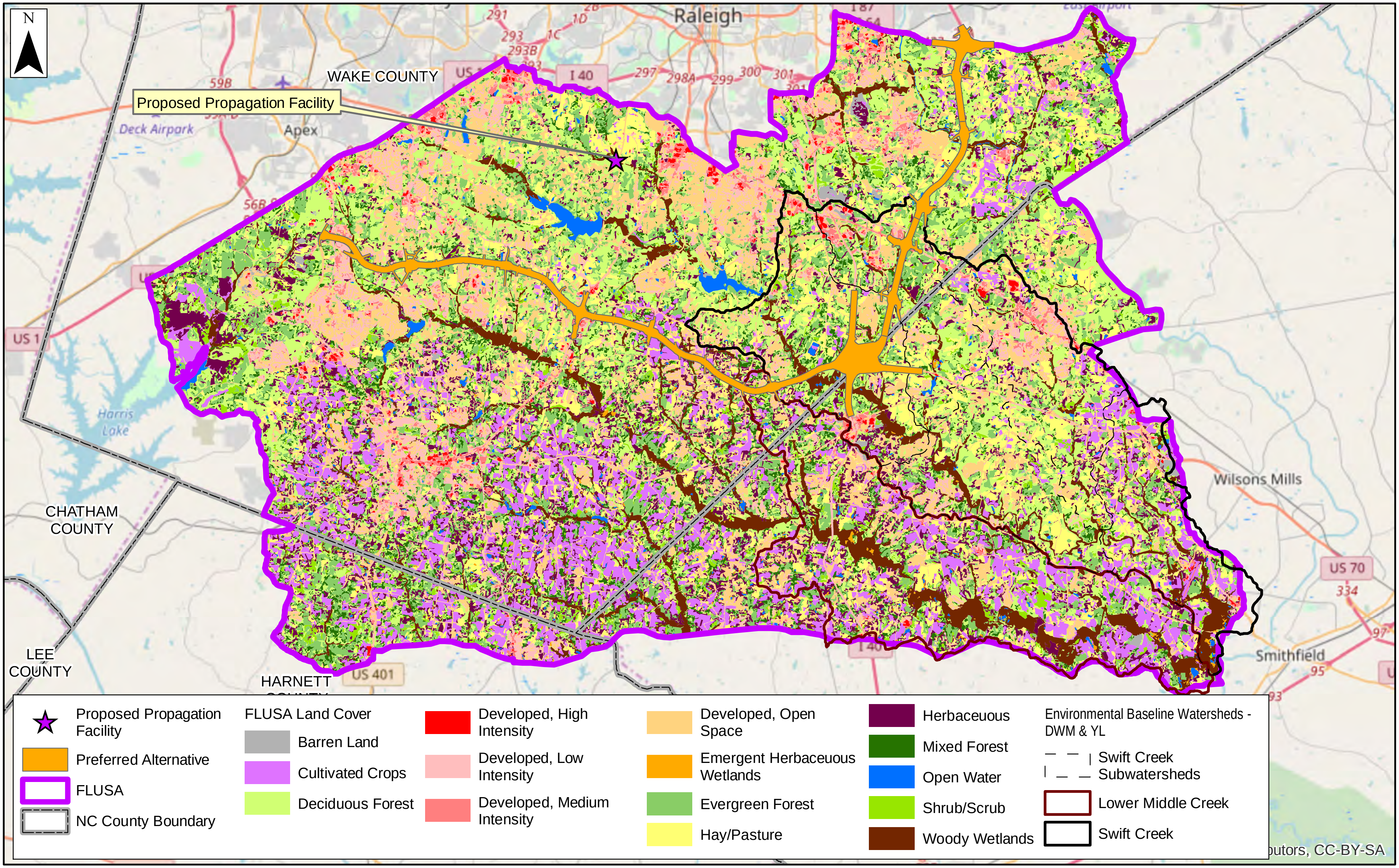
National Pollutant Discharge Elimination System Discharges

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure

5



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

Land Cover
National Land Cover Data

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017

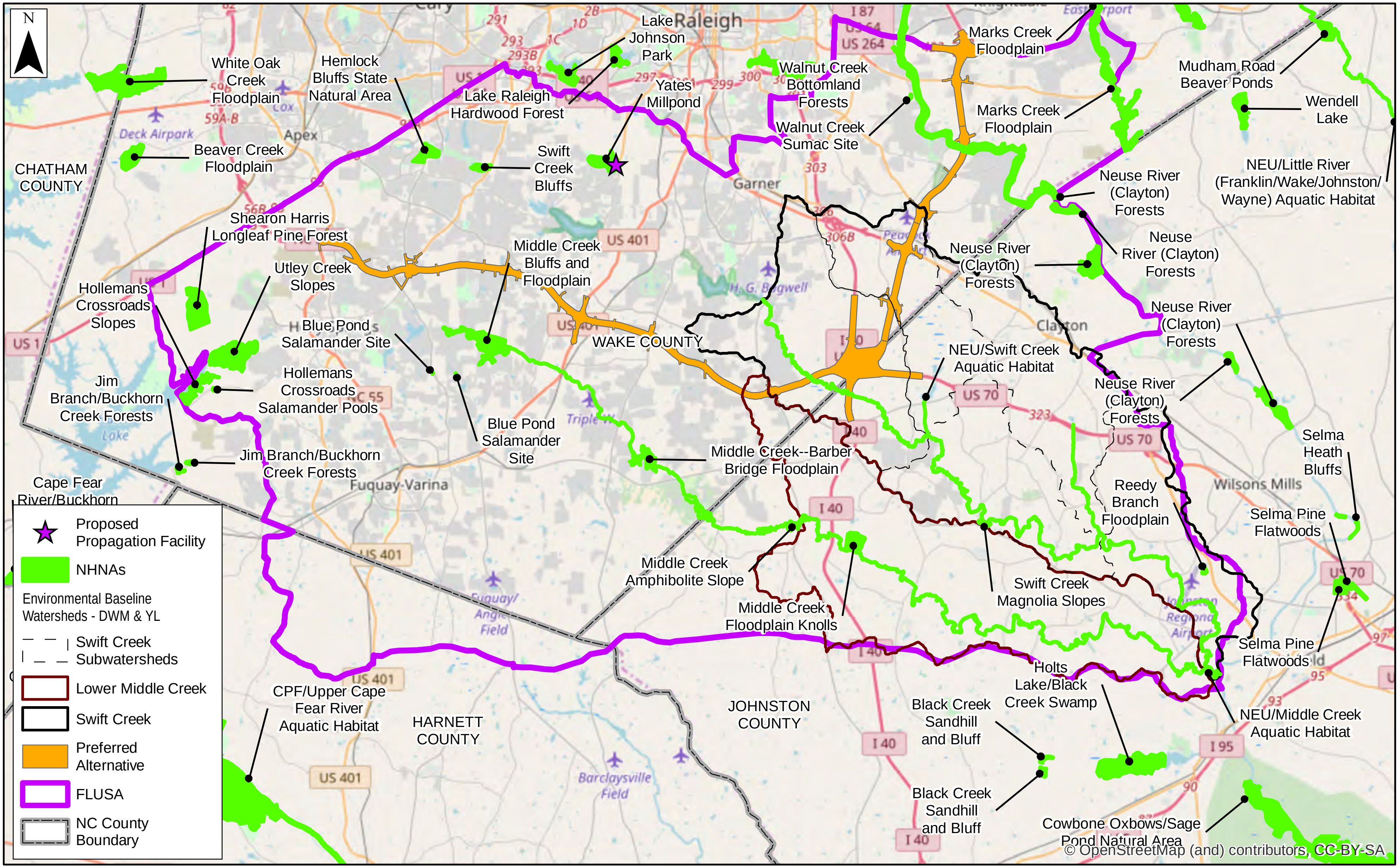
Scale: 0 1 2 Miles

Job No.: 1200

Drawn By: NMS

Checked By: KMS

Figure 6



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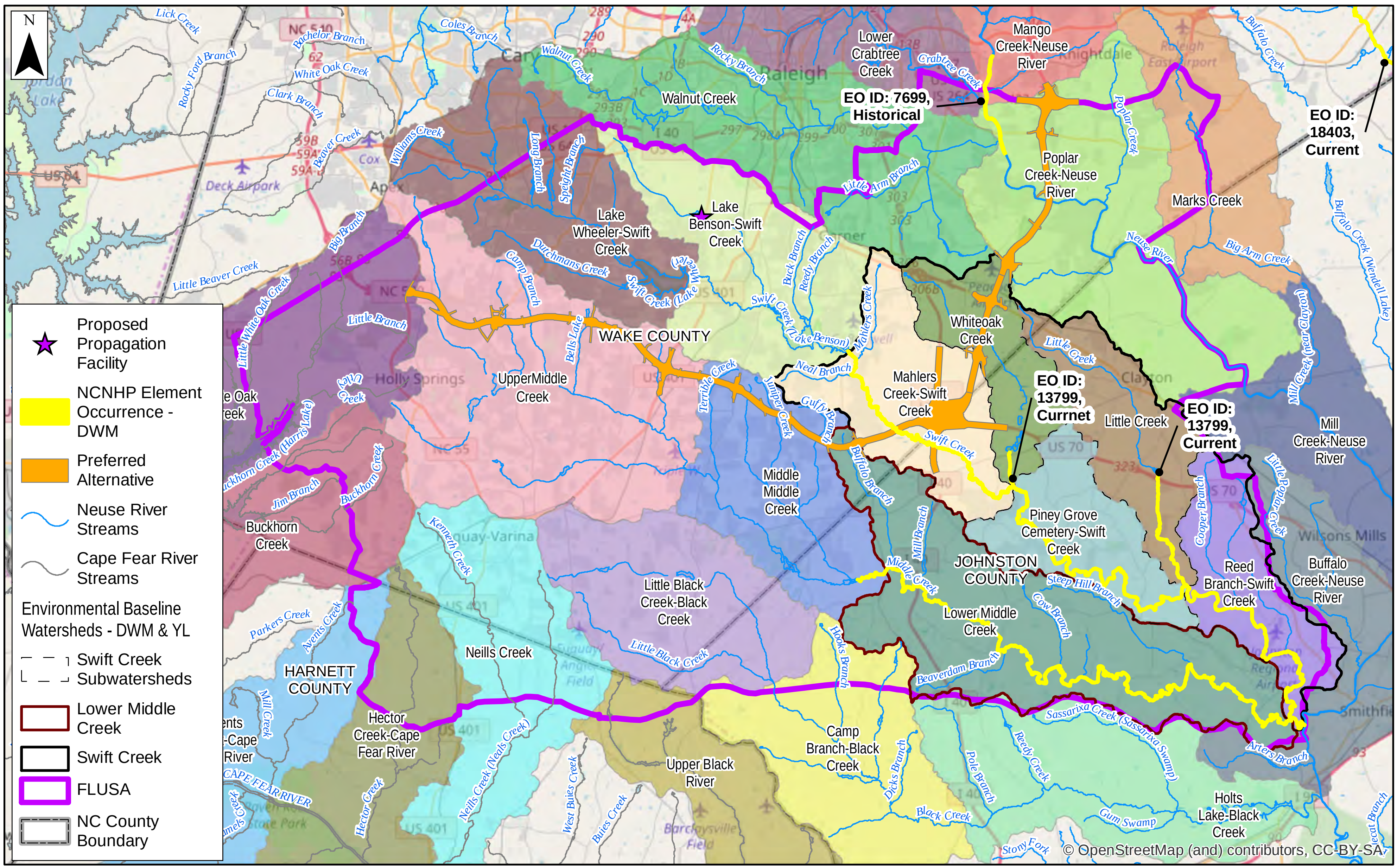
Complete 540 Triangle Expressway Southeast Extension

Natural Heritage Natural Areas

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure 7



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

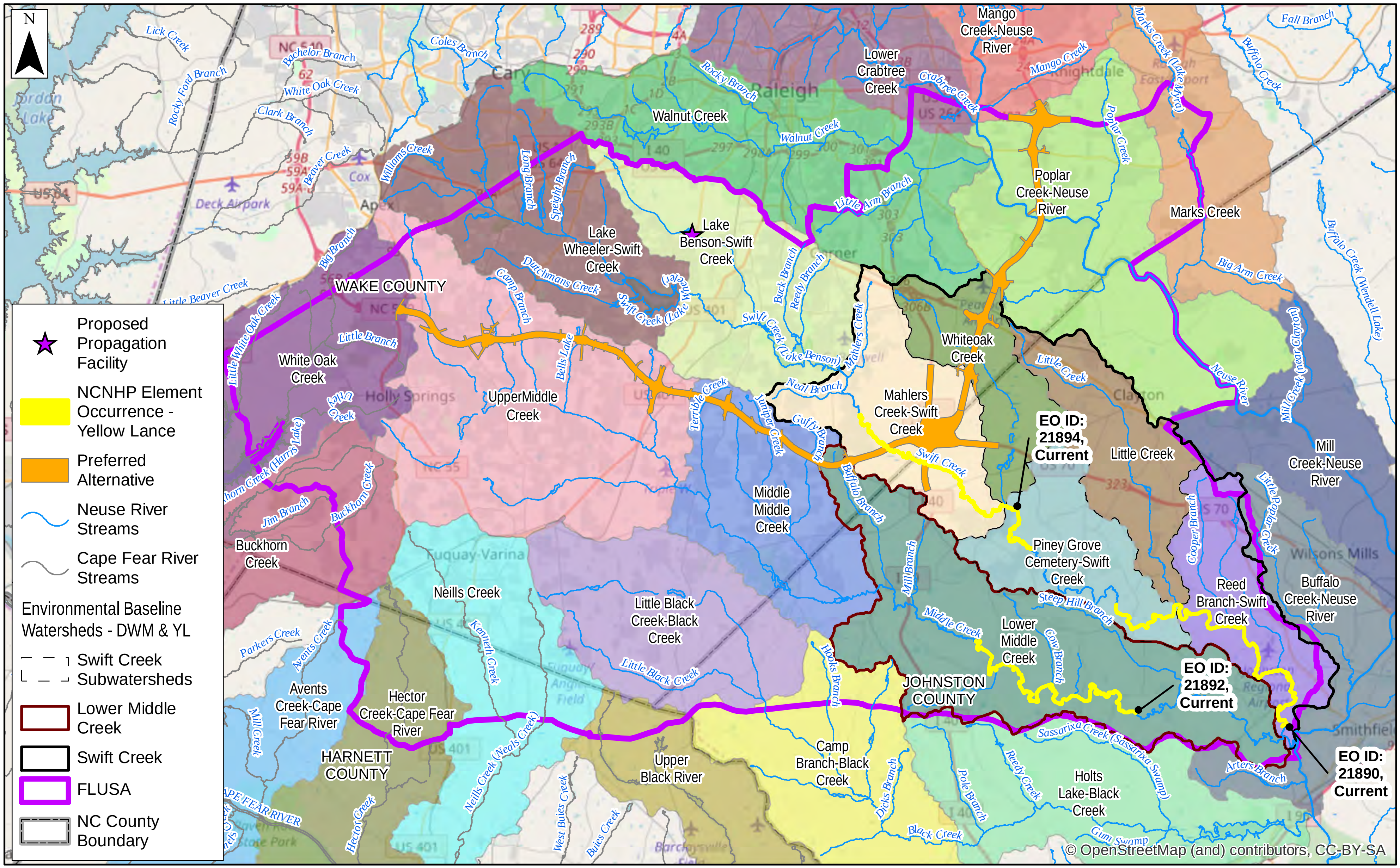
Dwarf Wedgemussel Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 1 2 Miles
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure

8



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

Yellow Lance Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017

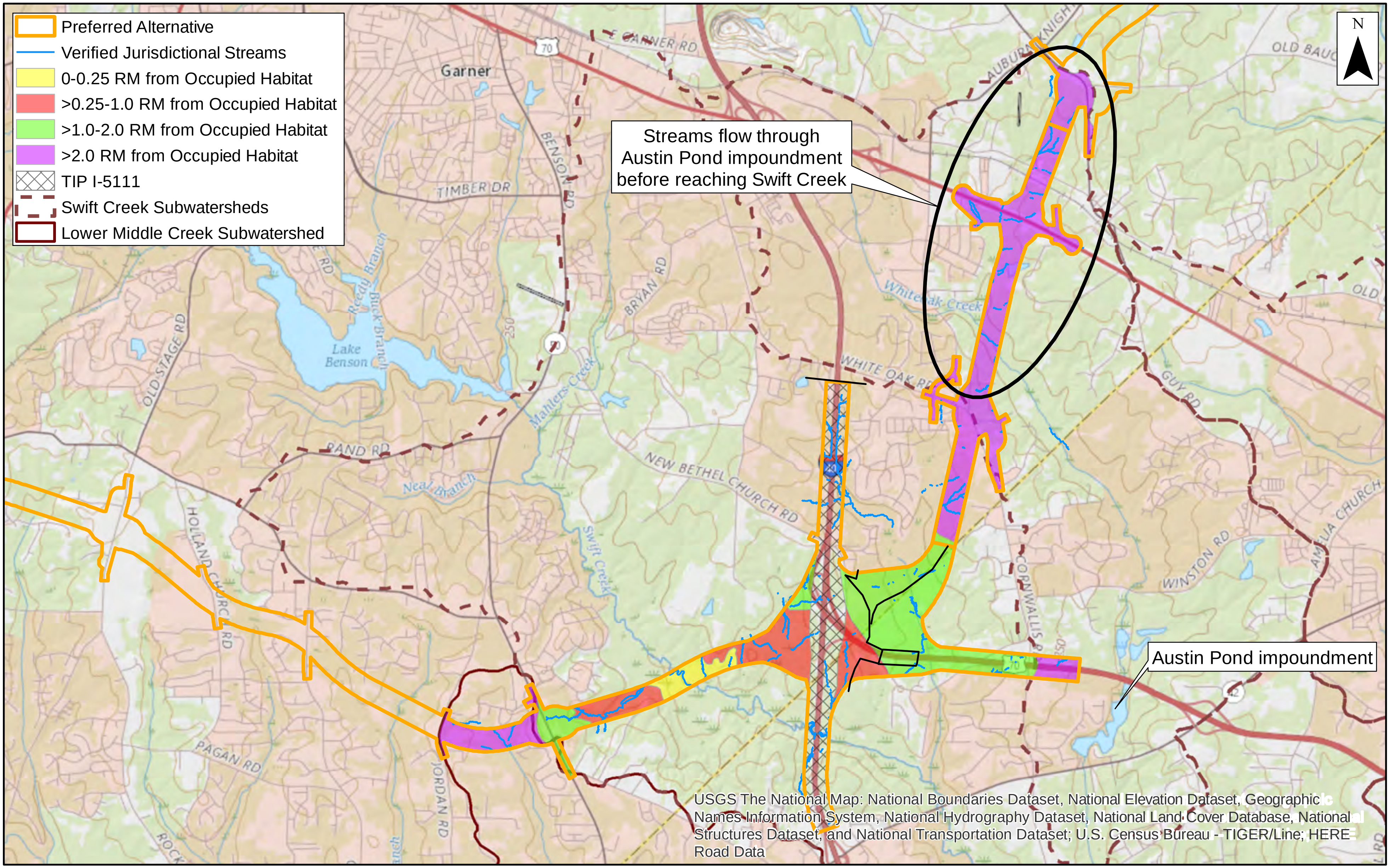
Scale: 0 1 2 Miles

Job No.: 1200

Drawn By: NMS

Checked By: KMS

Figure 9



Prepared For:

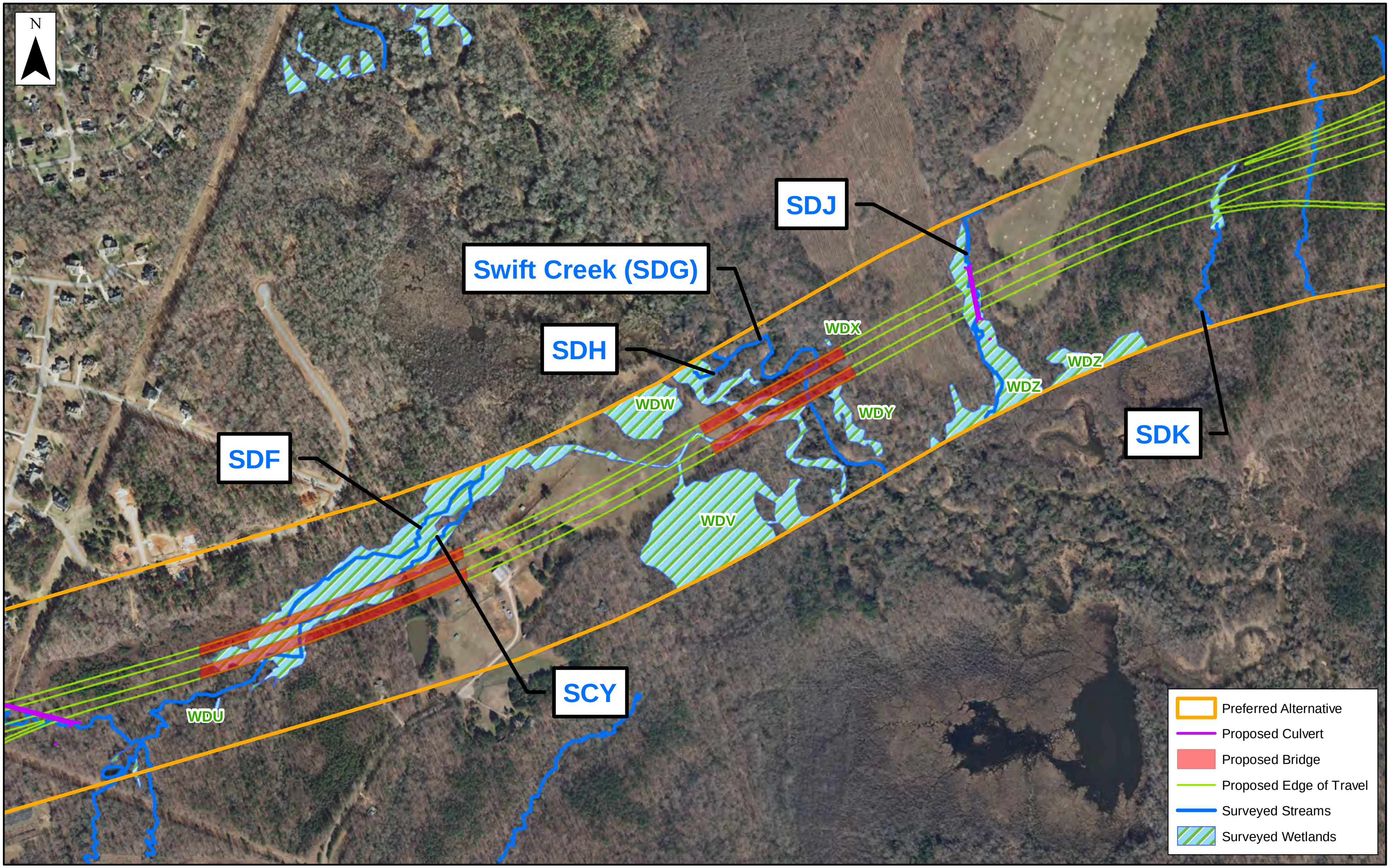
Complete 540 Triangle Expressway Southeast Extension

Distance to Occupied Habitat

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 2,000 4,000 Feet
Job No.:	1200
Drawn By: KMS	Checked By: NMS

Figure 10



THREE OAKS ENGINEERING

Prepared For: STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

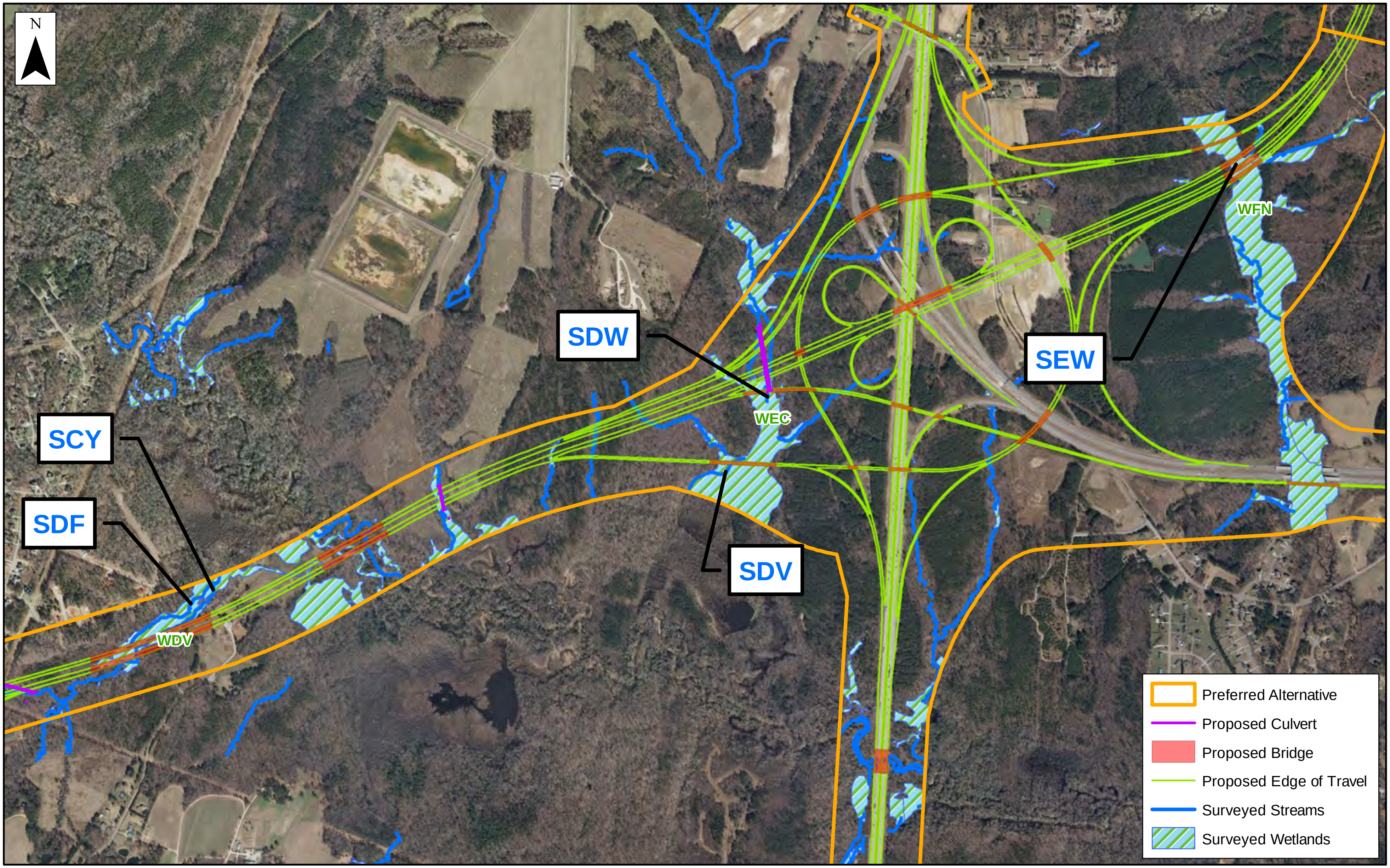
Complete 540 Triangle Expressway Southeast Extension

Streams Within 0.25 RM of Occupied Habitat within Swift Creek Watershed

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017	
Scale: 0 200 400 Feet	
Job No.: 1200	
Drawn By: NMS	Checked By: KMS

Figure 11



THREE OAKS ENGINEERING

Prepared For:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Complete 540 Triangle Expressway Southeast Extension

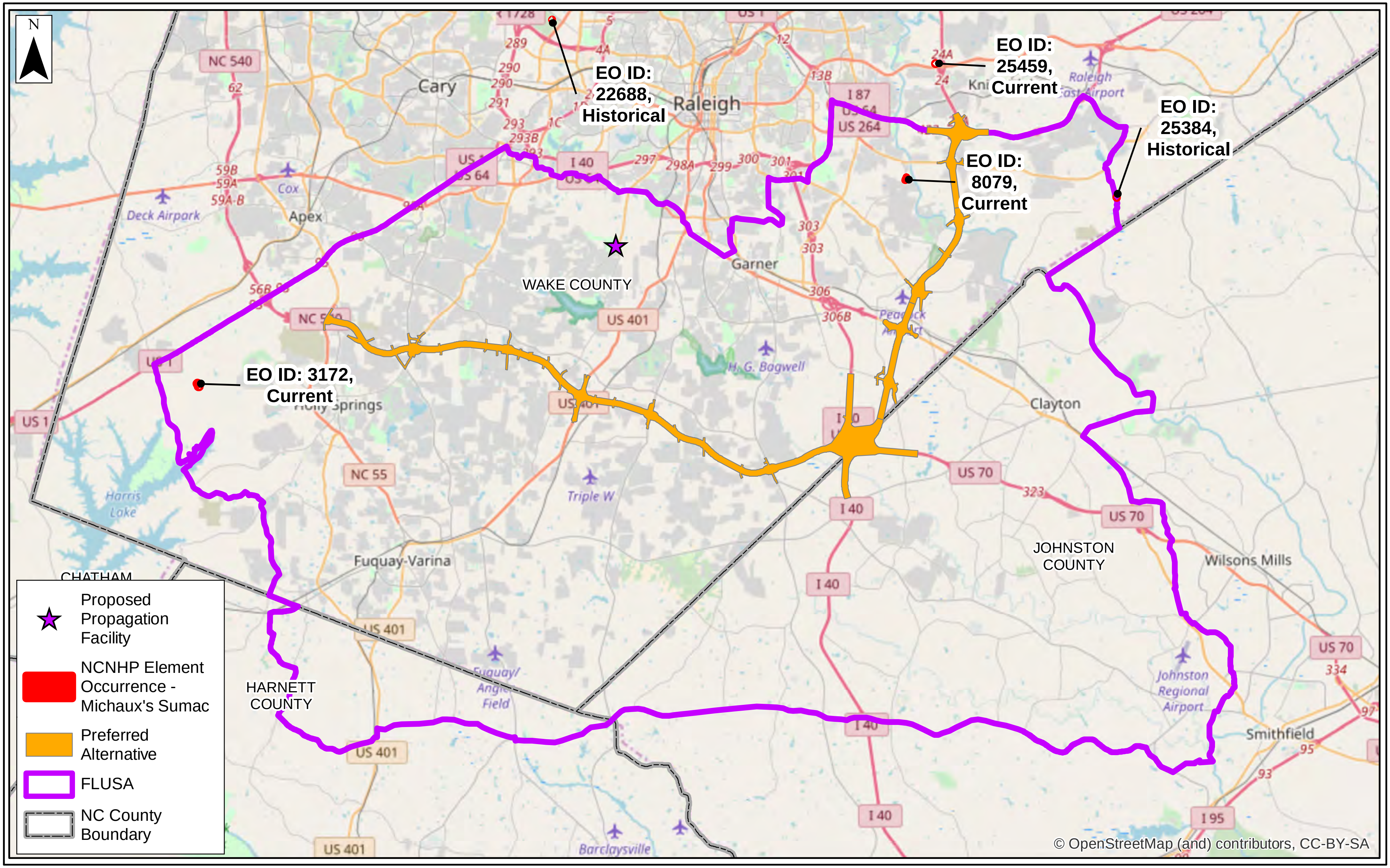
Stream and Wetland Crossings with Larger Proposed Structures

Wake, Johnston, & Harnett Counties, North Carolina

Date:	October 2017
Scale:	0 400 800 Feet
Job No.:	1200
Drawn By: NMS	Checked By: KMS

Figure

12



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

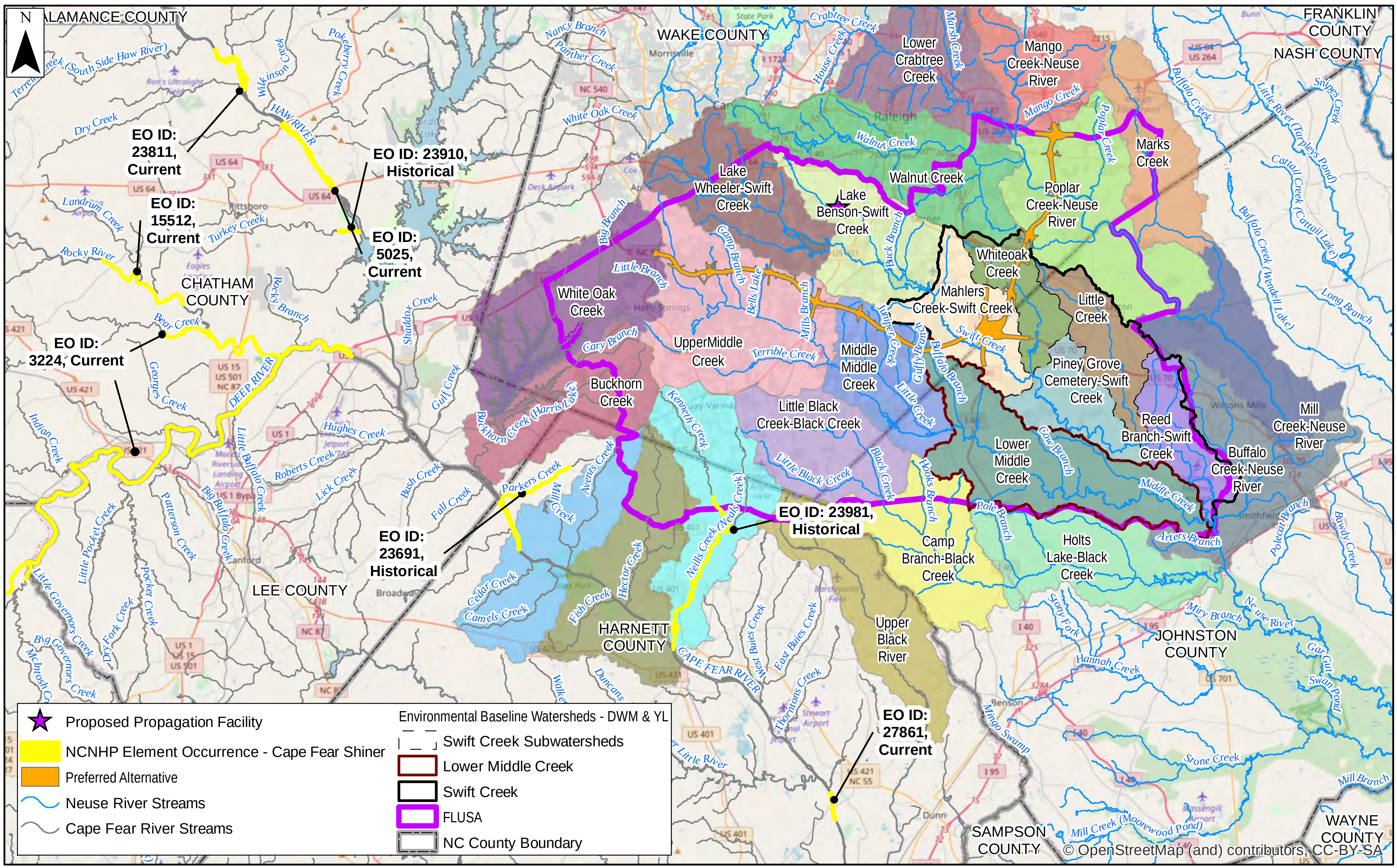
Michaux's Sumac Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017	
Scale: 0 1 2 Miles	
Job No.: 1200	
Drawn By: NMS	Checked By: KMS

Figure

13



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

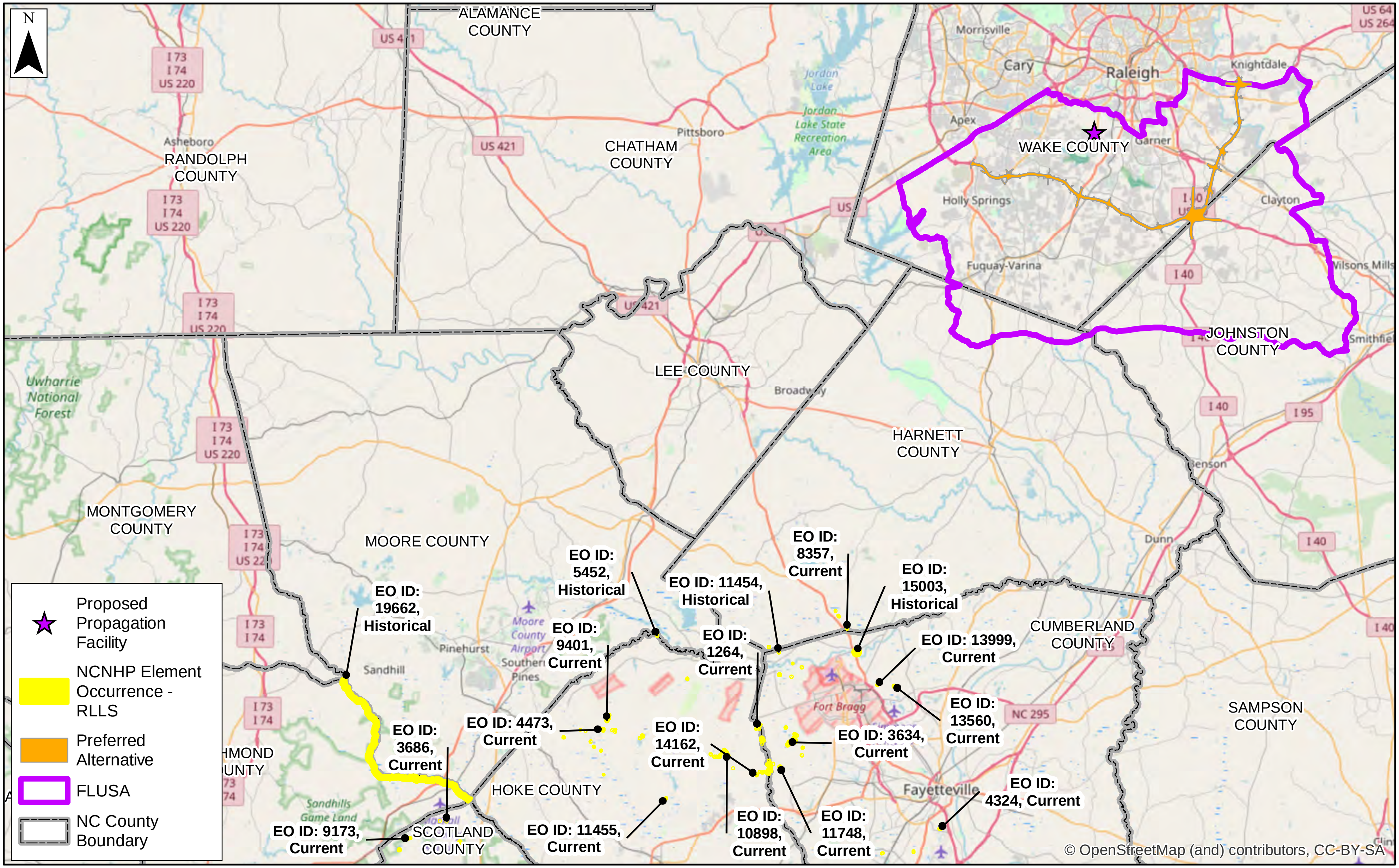
Cape Fear Shiner Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017	
Scale: 0 1.5 3 Miles	
Job No.: 1200	
Drawn By: NMS	Checked By: KMS

Figure

14



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

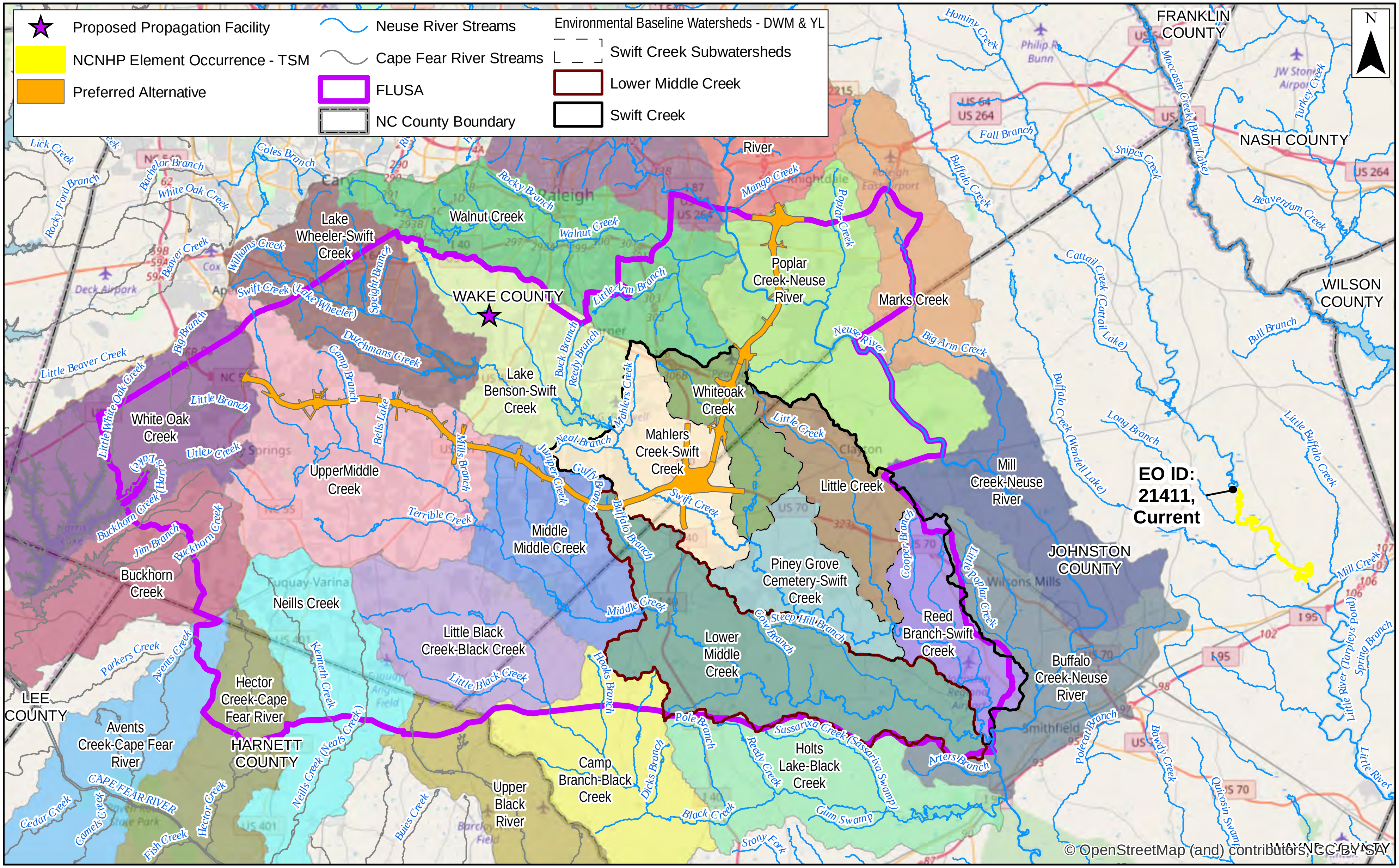
Rough-Leaved Loosestrife Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017	
Scale: 0 2.5 5 Miles	
Job No.: 1200	
Drawn By: NMS	Checked By: KMS

Figure

15



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

Tar Spinymussel Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017

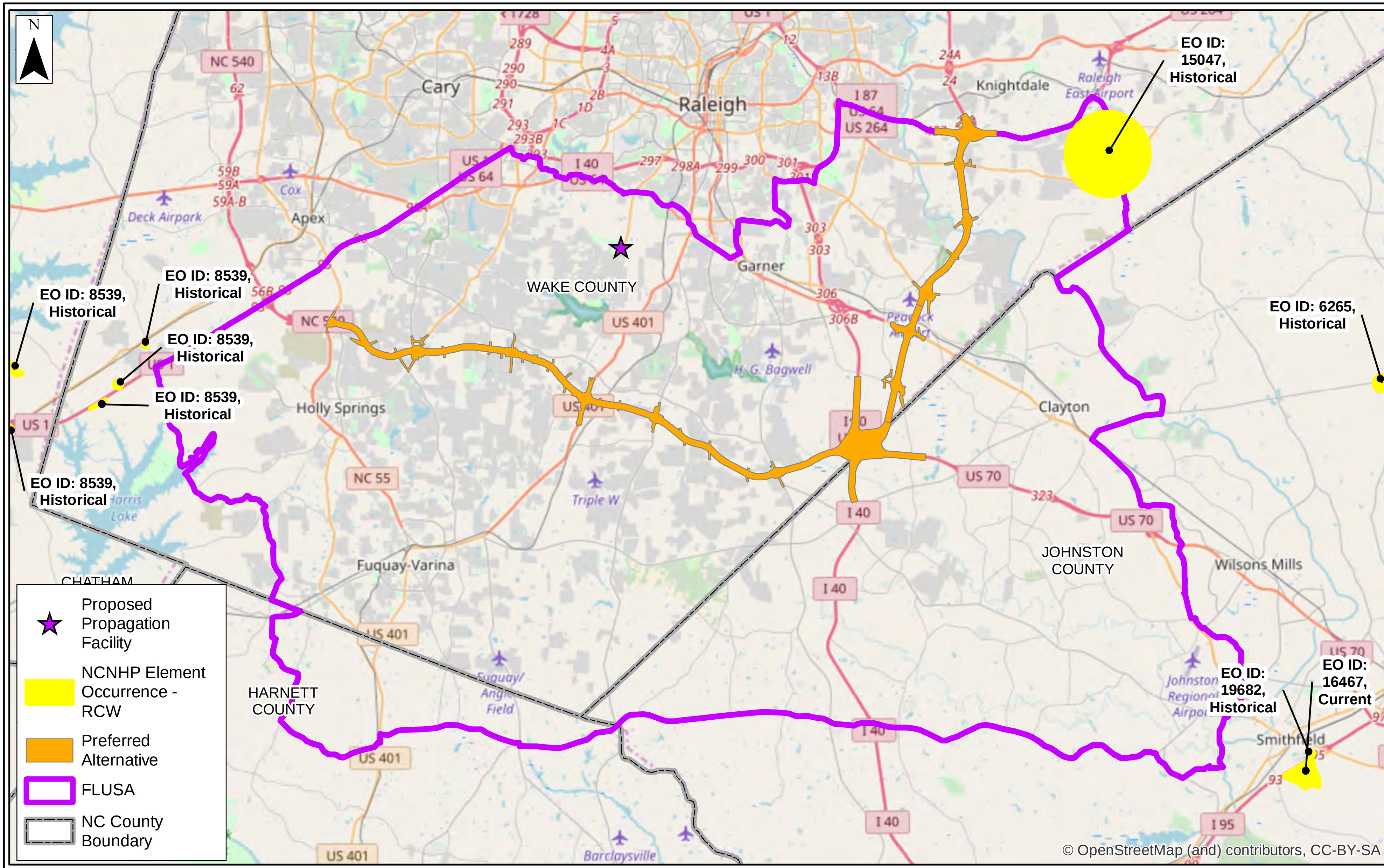
Scale: 0 1 2 Miles

Job No.: 1200

Drawn By: NMS

Checked By: KMS

Figure 16



Prepared For:

Complete 540 Triangle Expressway Southeast Extension

Red-Cockaded Woodpecker Element Occurrences

Wake, Johnston, & Harnett Counties, North Carolina

Date: October 2017

Scale: 0 1 2 Miles

Job No.: 1200

Drawn By: NMS

Checked By: KMS

Figure 17

Appendix B

Dwarf Wedgemussel and Yellow Lance Records in Future Land Use Study Area

Appendix B

DWM Records in the FLUSA

Location	Date	Site ID #	# of DWM	Y	X
Swift Creek	3/27/1991	910327.1jma	1 live	35.54522	-78.39826
Swift Creek	4/11/1991	910411.1jma	1 shell	35.57402	-78.49949
Swift Creek	3/19/1992	920319.2jma	2 live	35.57302	-78.50005
White Oak Creek	4/20/1992	920420.1jma	1 live	35.60618	-78.52709
Middle Creek	5/18/1992	920518.1jma	2 live	35.56741	-78.59562
Swift Creek	8/10/1992	Flowers-1992-22	2 shells	35.58900	-78.52000
Swift Creek	8/10/1992	Flowers-1992-23	2 shells	35.59500	-78.52200
Middle Creek	9/10/1992	920910.5jma	1 live	35.52112	-78.48501
Swift Creek	9/14/1992	920914.1jma	1 shell	35.62221	-78.57060
Swift Creek	9/1/1994	940901.0jma	1 live	35.60840	-78.54901
Swift Creek	9/1/1994	940901.4jma	1 live	35.59997	-78.53665
Swift Creek @ White Oak Creek	9/15/1994	940915.7jma	1 live	35.60393	-78.52627
Swift Creek	5/20/1996	960520.7jma	1 live	35.62623	-78.57930
Swift Creek	5/21/1996	960521.1jma	1 live	35.62117	-78.56474
Swift Creek	5/21/1996	960521.3jma	1 live	35.61951	-78.55847
Swift Creek	7/28/1997	970728.4jaj	3 live	35.60173	-78.53853
Swift Creek	7/29/1997	970729.2jaj	2 live, 1 shell	35.62050	-78.56202
Swift Creek	7/29/1997	970729.3jaj	2 live	35.62035	-78.56087
Swift Creek	10/13/1997	971013.1jaj	4 live	35.62050	-78.56202
Swift Creek	6/2/1998	980602.4jaj	1 live, 1 shell	35.62563	-78.57858
Swift Creek	6/2/1998	980602.7jaj	1 live	35.62540	-78.57657
Swift Creek	11/24/1998	981124.1jaj	2 live	35.62020	-78.56193
Swift Creek	7/17/2002	020717.7jnb	3 Live	35.62020	-78.56193
Little Creek	7/24/2003	030724.5tws	1 live	35.58039	-78.44558
Little Creek	7/24/2003	030724.6tws	1 live	35.58097	-78.44619
Swift Creek	11/5/2003	031105.4TWS	1 live	35.62032	-78.55640
Swift Creek	8/10/2007	070810.2tws	1 live	35.62766	-78.58522
Swift Creek	8/29/2007	070829.5tws	1 live	35.60788	-78.54517
Swift Creek	8/30/2007	070830.2ted	1 live	35.62294	-78.56847
Swift Creek	8/30/2007	070830.4tws	1 live	35.62078	-78.56266
Swift Creek	10/23/2007	071023.5tws	1 live	35.60423	-78.52754
Swift Creek	10/23/2007	071023.7tws	2 live	35.60230	-78.52957
Swift Creek	10/13/2010	101013.1tws	1 live	35.60662	-78.54391
Swift Creek	10/26/2010	101026.4tcg	1 live	35.60610	-78.54292
Swift Creek	10/27/2010	101027.4ted	1 live	35.62252	-78.56998
Swift Creek	11/1/2010	101101.5tws	1 live	35.60226	-78.53124
Swift Creek	11/9/2010	101109.4ted	1 live	35.57261	-78.50063
Swift Creek	6/15/2011	110615.5tcg	1 live	35.58896	-78.52261
Swift Creek	6/28/2011	110628.1tcg	1 shell	35.57828	-78.50689
Swift Creek	6/28/2011	110628.4tcg	1 shell	35.58070	-78.50773
Swift Creek	3/2/2012	120302.1tws	1 live*	35.60647	-78.54409

Location	Date	Site ID #	# of DWM	Y	X
Swift Creek	3/15/2012	120315.2ted	1 shell	35.58450	-78.50910
Swift Creek	3/15/2012	120315.4ted	1 live	35.58570	-78.51240
Swift Creek	3/15/2012	120315.2tws	1 live	35.58772	-78.51623
Swift Creek	4/4/2012	120404.1tws	1 live	35.57445	-78.50588
Swift Creek	4/16/2012	120416.2tcg	1 live	35.60647	-78.54409
Swift Creek	5/2/2012	120502.1tws	1 shell	35.57189	-78.50263
Swift Creek	5/2/2012	120502.2tws	1 live	35.57293	-78.50549
Swift Creek	4/8/2013	130408.1tws	1 live	35.59927	-78.53487
Swift Creek	5/28/2015	150528.1ted	1 live	35.58634	-78.51402
Swift Creek	6/25/2015	150625.2ted	1 live	35.57245	-78.50075
Swift Creek	8/27/2015	150827.2ted	1 live	35.57210	-78.50204
Swift Creek	4/6/2016	160406.1tws	1 live	35.57251	-78.50072

* Individual found during pre-construction survey for bridge replacement and relocated to Currently Occupied Geomorph Site 1 (CO1)

Yellow Lance Records in the FLUSA

Location	Date	Site ID #	# of YL	Y	X
Swift Creek	3/27/1991	910327.1jma	1 Shell	35.54522	-78.39826
Middle Creek	9/10/1992	920910.5jma	2 Shell	35.52112	-78.48501
Swift Creek	9/11/1992	920911.1jma	1 Shell	35.51950	-78.37875
Swift Creek	9/11/1992	920911.3jma	3 Shell	35.55429	-78.46306
Swift Creek	9/11/1992	920911.4jma	2 Shell	35.60040	-78.53699
Swift Creek	9/14/1992	920914.1jma	1 Live	35.62221	-78.57060
Swift Creek	5/25/1994	940525.5tws	18 Live	35.59930	-78.53540
Swift Creek	9/1/1994	940901.3jma	1 Live	35.60567	-78.54470
Swift Creek	9/15/1994	940915.1jma	1 Live	35.60183	-78.53083
Swift Creek	9/15/1994	940915.3jma	1 Live	35.60183	-78.53083
Swift Creek	9/15/1994	940915.5jma	1 Live	35.60183	-78.53083
Middle Creek	9/1/1995	950901.1tws	2 Live	35.52208	-78.46712
Swift Creek	5/21/1996	960521.1jma	1 Shell	35.62117	-78.56474
Swift Creek	5/21/1996	960521.2jma	1 Live	35.62043	-78.56199
Swift Creek	5/21/1996	960521.3jma	2 Live	35.61951	-78.55847
Swift Creek	5/23/1996	960523.1jma	1 Shell	35.54478	-78.40055
Swift Creek	7/28/1997	970728.1jaj	1 Live	35.60180	-78.53775
Swift Creek	7/28/1997	970728.3jaj	1 Live	35.60173	-78.53853
Swift Creek	7/29/1997	970729.2jaj	2 Live	35.62050	-78.56202
Swift Creek	5/21/1998	980521.2jaj	1 Live	35.62770	-78.58447
Swift Creek	6/2/1998	980602.2jaj	1 Live	35.62752	-78.58168
Swift Creek	6/2/1998	980602.6jaj	1 Live	35.62523	-78.57808
Swift Creek	6/2/1998	980602.7jaj	1 Live	35.62540	-78.57657
Middle Creek	7/19/1999	990719.1tws	1 Live	35.54070	-78.53330
Swift Creek	8/2/2001	010802.2btw	1 Live	35.51872	-78.38138
Swift Creek	8/9/2001	010809.2tws	1 Shell	35.55217	-78.46088

Location	Date	Site ID #	# of YL	Y	X
Swift Creek	11/5/2003	031105.5TWS	1 Shell	35.61986	-78.55893
Swift Creek	11/5/2003	031105.6TWS	1 Live	35.62002	-78.56117
Swift Creek	11/5/2003	031105.8TWS	1 Live	35.62113	-78.56368
Swift Creek	8/12/2004	040812.2mgw	1 Live, 1 Shell	35.55250	-78.46110
Swift Creek	6/1/2007	070601.2ted	1 Live	35.55340	-78.46134
Swift Creek	8/29/2007	070829.2ted	3 Live	35.62019	-78.56139
Swift Creek	8/29/2007	070829.2tws	1 Live	35.60645	-78.54406
Swift Creek	8/30/2007	070830.2tws	2 Live	35.61984	-78.55895
Swift Creek	10/23/2007	071023.1tws	1 Shell	35.60326	-78.52392
Swift Creek	10/23/2007	071023.7tws	1 Live	35.60230	-78.52957
Swift Creek	10/23/2007	071023.8tws	1 Shell	35.60207	-78.53013
Swift Creek	6/4/2009	090604.2cjw	1 Shell	35.61409	-78.54893
Swift Creek	5/13/2010	100513.1cbe	1 Live, 1 Shell	35.61337	-78.54883
Swift Creek	10/11/2010	101011.1KML	2 Shell	35.62072	-78.56246
Swift Creek	10/12/2010	101012.5tws	1 Live	35.61843	-78.55245
Swift Creek	10/12/2010	101012.5tws	1 Live	35.61843	-78.55245
Swift Creek	10/13/2010	101013.2tws	1 Live	35.60714	-78.54445
Swift Creek	10/13/2010	101013.2tws	1 Live	35.60714	-78.54445
Swift Creek	10/21/2010	101021.1tcg	1 Live	35.62009	-78.55836
Swift Creek	10/21/2010	101021.6tcg	1 Live, 1 Shell	35.62034	-78.56019
Swift Creek	10/21/2010	101021.1tcg	1 Live	35.62009	-78.55836
Swift Creek	10/21/2010	101021.6tcg	1 Live, 1 Shell	35.62034	-78.56019
Swift Creek	10/26/2010	101026.1tcg	1 Live	35.60396	-78.54167
Swift Creek	10/26/2010	101026.4tcg	1 Live	35.60610	-78.54292
Swift Creek	10/26/2010	101026.1tcg	1 Live	35.60396	-78.54167
Swift Creek	10/26/2010	101026.4tcg	1 Live	35.60610	-78.54292
Swift Creek	10/27/2010	101027.4ted	1 Live	35.62252	-78.56998
Swift Creek	10/27/2010	101027.6ted	1 Live	35.62411	-78.57330
Swift Creek	10/27/2010	101027.4ted	1 Live	35.62252	-78.56998
Swift Creek	10/27/2010	101027.6ted	1 Live	35.62411	-78.57330
Swift Creek	4/7/2011	110407.2tcg	1 Live	35.60566	-78.54290
Swift Creek	4/7/2011	110407.3tcg	1 Live	35.60638	-78.54304
Swift Creek	4/7/2011	110407.5tcg	1 Live	35.60785	-78.54646
Swift Creek	4/7/2011	110407.2tcg	1 Live	35.60566	-78.54290
Swift Creek	4/7/2011	110407.3tcg	1 Live	35.60638	-78.54304
Swift Creek	4/7/2011	110407.5tcg	1 Live	35.60785	-78.54646
Swift Creek	4/27/2011	110427.2ted	1 Live	35.62010	-78.55839
Swift Creek	4/27/2011	110427.5ted	1 Shell	35.62036	-78.56343
Swift Creek	4/27/2011	110427.2ted	1 Live	35.62010	-78.55839
Swift Creek	4/27/2011	110427.5ted	1 Shell	35.62036	-78.56343
Swift Creek	5/9/2011	110509.3ted	1 Live	35.62516	-78.57848
Swift Creek	5/9/2011	110509.3ted	1 Live	35.62516	-78.57848
Swift Creek	4/9/2012	120409.3tws	1 Live	35.62050	-78.55781
Swift Creek	4/9/2012	120409.5tws	1 Live	35.62004	-78.56074
Swift Creek	4/9/2012	120409.3tws	1 Live	35.62050	-78.55781

Location	Date	Site ID #	# of YL	Y	X
Swift Creek	4/9/2012	120409.5tws	1 Live	35.62004	-78.56074
Swift Creek	4/16/2012	120416.1tcg	1 Live	35.60604	-78.54325
Swift Creek	4/16/2012	120416.1tcg	1 Live	35.60604	-78.54325
Swift Creek	5/2/2012	120502.2ted	2 Live	35.62040	-78.56090
Swift Creek	5/2/2012	120502.2ted	2 Live	35.62040	-78.56090
Swift Creek	5/2/2012	120502.2ted	2 Live	35.62040	-78.56090

Appendix C

Lower Swift Creek Water Quality Report

LOWER SWIFT CREEK WATER QUALITY REPORT

Complete 540
Triangle Expressway Southeast Extension

Wake and Johnston Counties

STIP Project Nos. R-2721, R-2828, and R-2829
State Project Nos. 6.401078, 6.401079, and 6.401080
Federal Aid Project Nos. STP-0540(19), STP-0540(20), and STP-0540(21)
WBS Nos. 37673.1.TA2, 35516.1.TA2, and 35517.1.TA1

Prepared for:

North Carolina Department of Transportation
North Carolina Turnpike Authority

Prepared by:

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November, 2015

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1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) of the North Carolina Department of Transportation (NCDOT) proposes construction of a new road corridor from NC-55 (Apex) East to US-64 Bypass (Knightdale). Dwarf Wedgemussel (*Alasmidonta heterodon,* DWM), which is listed by the US Fish and Wildlife Service (USFWS) as a federally endangered species, occurs in Swift Creek of the Neuse River Basin within the proposed action area of the project. It was first documented to occur in Swift Creek in 1991.

To update the environmental baseline for the DWM population in Swift Creek, a multi-tier study was conducted to determine the viability of this population. This report addresses water quality conditions in the Swift Creek Watershed (SCW) to assist in determining if conditions are sufficient to continue to support DWM. The historical range of DWM extends 23 miles from above the Wake/Johnston County line to Swift Creek Road in Johnston County. The study area for this report includes the historical range, which extends from Lake Benson to the confluence with the Neuse River, and is referred to here as Lower SCW.

As detailed in the Phase 1 Dwarf Wedgemussel Viability Study completed for this project by Three Oaks Engineering/The Catena Group (Catena 2014), there are limited water quality datasets in the Lower SCW. Therefore, greater efforts were made to gather water quality information for the Lower SCW, particularly in regard to parameters that threaten the DWM, such as pH, dissolved oxygen (DO), ammonia, and copper.

1.1.Background

Under the Clean Water Act, the U.S. Environmental Protection Agency (EPA) recommends levels of ambient water quality concentrations to protect aquatic organisms living in surface waters. These levels are developed by determining the effects of pollutants on aquatic organisms. An aquatic life criterion is set at the highest concentration of a pollutant that is not expected to pose a significant threat to the majority of species in a given environment. Given the sensitivity of freshwater mussels' life cycle, means of consuming food, and inability to move long distances, there is concern that certain water quality criteria might not protect mussels from dangerous levels of some pollutants.

The North Carolina Division of Water Resources (DWR, formerly the Division of Water Quality) is responsible for managing North Carolina's surface waters. Effective January 1, 2015, North Carolina has adopted water quality standards for several dissolved metals, including copper. Though the EPA has not yet approved these standards, for the purposes of this report, they will be used as the water quality standards for copper (USEPA 2007, NC Register 2014). Similar standards for copper have been accepted by EPA for recommended water quality criteria, so the newly adopted NC rules will likely get approved. There are no state water quality standards for ammonia, so the EPA approved water quality criteria will be used for analysis of ammonia (USEPA 2013).

Several studies have examined methods for determining toxicity levels of certain water quality parameters on freshwater mussels. A discussion of two of these methods follows. The first study (Ward et al. 2007) examines both copper and ammonia ambient concentrations and implications for toxicity. The second study (Augspurger 2012) focuses on copper, which the Ward study identifies as the most significant pollutant to freshwater mussels in the SCW.

1.2. Previous Studies

Ward et al. (2007) examined water quality by analyzing copper, ammonia, and chlorine in three river basins in NC that contain either DWM or Carolina Heelsplitter (*Lasmigona decorata*), both endangered freshwater mussels. Along with several sampling locations in the SCW, they also sampled in Fishing Creek (part of the Tar-Pamlico River basin) and Goose Creek (part of the Yadkin-Pee Dee River basin). Sampling was conducted at five sites in each drainage basin, with varying proximity to wastewater treatment facilities (often sources of contamination). Samples were collected every two months for one year, usually during base flow conditions (not during storm events). In addition to DO, temperature, pH, and total residual chlorine (measured in the field), total ammonia and total recoverable copper were analyzed. Additionally, ammonia and copper data were obtained from DWR ambient monitoring stations in each of the three drainage basins.

Ammonia toxicity is dependent on temperature and pH. The 2007 Ward et al. study used EPA's "1999 Update of ambient water quality criteria for ammonia" and mussel toxicity data to determine acute and chronic concentrations of ammonia that should not harm mussels based on site-specific pH (USEPA 1999).

Copper toxicity is influenced by pH, dissolved organic carbon, water hardness, sodium, potassium, sulfate, chloride, alkalinity, and temperature. The EPA's "1996 Water quality criteria documents for the protection of aquatic life in ambient water", which was based only on water hardness, was used to determine acute and chronic concentrations that should not harm mussels based on site-specific hardness (USEPA 1996). The "2007 EPA updated aquatic life criteria for copper" uses a biotic ligand model (BLM), which requires several more parameters than were available for the Ward study (see Section 1.3 for more details, USEPA 2007).

In measuring concentrations of the three parameters in the three river basins, Ward et al. (2007) found that Goose Creek had the most elevated ammonia concentrations. Copper was less than or equal to 10 ug/L in all but 7 of the 95 samples, all 7 of which occurred in Goose Creek on one day during a heavy storm event, indicating that the elevated levels were likely due to an increase in suspended sediment in the stream. Chlorine was detected less frequently than ammonia or copper. The median chlorine level was below the method detection limit (MDL) (5.7 ug/L), yet several samples were above 200 ug/L. These elevated samples were in Tar River and Goose Creek and below Waste Water Treatment Plants.

While risk of exposure to all parameters was highest in Goose Creek, copper concentrations were concerns in all three drainages, including Swift Creek. Chlorine concentrations were infrequently a concern, and risks associated with periodic spikes were not well understood.

1.3. Biotic Ligand Model

Metal toxicity and biological availability is known to be dependent on water chemistry (Adams and Chapman 2007). HydroQual developed a method for determining metal toxicity using the BLM (HydroQual 2005). This model incorporates a total of 12 water quality parameters to analyze how metal toxicity changes at the biotic ligand, or the site of action on an aquatic organism. This model is thought to more accurately represent the sensitivity of freshwater mussels to metals, and it was incorporated into the EPA's revised water quality criteria in 2007 (USEPA 2007).

A study by Augspurger (2012) analyzed copper concentrations in the Goose Creek watershed in Union County, NC, the same watershed examined in the 2007 Ward study, and evaluated the potential for toxicity using the BLM. This 2012 study found that Goose Creek copper concentrations did not exceed acute or chronic concentrations as derived from the BLM. A sensitivity analysis of the BLM indicated pH and dissolved organic carbon were the most influential of the 12 water quality parameters on the outcome of the BLM analysis. These papers form the foundation of the water quality analysis performed here. The BLM was published after the Ward study, so it could not be used to analyze the data from the Ward study.

2.0 METHODS

2.1. Water Quality Data Collection

Water quality sampling in the Lower SCW was performed at three locations; Swift Creek crossings of NC 50 (Benson Road), SR 1555 (Barber Mill Road), and NC 210 (Figure 1). The sites were selected for ease of access and it is the opinion of Three Oaks that water quality conditions at these locations are indicative of the current occupied range of DWM in Swift Creek. These sampling sites are believed to represent the range of conditions in the watershed in terms of habitat conditions and flow conditions. At the upper most site (NC 50), Swift Creek is largely influenced by development. As the stream flows southeast, it moves further from urban areas and becomes more stable. Samples were collected from November 2014 through July 2015. Water quality parameters that were measured are listed in Table 1.

Table 1. Water quality parameters measured in Lower SCW.

Field Parameters	Laboratory Parameters
Dissolved Oxygen Temperature* Conductivity pH*	Calcium (Ca)* Magnesium (Mg)* Sodium (Na)* Potassium (K)* Sulfate as SO_4* Chloride (Cl)* Total Alkalinity (as $CaCO_3$)* Dissolved Organic Carbon (DOC)* Copper (Total and dissolved*) Lead Nickel Zinc Cadmium

* indicates parameters used in the BLM to predict copper toxicity to freshwater mussels

Water samples were collected a total of eight times from each site over the course of the sampling period: once during each season, twice during a high-flow event (when flow at USGS gauge 0208773375 was >50% above the median daily statistic), and twice during a low-flow event (when flow at the same gauge was <50% below the median daily statistic) (Table 2). While extreme flow conditions were not observed, a range of flows are represented by the days on which sampling occurred.

Table 2. Dates of sampling events and approximate flows during each event

Date Sampled	Sites Sampled	Flow (in cfs)	Median Daily Discharge*	Flow Category**
Nov 4, 2014	NC 210, NC 50	30	33	Base
Nov 19, 2014	NC 210, SR 1555, NC 50	50	27	Base/High
Dec 16, 2014	SR 1555	38	34	Base
Feb 6, 2015	NC 210, SR 1555, NC 50	100	110	Base
April 7, 2015	NC 210, SR 1555, NC 50	47	79	Base/Low
May 7, 2015	NC 210, SR 1555, NC 50	39	112	Low
June 9, 2015	NC 210, SR 1555, NC 50	11	50	Low
July 1, 2015	NC 210, SR 1555, NC 50	53	11	High
July 10, 2015	NC 210, SR 1555, NC 50	127	15	High

*Median Daily Discharge is based on 6 years of data
**Flow at time of sampling varied slightly, so several samples were on the line between base flow and low flow or base flow and high flow. These values are approximate.

Field parameters were measured at the time of sampling by use of a multi-parameter meter (YSI Professional Plus, Yellow Spring, OH, USA). For all parameters, grab samples were collected from visibly flowing portions of the stream (not in stagnant pools), approximately one meter away from the bank toward mid-channel. All samples were stored on ice (at ~4°C) in the field and taken the same day to ENCO Laboratory (Cary, NC) for analysis.

Grab samples for ammonia were collected in chemically cleaned 250mL polyethylene bottles and acidified with concentrated sulfuric acid (H_2SO_4) to pH <2. Ammonia as nitrogen was measured by the semi-automated colorimetry method following protocols described in EPA method 350.1 (USEPA 1993a). Quality control for ammonia measurements included analyses of reagent blanks, matrix spike, and duplicate matrix spike. The MDL was 0.045 mg/L.

Grab samples for copper were collected unfiltered in chemically cleaned 250 mL polyethylene bottles and acidified with nitric acid (HNO_3). Total copper and dissolved copper were measured by the inductively coupled plasma-atomic emission spectrometry method following protocols described in EPA method 6010C (USEPA 2000). Quality control for copper measurements included analyses of reagent blanks, a laboratory control sample, matrix spike, duplicate matrix spike, and post spike. The MDL was 1.60 ug/L.

Grab samples for dissolved organic carbon (DOC) were collected in chemically cleaned 250ml polyethylene bottles. Dissolved organic carbon was measured by the high-temperature combustion method described in Standard Method 5310 B (SM 5310B-2000). Quality control for DOC measurements included analyses of reagent blanks, a laboratory control sample, matrix spike, and duplicate matrix spike. The MDL was 0.32 mg/L.

Grab samples for cadmium, calcium, lead, magnesium, nickel, potassium, sodium, and zinc were collected in chemically cleaned bottles. These ions were measured by the inductively couple plasma-atomic emission spectrometry method following protocols described in EPA method 6010C (USEPA 2000). Quality control for these measurements included analyses of reagent blanks, a laboratory control sample, matrix spike, duplicate matrix spike and post spike. The MDL for cadmium was 0.36 ug/L. The MDL for calcium was 39.0 ug/L. The MDL for lead was 2.10 ug/L. The MDL for magnesium was 23.0 ug/L. The MDL for nickel was 1.80 ug/L. The MDL for potassium was 150 ug/L. The MDL for sodium was 400 ug/L. The MDL for zinc was 3.80 ug/L.

Grab samples for chloride and sulfate were collected in chemically cleaned bottles. These ions were measured by the ion chromatography method described in EPA method 300 (EPA 1993b). Quality control for the ion measurements included analyses of reagent blanks, a laboratory control sample, matrix spike, and duplicate matrix spike. The MDL for chloride was 2.2 mg/L. The MDL for sulfate was 2.9 mg/L.

2.2.Toxicity Analysis

The toxicity of ammonia and copper were analyzed using the most up to date methods. The first method simply compares the measured concentration of each parameter to the NC water quality standard (for copper, based on the EPA criteria for that parameter, “Aquatic Life Ambient Freshwater Quality Criteria – Copper, 2007 Revision”) and the EPA criteria for ammonia (“Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater, 2013”). Additionally, the BLM method was used to evaluate the potential for copper toxicity.

Water samples collected for this study were evaluated using BLM in Water Quality Criteria Calculation mode. Using the model in this mode analyzes the parameters in Table 2 (with an asterisk) to adjust the EPA acute and chronic water quality criteria for protection of aquatic species to local water quality conditions. The criteria that the BLM predicts are then compared to dissolved copper concentrations. If dissolved copper was not detected in a sample, the total copper concentration was multiplied by a conversion factor of 0.96. If neither dissolved nor total copper was detected, then the model was not run.

3.0 RESULTS AND DISCUSSION

All water sample analyses were completed with quality control / quality assurance samples (blanks, spikes, duplicates). Review of quality assurance data indicates acceptable precision and accuracy for most analyses. The laboratory blank sample for copper analysis contained low levels of copper (2.56 ug/L and 3.11 ug/L for total and dissolved copper, respectively) on one of the sampling dates (April 7, 2015). The three samples from that day were reported with some of the highest concentrations of copper from the study (between 4.13 ug/L and 5.91 ug/L). The spiked and duplicate samples were reported with acceptable recovery. It is possible that some of the copper in these samples is a result of laboratory contamination, or that the laboratory blank was contaminated but the samples were accurate. It is impossible to know for sure. For data analysis purposes, we are assuming that all the copper in the April 7th samples is from Swift Creek. Another way to interpret these results is to assume an extra 2.56-3.11 ug/L of copper were in the samples and subtract that amount out of the final result. The significance of these results will be discussed further in Section 3.3.

The laboratory blank sample for zinc and nickel analysis contained low levels of zinc and nickel from samples taken on November 4, 2014. Samples did not contain high levels of zinc or nickel, so we assumed that those samples were not compromised. There was poor matrix spike and matrix spike duplicate recoveries for DOC, chloride, sulfate, magnesium, sodium, alkalinity, and ammonia on several occasions, but in each instance, the batch was accepted for these analytes based on the laboratory control spike recoveries. Laboratory reports provided by ENCO for sample analysis are in Appendix B.

3.1. Environmental Exposure Concentrations

Copper concentrations gathered for this report are summarized in Table 6 (along with BLM-derived criteria concentrations, which are discussed in Section 3.3). Total copper was detected in half of the samples, while dissolved copper was detected in about a third (MDL for both analyses is 1.60 ug/L). Four of these samples exceeded the chronic event-specific North Carolina water quality standard for copper (derived from hardness levels measured at each sampling event). Additionally, three of these samples exceeded the acute event-specific water quality standard for copper. The elevated concentrations of copper appear to occur during lower flow rates, which is typically contrary to what would be expected; that copper levels spike during significant rain events when sediment loads into streams increases.

Ammonia concentrations gathered for this study are summarized in Table 3. Ammonia was detected in 11 of 24 samples collected (MDL is 0.045 mg/L). None of these samples exceeded the event-specific chronic or the acute criteria (USEPA 2013).

Table 3. Ammonia concentrations in Swift Creek during 2014-2015 sampling events and corresponding CMC and CCC values in mg/L (USEPA 2013).

Location	Flow	Sampling Date	Ammonia as N	pH (SU)	Temp (°C)	CMC	CCC
NC 50	Base	11/4/14	0.063	6.51	14.8	32.5	2.97
NC 50	Base/High	11/19/14	0.25	7.22	9.1	19.3	3.44
NC 50	Base	2/6/15	<0.045	7.15	6.6	20.8	4.20
NC 50	Base/Low	4/7/15	<0.045	7.32	18.4	13.6	1.77
NC 50	Low	5/7/15	0.051	6.86	22.5	15.2	1.68
NC 50	Low	6/9/15	0.072	7.01	25.7	10.4	1.30
NC 50	High	7/1/15	<0.045	7.42	29.7	4.64	0.80
NC 50	High	7/10/15	0.069	7.17	29.8	6.29	0.93
SR 1555	Base/High	11/19/14	0.35	7.23	5.9	19.1	4.20
SR 1555	Base	12/16/14	<0.045	-	-	-	-
SR 1555	Base	2/6/15	<0.045	7.28	5.2	17.9	4.26
SR 1555	Base/Low	4/7/15	<0.045	7.23	17.7	16.0	1.96
SR 1555	Low	5/7/15	0.078	6.81	21	17.8	1.88
SR 1555	Low	6/9/15	<0.045	7.05	24	11.5	1.43
SR 1555	High	7/1/15	0.073	7.14	26.2	8.76	1.19
SR 1555	High	7/10/15	0.06	7.02	27.7	8.70	1.14
NC 210	Base	11/4/14	<0.045	6.56	10	31.8	4.02
NC 210	Base/High	11/19/14	0.58	8.16	5.7	4.13	1.53
NC 210	Base	2/6/15	<0.045	7.56	5.2	12.1	3.43
NC 210	Base/Low	4/7/15	<0.045	7.38	17.6	13.3	1.79
NC 210	Low	5/7/15	0.06	7.12	20	15.0	1.79
NC 210	Low	6/9/15	<0.045	7.47	23.6	7.16	1.13
NC 210	High	7/1/15	<0.045	6.98	25.5	10.8	1.33
NC 210	High	7/10/15	<0.045	7.5	26.1	5.57	0.94

No sample exceeds the event-specific acute or chronic criteria according to USEPA 2013 recommended criteria.

Other metals and compounds were analyzed for this study, statistical information for which is provided in Table 4 along with corresponding North Carolina water quality standards (NCDWR 2003, NC Register 2014). As illustrated in Table 4, none of the provided parameters exceeded North Carolina water quality standards.

Table 4. Statistical information for other metals and compounds analyzed for this study, as compared to water quality standards (NCDWR 2003).

Parameter	Median concentration	Maximum concentration	NCDWR Water Quality Standard
Cadmium (ug/L)	0.36	0.36	2
Chloride (mg/L)	7.25	11	230
Lead (ug/L)	<2.10*	<2.10*	25
Nickel (ug/L)	2.02	2.02	88
Sulfate (mg/L)	3.85	4.9	250
Zinc (ug/L)	6.14	16.7	50

*indicates MDL

3.2. Ward et al. Ammonia Update

Ammonia concentrations documented in the 2007 Ward et al. study have been updated with the EPA 2013 water quality criteria, using both pH and temperature measurements. Table 5 provides the event-specific CMC and CCC for ammonia expected to be protective for freshwater mussels (USEPA 2013). None of these samples exceeded the event-specific chronic or the acute criteria (USEPA 2013).

Table 5. Ammonia concentrations measured in Ward et al. from 2002-2003 compared to CMC and CCC (USEPA 2013).

Sample Site	Date	Ammonia as N	pH (SU)	Temp (°C)	CMC	CCC
SC1	07/11/02	0.10	7.1	28.5	7.54	1.05
SC1	09/30/02	0.14	6.3	23.0	18.82	1.79
SC1	01/09/03	0.32	6.4	7.5	33.74	4.82
SC1	03/19/03	0.06	7.1	5.0	21.94	4.76
SC1	05/12/03	0.30	7.3	25.2	7.91	1.16
SC1	07/16/03	0.07	6.9	27.2	10.01	1.23
SC2	07/11/02	0.11	7.0	24.5	11.54	1.41
SC2	09/30/02	0.09	6.6	21.8	18.74	1.87
SC2	01/09/03	0.45	7.0	7.5	24.10	4.22
SC2	03/19/03	0.02	7.1	4.7	21.94	4.85
SC2	05/12/03	0.18	7.0	23.0	13.07	1.56
SC2	07/16/03	0.10	6.9	25.9	11.15	1.34
SC3	07/11/02	0.06	7.2	26.0	8.34	1.17
SC3	09/30/02	0.14	7.1	22.0	12.93	1.59
SC3	01/09/03	0.04	6.7	8.8	29.76	4.24
SC3	03/19/03	0.02	7.0	5.0	24.10	4.96
SC3	05/12/03	0.14	7.0	23.2	12.86	1.54
SC3	07/16/03	0.07	6.9	26.0	11.06	1.33
SC4	07/11/02	0.04	7.1	25.4	9.75	1.28
SC4	09/30/02	0.10	7.4	23.0	8.32	1.25
SC4	01/09/03	0.03	7.3	8.2	17.51	3.47
SC4	03/19/03	0.02	7.1	6.5	21.94	4.32
SC4	05/12/03	0.10	7.1	23.5	11.42	1.44
SC4	07/16/03	0.04	7.1	25.0	10.08	1.31
WO1	07/11/02	0.04	7.1	24.5	10.51	1.35
WO1	09/30/02	0.03	6.8	21.0	17.95	1.88
WO1	01/09/03	0.02	6.7	7.2	29.76	4.70
WO1	03/19/03	0.02	6.8	5.2	28.05	5.22
WO1	05/12/03	0.10	6.8	22.0	16.52	1.77
WO1	07/16/03	0.02	6.6	24.0	15.61	1.62
WO2	07/11/02	0.05	7.0	23.0	13.07	1.56

No sample exceeds the event-specific acute or chronic criteria according to USEPA 2013 recommendations.

3.3.BLM Analysis

Table 6 provides the copper concentrations for each sampling event and compares them to the state water quality standards, and also provides the BLM-derived event specific criteria for comparison. Only one sample result exceeded either the CMC or CCC, the NC 50 crossing of Swift Creek on November 19, 2014. The CMC and CCC values vary between sampling events, indicating changing conditions in the watershed over time (and throughout seasons), and between sampling sites.

Table 6. Comparison of Swift Creek total and dissolved copper concentrations to water quality criteria and BLM-derived CMC and CCC (in ug/L)

Location	Flow	Sampling Date	Total Copper	Dissolved Copper	NCDWR Acute std	NCDWR Chronic std	CMC	CCC
NC 50	Base	11/4/14	1.98	<1.60	3.10	2.36	4.79	2.98
	Base/High	11/19/14	<1.60	1.96**	3.35	2.54	1.96	1.22
	Base	2/6/15	2.46	2.24*	2.91	2.23	12.02	7.47
	Base/Low	4/7/15	5.91	4.92*	3.90	2.92	18.94	11.77
	Low	5/7/15	2.03	1.75	3.49	2.64	9.35	5.81
	Low	6/9/15	5.53	2.79	4.36	3.23	11.72	7.28
	High	7/1/15	<1.60	<1.60	4.12	3.06	21.89	13.59
	High	7/10/15	<1.60	<1.60	4.06	3.03	15.22	9.45
SR 1555	Base/High	11/19/14	<1.60	<1.60	3.56	2.68	1.21	0.75
	Base	12/16/14	<1.60	<1.60	3.39	2.57	12.32	7.66
	Base	2/6/15	2.75	<1.60	3.00	2.30	12.18	7.56
	Base/Low	4/7/15	4.13	4.17*	3.71	2.79	13.01	8.08
	Low	5/7/15	<1.60	<1.60	3.23	2.46	7.04	4.37
	Low	6/9/15	1.69	<1.60	3.79	2.84	8.85	5.50
	High	7/1/15	<1.60	<1.60	3.90	2.92	12.82	7.96
	High	7/10/15	<1.60	<1.60	3.48	2.63	10.59	6.58
NC 210	Base	11/4/14	<1.60	<1.60	3.82	2.86	4.20	2.61
	Base/High	11/19/14	<1.60	<1.60	3.82	2.86	3.14	1.96
	Base	2/6/15	<1.60	<1.60	3.03	2.32	17.75	11.03
	Base/Low	4/7/15	4.65	4.13*	4.05	3.02	17.11	10.63
	Low	5/7/15	2.01	<1.60	3.48	2.63	12.37	7.68
	Low	6/9/15	1.74	1.66	4.02	3.00	16.52	10.26
	High	7/1/15	<1.60	<1.60	3.97	2.96	10.84	6.74
	High	7/10/15	1.61	<1.60	3.34	2.53	21.53	13.37

* Dissolved copper concentrations exceed either the event-specific acute or chronic North Carolina Water Quality Standard

** Sample exceeds the BLM-derived event-specific CMC/CCC for copper.

As mentioned at the beginning of Section 3.0, the method blank associated with the copper samples taken April 7, 2015 contained low levels of copper. We have assumed that this blank was contaminated in the lab, and that the samples were not compromised. This assumption leads to state water quality standards for copper for acute and chronic levels being exceeded by all three of the April 7th samples, and yet these samples do not exceed the BLM-derived CMC or CCC. If, however, we were to think the samples were somehow contaminated and results reflected artificially high copper levels, we could subtract out the blank level of dissolved copper (3.11 ug/L). This would reduce the sample results significantly (1.81, 1.06, and 1.03 ug/L for NC 50, SR 1555, and NC 210, respectively) and put the results below the state water quality standards. However, there were other samples containing elevated levels of copper, and the other eight of the total of nine batches of samples had clean blanks. Therefore, we believe these results are accurate and yet show copper to be at safe levels according to the BLM results.

Table 7 provides statistics for the water quality parameters.

Table 7. Statistics for water quality parameters collected in Swift Creek (n=24 for all parameters)

Parameter	Median	Maximum	Minimum	10^{th} percentile	90^{th} percentile
Temperature (°C)	20	29.8	5.2	5.74	27.4
pH	7.17	8.16	6.51	6.82	7.49
DOC (mg/L)	5.1	6.2	0.44	1.81	5.97
Ca (mg/L)	6.38	8.18	5.01	5.26	7.27
Mg (mg/L)	2.22	2.66	1.74	1.85	2.48
Na (mg/L)	7.46	8.62	4.29	4.95	8.39
K (mg/L)	2.5	3.77	2.08	2.17	3.20
SO_4 (mg/L)	3.85	4.9	3.2	3.7	4.47
Cl (mg/L)	7.25	11	4.9	5.23	9.58
$CaCO_3$ (mg/L)	25.5	35	19	20.3	30.7

A sensitivity analysis was performed, in which the median of each parameter was used in the BLM. Then each parameter was individually changed to the maximum and minimum values observed to see how each parameter altered the outcome (CMC and CCC values). The results of this analysis (Table 8) indicate that, as reported by Augspurger (2012), pH and dissolved organic carbon have the most influence on the results of the model.

Table 8. Results of sensitivity analysis of Swift Creek water quality data in the BLM analysis of water quality criteria for copper. Dissolved organic carbon and pH (shaded) are the parameters with the most influence on the model output.

	CMC (ug/L)	CCC (ug/L)	% Deviation from Median CCC
All medians	**12.7823**	**7.9393**	
max T	13.1127	8.1445	2.6
min T	12.5694	7.8071	-1.7
max pH	42.5758	26.4446	233.1
min pH	4.0797	2.5339	-68.1
max DOC	15.6736	9.7352	22.6
min DOC	1.0844	0.6735	-91.5
max Ca	12.6425	7.8525	-1.1
min Ca	12.938	8.036	1.2
max Mg	12.7727	7.9334	-0.1
min Mg	12.795	7.9472	0.1
max Na	12.957	8.0478	1.4
min Na	12.2739	7.6235	-4.0
max K	12.7569	7.9235	-0.2
min K	12.7823	7.9393	0.0
max SO4	12.7569	7.9235	-0.2
min SO4	12.7918	7.9452	0.1
max Cl	12.7124	7.8959	-0.5
min Cl	12.8172	7.961	0.3
max Alk	12.6806	7.8762	-0.8
min Alk	12.8458	7.9788	0.5

3.4. USGS and City of Raleigh Water Quality Monitoring

There are limited datasets available with which to compare the information generated in this study. The data that are available include City of Raleigh and USGS datasets that cover some of these parameters to varying degrees. The most common parameters that are monitored regularly include temperature, pH, and ammonia. The City of Raleigh has been monitoring water quality conditions below Lake Benson since 2009, corresponding to the opening of the Dempsey E. Benton Water Treatment Plant. A USGS gauge located below Lake Benson monitored water quality from 1989 to 1995 and then again from 2005 to 2011 (Figure 1). Analysis of ammonia and copper was performed using the available data from these organizations (Appendix C).

The City of Raleigh monitoring program includes collections measuring temperature, pH, DO, conductivity, fecal coliform, turbidity, ammonia, total nitrogen, and total phosphorous. The City monitors these parameters at a number of locations, in coordination with other local non-profits, including five stations in the Lower SCW. Though this information is broken down by site, it is apparent that measurements are fairly consistent throughout the watershed. During monthly sampling beginning August 2009 and continuing through the present, no sample exceeded the event-specific acute or chronic criteria according to USEPA 2013 recommendations at stations J4500000, J4510000, J4511000, and J4520000 for ammonia. Sampling for station J4580000 took place between May 2012 and present, with no sample exceeding the event-specific acute or chronic criteria according to USEPA 2013 recommendations.

The USGS station (02087701) collected water quality data, including temperature, pH, DO, ammonia, hardness, and copper, among other parameters. Ammonia was measured approximately four times per year between April and November. During this period, two samples exceeded the event-specific chronic criteria, according to USEPA 2013 recommendations (on August 30, 2006 and August 20, 2009). The recommended acute criteria was not exceeded at this station during the sampling period. This gauge also collected some hardness and copper data. Copper was measured above the NCDWR recommended event-specific chronic standard thirteen times during the sampling period, and was measured above the event-specific acute standard seven times during the sampling period (Appendix C). When the BLM is used to derive acute and chronic water quality standards, however, there is only one day on which the chronic standard is exceeded (April 15, 2010, Table 9). Interestingly, station 02087701 is directly downstream of the Lake Benson dam and the Dempsey E. Benton WTP (Figure 1), though the WTP was constructed in 2010, so it does not explain all of the elevated copper levels in Swift Creek during this sampling period.

Table 9. USGS Gauge 02087701 BLM results

Sample Date	Cu (ug/L)	CMC	CCC
10/18/1989	0.96	5.6969	3.5384
6/20/1990	2.88	23.4103	14.5406
8/14/1990	2.88	82.864	51.4683
9/5/1990	5.76	37.8734	23.5239
9/5/1990	2.88	33.2663	20.6623
10/24/1990	1.92	9.157	5.6876
4/25/1991	2.88	7.1966	4.4699
6/11/1991	1.92	134.4316	83.4979
7/23/1991	1.92	26.7688	16.6266
8/6/1991	3.84	20.0361	12.4448
9/17/1991	2.88	14.606	9.0721
4/16/1992	4.8	22.8607	14.1992
6/2/1992	0.96	15.1239	9.3938
8/13/1992	1.92	15.2669	9.4826
10/15/1992	0.96	30.4576	18.9178
4/26/1993	1.92	49.5023	30.7468
6/25/1993	1.92	8.0672	5.0107
8/4/1993	0.96	15.788	9.8062
10/14/1993	0.96	12.9189	8.0242
11/15/1993	0.96	15.7785	9.8003
4/22/1994	1.92	13.6179	8.4583
6/21/1994	1.92	19.6611	12.2119
8/2/1994	1.92	10.1102	6.2796
12/6/1994	3.84	12.5599	7.8012
5/1/1995	1.92	19.1845	11.9159
6/16/1995	1.92	8.9187	5.5396
10/19/2005	0.768	18.8636	11.7165
4/20/2006	1.248	7.7272	4.7995
10/15/2009	2.592	9.2269	5.731
4/15/2010	8.352*	10.2277	6.3526
10/14/2010	1.728	15.5847	9.6799
4/25/2011	1.344	11.0157	6.842

* Denotes copper exceeding BLM-derived chronic standard.

4.0 CONCLUSION

Both ammonia and copper have been detected in Swift Creek during the sampling period from November 2014 to July 2015. These parameters have been identified as the most significant toxicants to freshwater mussels (USEPA 2008), and the detection of them is cause for concern if detected at concentrations in excess of those thought to be safe for mussels. Whether or not the levels of ammonia and copper are high enough to be detrimental to mussels is still in question. To fully answer the question of whether water quality conditions in Swift Creek are harmful to DWM, long-term toxicity analysis on DWM analyzing growth, survival, and reproduction is needed. In the absence of that data, similar analysis on other species of the same genus and/or associate species could be done instead. Such analysis is outside the scope of this report.

Considering that mussels still exist in Swift Creek suggests that they are not severely impacted by water quality conditions. Population trend analysis, however, suggests that the overall mussel fauna has been in a slow decline since the early 1990's when periodic monitoring began. This decline coincides with land use changes during this period in the SCW, most notably with increases in residential and commercial development (Catena 2014).

Copper concentrations in Swift Creek appear to be mostly dependent on organic carbon and pH. Since the potential for toxicity can be determined by measuring only a few additional water quality parameters, monitoring could continue at less cost into the future to examine how mussel populations respond to changing water quality conditions. Studying the watershed for less than a year cannot provide a full assessment of the relationship between water quality and mussel populations. Long-term monitoring is needed to get a clearer picture of this relationship.

Ammonia concentrations do not appear to be of concern in Swift Creek, with some elevated concentrations limited to directly below Lake Benson. The long-term monitoring of Swift Creek by the USGS has demonstrated that event-specific criteria for ammonia are rarely exceeded. Monitoring efforts, however, could be improved to fill in gaps and better understand how to best reduce ammonia contamination.

Other pollutants that were measured, including some heavy metals, did not appear to be at toxic levels to aquatic organisms. As has been discussed, metal toxicity is more complex than just a simple measurement of water conditions at a single sampling. Future analysis may be possible, particularly with the use of the BLM, to determine toxicity to freshwater mussels and other aquatic organisms.

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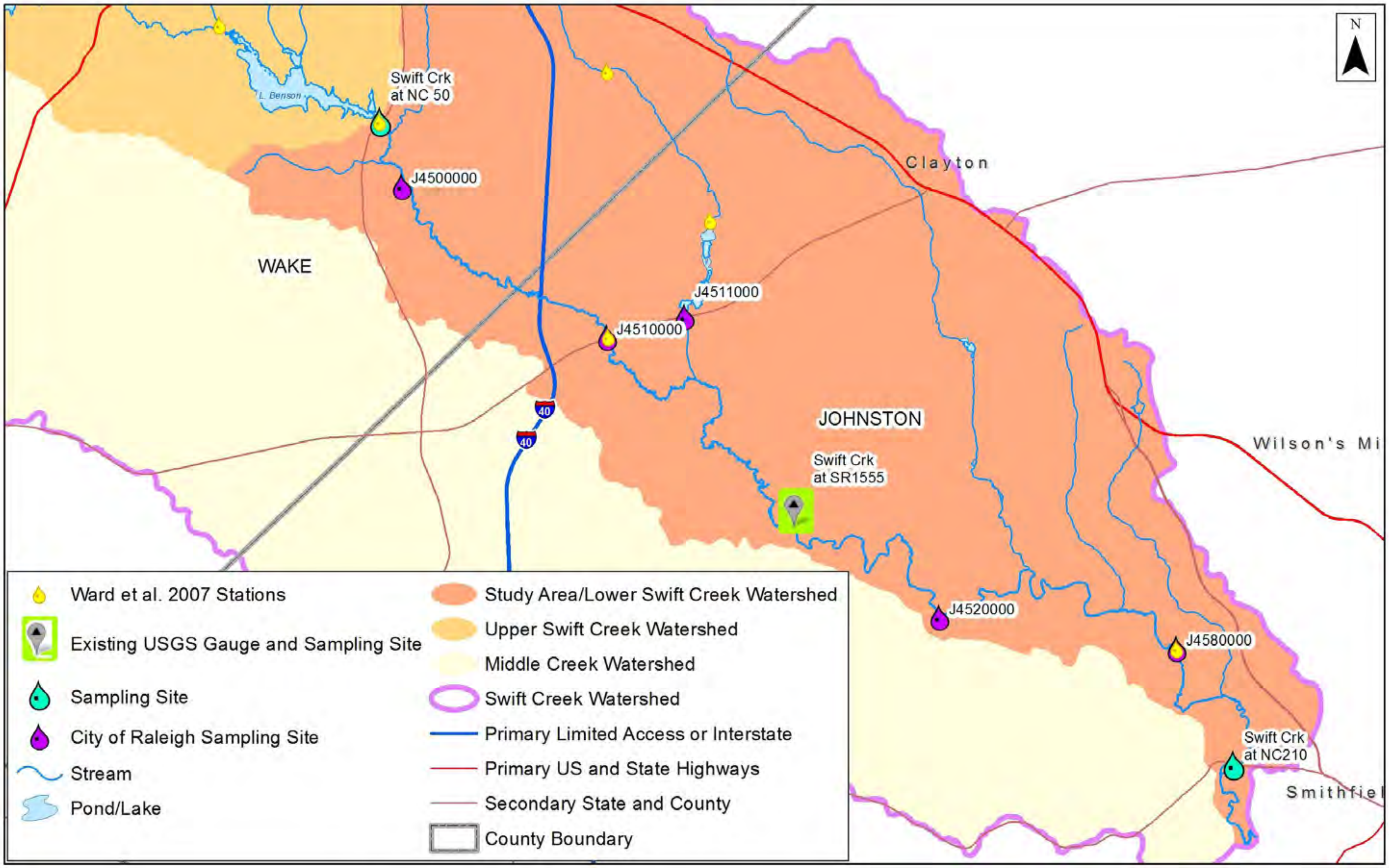

The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 2

Water Quality Monitoring Stations
Lower Swift Creek Watershed

Wake & Johnston Counties, North Carolina

Date: August 2015

Scale: 0 0.5 1 Miles

Job No.: 1175

Figure 1

Appendix A – 2014-2015 Water Quality Laboratory Results

NC 50 (Benson Road) below Lake Benson in Garner								
Flow:	Baseflow (30 cfs)	High (50 cfs)	Baseflow (100 cfs)	Baseflow (47 cfs)	Low Flow (39 cfs)	Low Flow (11cfs)	High Flow (53 cfs)	High Flow (127 cfs)
Date of Sampling	11/4/2014	11/19/2014	2/6/2015	4/7/2015	5/7/2015	6/9/2015	7/1/2015	7/10/2015
Analyte	Result	Result	Result	Result	Result	Result	Result	Result
Cadmium (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	5.54	6.01	5.01	7	6.31	8.18	7.47	7.37
Copper (total, ug/L)	1.98	ND	2.46	5.91	2.03	5.53	ND	ND
Lead (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	1.74	1.91	1.74	2.29	1.97	2.4	2.4	2.37
Nickel (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Potassium (mg/L)	3.25	3.25	2.42	2.57	2.5	2.99	2.72	2.48
Sodium (mg/L)	4.35	4.76	4.29	8.62	7.01	8.24	7.8	7.76
Zinc (ug/L)	6.33	6.14	ND	ND	ND	16.7	4.09	ND
Ammonia (mg/L)	0.063	0.25	ND	ND	0.051	0.072	ND	0.069
Chloride (mg/L)	5	7.2	4.9	11	8.8	9.9	9.7	9.3
Sulfate (mg/L)	3.8	3.7	4.5	4.9	4.2	4.1	4.1	4
Total Alkalinity (mg/L)	26	26	20	29	19	30	27	23
Total Organic Carbon (mg/L)	6.2	0.79	5.1	6.1	6	5.9	5.9	5.9
Dissolved Copper (ug/L)	ND	1.96	2.24	4.92	1.75	2.79	ND	ND
Temperature (°C)	14.8	9.1	6.6	18.4	22.5	25.7	29.7	29.8
DO (%)	102.2	96.3	110	106.4	66	52.1	89.2	68.8
DO (mg/L)	10.2	11.29	13.25	9.9	5.72	4.16	6.82	5.25
Conductivity (us/cm)	71.5	73.7	65.1	93.2	90.9	103.8	9.99	96.8
pH	6.51	7.22	7.15	7.32	6.86	7.01	7.42	7.17

SR 1555 (Barber Mill Rd) in Clayton								
Flow:	High (50 cfs)	Baseflow (38 cfs)	Baseflow (100 cfs)	Baseflow (47 cfs)	Low flow (39 cfs)	Low Flow (11cfs)	High Flow (53 cfs)	High Flow (127 cfs)
Date of Sampling	11/19/2014	12/16/2014	2/6/2015	4/7/2015	5/7/2015	6/9/2015	7/1/2015	7/10/2015
Analyte	Result	Result	Result	Result	Result	Result	Result	Result
Cadmium (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	6.16	5.94	5.17	6.55	5.46	6.87	6.89	6.02
Copper (total, ug/L)	ND	ND	2.75	4.13	ND	1.69	ND	ND
Lead (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	2.2	2.03	1.82	2.23	2.03	2.18	2.35	2.13
Nickel (ug/L)	ND	ND	ND	ND	ND	2.02	ND	ND
Potassium (mg/L)	3.77	2.88	2.19	2.33	2.16	2.08	2.55	2.4
Sodium (mg/L)	7.79	6.91	5.5	8.04	7.5	8.52	7.55	7.34
Zinc (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Ammonia (mg/L)	0.35	ND	ND	ND	0.078	ND	0.073	0.06
Chloride (mg/L)	5.2	6.1	5.3	8.3	7.3	7.2	8.5	8
Sulfate (mg/L)	3.7	4	4.4	4	3.8	3.2	3.8	3.8
Total Alkalinity (mg/L)	26	20	22	30	21	32	29	22
Total Organic Carbon (mg/L)	0.46	4.2	4.3	4.8	4.9	4.2	5.3	5.2
Dissolved Copper (ug/L)	ND	ND	ND	4.17	ND	ND	ND	ND
Temperature (°C)	5.9		5.2	17.7	21	24	26.2	27.7
DO (%)	95.7		106.7	96.8	89.6	92.6	84.4	73.2
DO (mg/L)	11.87		13.35	9.2	8	7.8	6.74	5.77
Conductivity (us/cm)	92.1		70.2	78.4	84.9	90.5	96.1	84.5
pH	7.23		7.28	7.23	6.81	7.05	7.14	7.02

NC 210 upstream of Neuse River in Smithfield								
Flow:	Baseflow (30 cfs)	High (50 cfs)	Baseflow (100 cfs)	Baseflow (47 cfs)	Low Flow (39 cfs)	Low Flow (11cfs)	High Flow (53 cfs)	High Flow (127 cfs)
Date of Sampling	11/4/2014	11/19/2014	2/6/2015	4/7/2015	5/7/2015	6/9/2015	7/1/2015	7/10/2015
Analyte	Result	Result	Result	Result	Result	Result	Result	Result
Cadmium (mg/L)	ND	ND	ND	ND	ND	0.36	ND	ND
Calcium (mg/L)	6.44	6.46	5.05	6.85	5.79	7.03	7	5.59
Copper (total, ug/L)	ND	ND	ND	4.65	2.01	1.74	ND	1.61
Lead (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	2.48	2.47	1.95	2.66	2.27	2.49	2.42	2.15
Nickel (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND
Potassium (mg/L)	2.86	3.08	2.11	2.46	2.36	2.31	2.65	2.5
Sodium (mg/L)	6.95	7.42	5.39	8.46	7.07	8.03	7.64	6.62
Zinc (ug/L)	3.8	ND	ND	ND	ND	ND	ND	ND
Ammonia (mg/L)	ND	0.58	ND	ND	0.06	ND	ND	ND
Chloride (mg/L)	6.7	7.2	6	8.5	7.1	7.5	8.5	7
Sulfate (mg/L)	3.7	3.7	4.6	4.2	3.8	3.3	3.9	3.7
Total Alkalinity (mg/L)	31	35	22	26	25	23	23	22
Total Organic Carbon (mg/L)	4.8	0.44	4.4	5.1	5.3	4.3	5.7	5.3
Dissolved Copper (ug/L)	ND	ND	ND	4.13	ND	1.66	ND	ND
Temperature (°C)	10	5.7	5.2	17.6	20	23.6	25.5	26.1
DO (%)	99.4	102.6	104.1	93.35	84.9	73.5	85.7	75.2
DO (mg/L)	11.18	12.8	13.08	8.72	7.6	6.16	6.9	6.16
Conductivity (us/cm)	92.1	94.8	72.8	86.6	87.5	96.2	94.9	80
pH	6.56	8.16	7.56	7.38	7.12	7.47	6.98	7.5

Appendix B – ENCO Laboratory Reports

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Thursday, November 20, 2014
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C414241

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Tuesday, November 4, 2014.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: Swift Creek 210 | **Lab ID: C414241-01** | **Sampled: 11/04/14 14:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	12/02/14	11/06/14	07:22	11/06/14 14:51
EPA 350.1	12/02/14	11/07/14	08:56	11/07/14 13:24
EPA 6010C	05/03/15	11/11/14	14:04	11/13/14 10:33
SM 5310B-2000	12/02/14	11/12/14	08:06	11/12/14 15:00

Client ID: Swift Creek 210 | **Lab ID: C414241-01RE1** | **Sampled: 11/04/14 14:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 310.2	11/18/14	11/05/14	09:04	11/05/14 13:23

Client ID: Swift Creek 50 | **Lab ID: C414241-02** | **Sampled: 11/04/14 13:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	12/02/14	11/06/14	07:22	11/06/14 15:59
EPA 350.1	12/02/14	11/07/14	08:56	11/07/14 13:26
EPA 6010C	05/03/15	11/11/14	14:04	11/13/14 10:35
SM 5310B-2000	12/02/14	11/12/14	08:06	11/12/14 15:00

Client ID: Swift Creek 50 | **Lab ID: C414241-02RE1** | **Sampled: 11/04/14 13:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 310.2	11/18/14	11/05/14	09:04	11/05/14 13:24

Client ID: Swift Creek 210 Dissolved | **Lab ID: C414241-03** | **Sampled: 11/04/14 14:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	05/03/15	11/11/14	14:04	11/13/14 10:38

Client ID: Swift Creek 50 Dissolved | **Lab ID: C414241-04** | **Sampled: 11/04/14 13:05** | **Received: 11/04/14 14:48**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	05/03/15	11/11/14	14:04	11/13/14 10:40

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SAMPLE DETECTION SUMMARY

Client ID: Swift Creek 210 **Lab ID: C414241-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	6440		39.0	100	ug/L	EPA 6010C	R-05
Chloride	6.7		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2480		23.0	100	ug/L	EPA 6010C	R-05
Potassium - Total	2860		150	500	ug/L	EPA 6010C	R-05
Sodium - Total	6950		400	500	ug/L	EPA 6010C	R-05
Sulfate as SO4	3.7	J	2.9	5.0	mg/L	EPA 300.0	
Total Organic Carbon - Dissolved	4.8		0.32	1.0	mg/L	SM 5310B-2000	
Zinc - Total	3.80	JB	3.80	10.0	ug/L	EPA 6010C	J-01, R-05

Client ID: Swift Creek 210 **Lab ID: C414241-01RE1**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Total Alkalinity as CaCO3	31		14	15	mg/L	EPA 310.2	

Client ID: Swift Creek 50 **Lab ID: C414241-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.063	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	5540		39.0	100	ug/L	EPA 6010C	
Chloride	5.0		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	1.98	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	1740		23.0	100	ug/L	EPA 6010C	
Potassium - Total	3250		150	500	ug/L	EPA 6010C	
Sodium - Total	4350		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.8	J	2.9	5.0	mg/L	EPA 300.0	
Total Organic Carbon - Dissolved	6.2		0.32	1.0	mg/L	SM 5310B-2000	
Zinc - Total	6.33	JB	3.80	10.0	ug/L	EPA 6010C	J-01

Client ID: Swift Creek 50 **Lab ID: C414241-02RE1**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Total Alkalinity as CaCO3	26		14	15	mg/L	EPA 310.2	

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ANALYTICAL RESULTS

Description: Swift Creek 210 **Lab Sample ID:** C414241-01 **Received:** 11/04/14 14:48

Matrix: Water **Sampled:** 11/04/14 14:05 **Work Order:** C414241

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Calcium [7440-70-2]^	**6440**		ug/L	1	39.0	100	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Magnesium [7439-95-4]^	**2480**		ug/L	1	23.0	100	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Potassium [7440-09-7]^	**2860**		ug/L	1	150	500	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Sodium [7440-23-5]^	**6950**		ug/L	1	400	500	4K11023	EPA 6010C	11/13/14 10:33	JDH	R-05
Zinc [7440-66-6]^	**3.80**	JB	ug/L	1	3.80	10.0	4K11023	EPA 6010C	11/13/14 10:33	JDH	J-01, R-05

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	4K07017	EPA 350.1	11/07/14 13:24	SHA	
Chloride [16887-00-6]^	**6.7**		mg/L	1	2.2	5.0	4K06002	EPA 300.0	11/06/14 14:51	CV	
Sulfate as SO4 [14808-79-8]^	**3.7**	J	mg/L	1	2.9	5.0	4K06002	EPA 300.0	11/06/14 14:51	CV	
Total Alkalinity as CaCO3 [471-34-1]^	**31**		mg/L	1	14	15	4K05003	EPA 310.2	11/05/14 13:23	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.8**		mg/L	1	0.32	1.0	4K12005	SM 5310B-2000	11/12/14 15:00	RSA	

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ANALYTICAL RESULTS

Description: Swift Creek 50 **Lab Sample ID:** C414241-02 **Received:** 11/04/14 14:48
Matrix: Water **Sampled:** 11/04/14 13:05 **Work Order:** C414241
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Calcium [7440-70-2]^	**5540**		ug/L	1	39.0	100	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Copper [7440-50-8]^	**1.98**	J	ug/L	1	1.60	10.0	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Magnesium [7439-95-4]^	**1740**		ug/L	1	23.0	100	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Potassium [7440-09-7]^	**3250**		ug/L	1	150	500	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Sodium [7440-23-5]^	**4350**		ug/L	1	400	500	4K11023	EPA 6010C	11/13/14 10:35	JDH	
Zinc [7440-66-6]^	**6.33**	JB	ug/L	1	3.80	10.0	4K11023	EPA 6010C	11/13/14 10:35	JDH	J-01

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.063**	J	mg/L	1	0.045	0.10	4K07017	EPA 350.1	11/07/14 13:26	SHA	
Chloride [16887-00-6]^	**5.0**		mg/L	1	2.2	5.0	4K06002	EPA 300.0	11/06/14 15:59	CV	
Sulfate as SO4 [14808-79-8]^	**3.8**	J	mg/L	1	2.9	5.0	4K06002	EPA 300.0	11/06/14 15:59	CV	
Total Alkalinity as CaCO3 [471-34-1]^	**26**		mg/L	1	14	15	4K05003	EPA 310.2	11/05/14 13:24	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**6.2**		mg/L	1	0.32	1.0	4K12005	SM 5310B-2000	11/12/14 15:00	RSA	

Description: Swift Creek 210 Dissolved **Lab Sample ID:** C414241-03 **Received:** 11/04/14 14:48
Matrix: Water **Sampled:** 11/04/14 14:05 **Work Order:** C414241
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K11023	EPA 6010C	11/13/14 10:38	JDH	

Description: Swift Creek 50 Dissolved **Lab Sample ID:** C414241-04 **Received:** 11/04/14 14:48
Matrix: Water **Sampled:** 11/04/14 13:05 **Work Order:** C414241
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K11023	EPA 6010C	11/13/14 10:40	JDH	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K11023 - EPA 3005A

Blank (4K11023-BLK1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 09:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	2.10	U	10.0	ug/L							
Magnesium	23.0	U	100	ug/L							
Nickel	**9.60**	**J**	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	**4.00**	**J**	10.0	ug/L							

LCS (4K11023-BS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 09:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.2		1.00	ug/L	20.0		106	80-120			
Calcium	2140		100	ug/L	2000		107	80-120			
Copper	201		10.0	ug/L	200		101	80-120			
Lead	210		10.0	ug/L	200		105	80-120			
Magnesium	2090		100	ug/L	2000		105	80-120			
Nickel	213	B	10.0	ug/L	200		106	80-120			
Potassium	10600		500	ug/L	10000		106	80-120			
Sodium	10600		500	ug/L	10000		106	80-120			
Zinc	218	B	10.0	ug/L	200		109	80-120			

Matrix Spike (4K11023-MS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:00

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.8		1.00	ug/L	20.0	0.360 U	104	75-125			
Calcium	9870		100	ug/L	2000	7880	100	75-125			
Copper	199		10.0	ug/L	200	1.60 U	99	75-125			
Lead	208		10.0	ug/L	200	2.10 U	104	75-125			
Magnesium	4720		100	ug/L	2000	2690	102	75-125			
Nickel	211	B	10.0	ug/L	200	1.80 U	105	75-125			
Potassium	14200		500	ug/L	10000	3590	106	75-125			
Sodium	36500		500	ug/L	10000	26000	105	75-125			
Zinc	217	B	10.0	ug/L	200	3.80 U	108	75-125			

Matrix Spike Dup (4K11023-MSD1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:02

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.8		1.00	ug/L	20.0	0.360 U	104	75-125	0.07	20	
Calcium	9340		100	ug/L	2000	7880	73	75-125	6	20	QM-05
Copper	201		10.0	ug/L	200	1.60 U	100	75-125	1	20	
Lead	207		10.0	ug/L	200	2.10 U	104	75-125	0.4	20	
Magnesium	4520		100	ug/L	2000	2690	92	75-125	4	20	
Nickel	210	B	10.0	ug/L	200	1.80 U	105	75-125	0.2	20	
Potassium	13600		500	ug/L	10000	3590	100	75-125	4	20	
Sodium	34500		500	ug/L	10000	26000	85	75-125	6	20	
Zinc	217	B	10.0	ug/L	200	3.80 U	108	75-125	0.04	20	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K11023 - EPA 3005A - Continued

Post Spike (4K11023-PS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:05

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0194		0.00100	mg/L	0.0200	0.000144	96	80-120			
Calcium	9.18		0.100	mg/L	2.00	7.88	65	80-120			QM-08
Copper	0.183		0.0100	mg/L	0.200	0.000187	92	80-120			
Lead	0.193		0.0100	mg/L	0.200	-0.000900	96	80-120			
Magnesium	4.50		0.100	mg/L	2.00	2.69	91	80-120			
Nickel	0.199	B	0.0100	mg/L	0.200	-0.000247	99	80-120			
Potassium	12.7		0.500	mg/L	10.0	3.59	91	80-120			
Sodium	33.6		0.500	mg/L	10.0	26.0	76	80-120			QM-08
Zinc	0.203	B	0.0100	mg/L	0.200	0.00329	100	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K11023 - EPA 3005A

Blank (4K11023-BLK1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 09:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

Blank (4K11023-BLK2) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 09:52

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (4K11023-BS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 09:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	201		10.0	ug/L	200		101	80-120			

Matrix Spike (4K11023-MS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:00

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	199		10.0	ug/L	200	1.60 U	99	75-125			

Matrix Spike Dup (4K11023-MSD1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:02

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	201		10.0	ug/L	200	1.60 U	100	75-125	1	20	

Post Spike (4K11023-PS1) Prepared: 11/11/2014 14:04 Analyzed: 11/13/2014 10:05

Source: C414425-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.183		0.0100	mg/L	0.200	0.000187	92	80-120			

Classical Chemistry Parameters - Quality Control

Batch 4K05003 - NO PREP

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4K05003 - NO PREP - Continued

Blank (4K05003-BLK1) Prepared: 11/05/2014 09:04 Analyzed: 11/05/2014 12:09

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (4K05003-BS1) Prepared: 11/05/2014 09:04 Analyzed: 11/05/2014 12:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	100		15	mg/L	100		103	80-120			

Matrix Spike (4K05003-MS1) Prepared: 11/05/2014 09:04 Analyzed: 11/05/2014 12:12

Source: C413508-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	680		75	mg/L	200	490	99	80-120			

Matrix Spike Dup (4K05003-MSD1) Prepared: 11/05/2014 09:04 Analyzed: 11/05/2014 12:14

Source: C413508-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	650		75	mg/L	200	490	82	80-120	5	25	

Batch 4K06002 - NO PREP

Blank (4K06002-BLK1) Prepared: 11/06/2014 07:22 Analyzed: 11/06/2014 08:36

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (4K06002-BS1) Prepared: 11/06/2014 07:22 Analyzed: 11/06/2014 09:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	48		5.0	mg/L	50.0		96	90-110			
Sulfate as SO4	47		5.0	mg/L	50.0		93	90-110			

Matrix Spike (4K06002-MS1) Prepared: 11/06/2014 07:22 Analyzed: 11/06/2014 11:27

Source: C413477-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	30		5.0	mg/L	20.0	12	95	90-110			
Sulfate as SO4	31		5.0	mg/L	20.0	13	90	90-110			

Matrix Spike Dup (4K06002-MSD1) Prepared: 11/06/2014 07:22 Analyzed: 11/06/2014 12:18

Source: C413477-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	31		5.0	mg/L	20.0	12	97	90-110	1	10	
Sulfate as SO4	31		5.0	mg/L	20.0	13	92	90-110	1	10	

Batch 4K07017 - NO PREP

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4K07017 - NO PREP - Continued

Blank (4K07017-BLK1) Prepared: 11/07/2014 08:56 Analyzed: 11/07/2014 12:26

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (4K07017-BS1) Prepared: 11/07/2014 08:56 Analyzed: 11/07/2014 12:32

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	1.0		0.10	mg/L	0.997		101	90-110			

Matrix Spike (4K07017-MS1) Prepared: 11/07/2014 08:56 Analyzed: 11/07/2014 12:36

Source: C411942-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	11		1.0	mg/L	3.98	6.6	100	90-110			

Matrix Spike Dup (4K07017-MSD1) Prepared: 11/07/2014 08:56 Analyzed: 11/07/2014 12:38

Source: C411942-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	11		1.0	mg/L	3.98	6.6	100	90-110	0.2	10	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 4K12005 - NO PREP

Blank (4K12005-BLK1) Prepared: 11/12/2014 08:06 Analyzed: 11/12/2014 15:00

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.32	U	1.0	mg/L							

LCS (4K12005-BS1) Prepared: 11/12/2014 08:06 Analyzed: 11/12/2014 15:00

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	38		1.0	mg/L	40.0		96	85-115			

Matrix Spike (4K12005-MS1) Prepared: 11/12/2014 08:06 Analyzed: 11/12/2014 15:00

Source: A406493-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	34		1.0	mg/L	40.0	2.0	80	85-115			QM-07

Matrix Spike Dup (4K12005-MSD1) Prepared: 11/12/2014 08:06 Analyzed: 11/12/2014 15:00

Source: A406493-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	33		1.0	mg/L	40.0	2.0	77	85-115	3	21	QM-07

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
J-01	Result is estimated due to positive results in the associated method blank.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-07	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
QM-08	Post-digestion spike did not meet method requirements due to confirmed matrix effects (dilution test).
R-05	The sample was diluted due to the presence of high levels of non-target analytes resulting in elevated reporting limits.

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD www.encolabs.com

10775 Central Port Dr.
Orlando, FL 32824
(407) 826-5314 Fax (407) 850-6945

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102-A Woodwinds Industrial Ct.
Cary, NC 27511
(919) 467-3090 Fax (919) 467-3515

Page ____ of ____

Client Name: The Catena Group (TH015)	Project Number: [none]
Address: 410-B Millstone Drive	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough, NC 27278	PO # / Billing Info:
Tel: (919) 417-2732 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print): Nancy Scott	Billing Contact: Nancy Scott
Sampler(s) Signature: N Scott	Site Location / Time Zone:

Requested Turnaround Times
Note : Rush requests subject to acceptance by the facility
___ Standard
___ Expedited
Due ___/___/___

Lab Workorder: C414241

Requested Analyses / Preservation (See Codes) (Combine as necessary)

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2,Chloride 300	Ammonia 350.1	Ca,Cd,Cu,K,Mg,Na,Ni,Pb,Zn	Cd/F	Sulfate 300	TOC SM5310B Dissolved					Sample Comments
	Swift Creek 210	11-4-14	1305		WA	6	X	X	X	X	X	X					
	" 50.	11-4-14	1305		WA	6	X	X	X	X	X	X					

<-- Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By: N Scott	Date/Time: 11/4/14 2:45	Received By: [signature]	Date/Time: 11-4-14 1448
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By	Date/Time
		Cooler #'s & Temps on Receipt: ~~19.8c~~ 19.8c		Condition Upon Receipt: ✓ Acceptable ___ Unacceptable	

Matrix : GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments) **Preservation:** I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note : All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist

ENCO Laboratories
Accurate. Timely. Responsive. Innovative.

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Friday, December 12, 2014
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C414195

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Wednesday, November 19, 2014.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott
Project Manager
Enclosure(s)

PROJECT NARRATIVE

Date: December 12, 2014
Client: The Catena Group (TH015)
Project: Swift Creek Water Quality
Lab ID: C414195

Overview

This report is an amendment to the original report for this work order. This report was revised to remove Mn results and report Mg.

Environmental Conservation Laboratories, Inc. (ENCO) analyzed all submitted samples in accordance with the methods referenced in the laboratory report. Any particular difficulties encountered during sample handling by ENCO are discussed in the QC Remarks section below.

Quality Control Samples

No Comments

Quality Control Remarks

No Comments

Other Comments

The analytical data presented in this report are consistent with the methods as referenced in the analytical report. Any exceptions or deviations are noted in the QC remarks section of this narrative or in the Flags/Notes and Definitions section of the report.

Released By:
Environmental Conservation Laboratories, Inc.

Bill Scott
Project Manager

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC-210 | **Lab ID: C414195-01** | **Sampled: 11/19/14 09:45** | **Received: 11/19/14 11:20**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	12/17/14	11/21/14	09:08	11/25/14 00:33
EPA 310.2	12/03/14	11/25/14	08:44	11/25/14 11:17
EPA 350.1	12/17/14	11/21/14	09:21	11/21/14 10:21
EPA 6010C	05/18/15	11/20/14	09:17	11/21/14 12:43
EPA 6010C	05/18/15	11/25/14	18:27	12/03/14 09:03
SM 5310B-2000	12/17/14	11/21/14	14:06	11/21/14 16:57

Client ID: SR-1555 | **Lab ID: C414195-02** | **Sampled: 11/19/14 10:15** | **Received: 11/19/14 11:20**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	12/17/14	11/21/14	09:08	11/25/14 00:50
EPA 310.2	12/03/14	11/25/14	08:44	11/25/14 11:18
EPA 350.1	12/17/14	11/21/14	09:21	11/21/14 10:28
EPA 6010C	05/18/15	11/20/14	09:17	11/21/14 12:53
EPA 6010C	05/18/15	11/25/14	18:27	12/03/14 09:15
SM 5310B-2000	12/17/14	11/21/14	14:06	11/21/14 16:57

Client ID: NC-50 | **Lab ID: C414195-03** | **Sampled: 11/19/14 10:50** | **Received: 11/19/14 11:20**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	12/17/14	11/21/14	09:08	11/25/14 01:07
EPA 310.2	12/03/14	11/25/14	08:44	11/25/14 11:19
EPA 350.1	12/17/14	11/21/14	09:21	11/21/14 10:34
EPA 6010C	05/18/15	11/20/14	09:17	11/21/14 12:56
EPA 6010C	05/18/15	11/25/14	18:27	12/03/14 09:18
SM 5310B-2000	12/17/14	11/21/14	14:06	11/21/14 16:57

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SAMPLE DETECTION SUMMARY

Client ID: NC-210 **Lab ID: C414195-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.58		0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6460		39.0	100	ug/L	EPA 6010C	
Chloride	7.2		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2470		23.0	100	ug/L	EPA 6010C	
Potassium - Total	3080		150	500	ug/L	EPA 6010C	
Sodium - Total	7420		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.7	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	35		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	0.44	J	0.32	1.0	mg/L	SM 5310B-2000	

Client ID: SR-1555 **Lab ID: C414195-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.35		0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6160		39.0	100	ug/L	EPA 6010C	
Chloride	5.2		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2200		23.0	100	ug/L	EPA 6010C	
Potassium - Total	3770		150	500	ug/L	EPA 6010C	
Sodium - Total	7790		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.7	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	26		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	0.46	J	0.32	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C414195-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.25		0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6010		39.0	100	ug/L	EPA 6010C	
Chloride	7.2		2.2	5.0	mg/L	EPA 300.0	
Copper - Dissolved	1.96	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	1910		23.0	100	ug/L	EPA 6010C	
Potassium - Total	3250		150	500	ug/L	EPA 6010C	
Sodium - Total	4760		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.7	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	26		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	0.79	J	0.32	1.0	mg/L	SM 5310B-2000	
Zinc - Total	6.14	J	3.80	10.0	ug/L	EPA 6010C	

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ANALYTICAL RESULTS

Description:	NC-210	**Lab Sample ID:**	C414195-01	**Received:**	11/19/14 11:20
Matrix:	Water	**Sampled:**	11/19/14 09:45	**Work Order:**	C414195
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Calcium [7440-70-2]^	**6460**		ug/L	1	39.0	100	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Magnesium [7439-95-4]^	**2470**		ug/L	1	23.0	100	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Potassium [7440-09-7]^	**3080**		ug/L	1	150	500	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Sodium [7440-23-5]^	**7420**		ug/L	1	400	500	4K21043	EPA 6010C	12/03/14 09:03	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	4K21043	EPA 6010C	12/03/14 09:03	JDH	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K20007	EPA 6010C	11/21/14 12:43	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.58**		mg/L	1	0.045	0.10	4K20012	EPA 350.1	11/21/14 10:21	SHA	
Chloride [16887-00-6]^	**7.2**		mg/L	1	2.2	5.0	4K21005	EPA 300.0	11/25/14 00:33	AJB	
Sulfate as SO4 [14808-79-8]^	**3.7**	J	mg/L	1	2.9	5.0	4K21005	EPA 300.0	11/25/14 00:33	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**35**		mg/L	1	14	15	4K25010	EPA 310.2	11/25/14 11:17	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**0.44**	J	mg/L	1	0.32	1.0	4K21035	SM 5310B-2000	11/21/14 16:57	RSA	

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ANALYTICAL RESULTS

Description: SR-1555 **Lab Sample ID:** C414195-02 **Received:** 11/19/14 11:20

Matrix: Water **Sampled:** 11/19/14 10:15 **Work Order:** C414195

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Calcium [7440-70-2]^	**6160**		ug/L	1	39.0	100	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Magnesium [7439-95-4]^	**2200**		ug/L	1	23.0	100	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Potassium [7440-09-7]^	**3770**		ug/L	1	150	500	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Sodium [7440-23-5]^	**7790**		ug/L	1	400	500	4K21043	EPA 6010C	12/03/14 09:15	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	4K21043	EPA 6010C	12/03/14 09:15	JDH	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K20007	EPA 6010C	11/21/14 12:53	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.35**		mg/L	1	0.045	0.10	4K20012	EPA 350.1	11/21/14 10:28	SHA	
Chloride [16887-00-6]^	**5.2**		mg/L	1	2.2	5.0	4K21005	EPA 300.0	11/25/14 00:50	AJB	
Sulfate as SO4 [14808-79-8]^	**3.7**	J	mg/L	1	2.9	5.0	4K21005	EPA 300.0	11/25/14 00:50	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**26**		mg/L	1	14	15	4K25010	EPA 310.2	11/25/14 11:18	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**0.46**	J	mg/L	1	0.32	1.0	4K21035	SM 5310B-2000	11/21/14 16:57	RSA	

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ANALYTICAL RESULTS

Description:	NC-50	**Lab Sample ID:**	C414195-03	**Received:**	11/19/14 11:20
Matrix:	Water	**Sampled:**	11/19/14 10:50	**Work Order:**	C414195
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Calcium [7440-70-2]^	**6010**		ug/L	1	39.0	100	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Magnesium [7439-95-4]^	**1910**		ug/L	1	23.0	100	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Potassium [7440-09-7]^	**3250**		ug/L	1	150	500	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Sodium [7440-23-5]^	**4760**		ug/L	1	400	500	4K21043	EPA 6010C	12/03/14 09:18	JDH	
Zinc [7440-66-6]^	**6.14**	J	ug/L	1	3.80	10.0	4K21043	EPA 6010C	12/03/14 09:18	JDH	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**1.96**	J	ug/L	1	1.60	10.0	4K20007	EPA 6010C	11/21/14 12:56	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.25**		mg/L	1	0.045	0.10	4K20012	EPA 350.1	11/21/14 10:34	SHA	
Chloride [16887-00-6]^	**7.2**		mg/L	1	2.2	5.0	4K21005	EPA 300.0	11/25/14 01:07	AJB	
Sulfate as SO4 [14808-79-8]^	**3.7**	J	mg/L	1	2.9	5.0	4K21005	EPA 300.0	11/25/14 01:07	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**26**		mg/L	1	14	15	4K25010	EPA 310.2	11/25/14 11:19	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**0.79**	J	mg/L	1	0.32	1.0	4K21035	SM 5310B-2000	11/21/14 16:57	RSA	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K21043 - EPA 3005A

Blank (4K21043-BLK1) Prepared: 11/25/2014 18:27 Analyzed: 12/03/2014 08:56

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	2.10	U	10.0	ug/L							
Magnesium	23.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (4K21043-BS1) Prepared: 11/25/2014 18:27 Analyzed: 12/03/2014 09:00

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.9		1.00	ug/L	20.0		100	80-120			
Calcium	2110		100	ug/L	2000		105	80-120			
Copper	195		10.0	ug/L	200		97	80-120			
Lead	198		10.0	ug/L	200		99	80-120			
Magnesium	2040		100	ug/L	2000		102	80-120			
Nickel	201		10.0	ug/L	200		101	80-120			
Potassium	10100		500	ug/L	10000		101	80-120			
Sodium	10300		500	ug/L	10000		103	80-120			
Zinc	203		10.0	ug/L	200		101	80-120			

Matrix Spike (4K21043-MS1) Prepared: 11/25/2014 18:27 Analyzed: 12/03/2014 09:05

Source: C414195-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.2		1.00	ug/L	20.0	0.360 U	101	75-125			
Calcium	8280		100	ug/L	2000	6460	91	75-125			
Copper	198		10.0	ug/L	200	1.60 U	99	75-125			
Lead	203		10.0	ug/L	200	2.10 U	102	75-125			
Magnesium	4440		100	ug/L	2000	2470	98	75-125			
Nickel	203		10.0	ug/L	200	1.80 U	102	75-125			
Potassium	13000		500	ug/L	10000	3080	99	75-125			
Sodium	17400		500	ug/L	10000	7420	100	75-125			
Zinc	206		10.0	ug/L	200	3.80 U	103	75-125			

Matrix Spike Dup (4K21043-MSD1) Prepared: 11/25/2014 18:27 Analyzed: 12/03/2014 09:08

Source: C414195-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.0		1.00	ug/L	20.0	0.360 U	105	75-125	4	20	
Calcium	8440		100	ug/L	2000	6460	99	75-125	2	20	
Copper	197		10.0	ug/L	200	1.60 U	98	75-125	0.3	20	
Lead	204		10.0	ug/L	200	2.10 U	102	75-125	0.3	20	
Magnesium	4480		100	ug/L	2000	2470	100	75-125	0.9	20	
Nickel	210		10.0	ug/L	200	1.80 U	105	75-125	3	20	
Potassium	13300		500	ug/L	10000	3080	103	75-125	3	20	
Sodium	17800		500	ug/L	10000	7420	104	75-125	2	20	
Zinc	214		10.0	ug/L	200	3.80 U	107	75-125	4	20	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K21043 - EPA 3005A - Continued

Post Spike (4K21043-PS1) Prepared: 11/25/2014 18:27 Analyzed: 12/03/2014 09:10

Source: C414195-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0190		0.00100	mg/L	0.0200	5.18E-5	95	80-120			
Calcium	8.15		0.100	mg/L	2.00	6.46	84	80-120			
Copper	0.181		0.0100	mg/L	0.200	-0.000376	91	80-120			
Lead	0.182		0.0100	mg/L	0.200	-0.000727	91	80-120			
Magnesium	4.31		0.100	mg/L	2.00	2.47	92	80-120			
Nickel	0.190		0.0100	mg/L	0.200	-0.000524	95	80-120			
Potassium	12.2		0.500	mg/L	10.0	3.08	92	80-120			
Sodium	16.5		0.500	mg/L	10.0	7.42	91	80-120			
Zinc	0.195		0.0100	mg/L	0.200	0.00190	96	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 4K20007 - EPA 3005A

Blank (4K20007-BLK2) Prepared: 11/20/2014 09:17 Analyzed: 11/21/2014 11:29

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (4K20007-BS1) Prepared: 11/20/2014 09:17 Analyzed: 11/21/2014 11:32

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	200		10.0	ug/L	200		100	80-120			

Matrix Spike (4K20007-MS1) Prepared: 11/20/2014 09:17 Analyzed: 11/21/2014 12:19

Source: C414012-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	207		10.0	ug/L	200	1.60 U	104	75-125			

Matrix Spike Dup (4K20007-MSD1) Prepared: 11/20/2014 09:17 Analyzed: 11/21/2014 12:21

Source: C414012-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	206		10.0	ug/L	200	1.60 U	103	75-125	0.6	20	

Post Spike (4K20007-PS1) Prepared: 11/20/2014 09:17 Analyzed: 11/21/2014 12:24

Source: C414012-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.186		0.0100	mg/L	0.200	0.00104	92	80-120			

Classical Chemistry Parameters - Quality Control

Batch 4K20012 - NO PREP

Blank (4K20012-BLK1) Prepared: 11/21/2014 09:21 Analyzed: 11/21/2014 10:17

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4K20012 - NO PREP - Continued

LCS (4K20012-BS1) Prepared: 11/21/2014 09:21 Analyzed: 11/21/2014 10:19

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	1.0		0.10	mg/L	0.997		103	90-110			

Matrix Spike (4K20012-MS1) Prepared: 11/21/2014 09:21 Analyzed: 11/21/2014 10:24

Source: C414195-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.99		0.10	mg/L	0.387	0.58	104	90-110			

Matrix Spike Dup (4K20012-MSD1) Prepared: 11/21/2014 09:21 Analyzed: 11/21/2014 10:26

Source: C414195-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.99		0.10	mg/L	0.387	0.58	105	90-110	0.4	10	

Batch 4K21005 - NO PREP

Blank (4K21005-BLK1) Prepared: 11/21/2014 09:08 Analyzed: 11/24/2014 16:37

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (4K21005-BS1) Prepared: 11/21/2014 09:08 Analyzed: 11/24/2014 19:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	48		5.0	mg/L	50.0		96	90-110			
Sulfate as SO4	47		5.0	mg/L	50.0		95	90-110			

Matrix Spike (4K21005-MS1) Prepared: 11/21/2014 09:08 Analyzed: 11/24/2014 19:27

Source: C414319-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	20		5.0	mg/L	20.0	3.1	82	90-110			QM-05
Sulfate as SO4	19		5.0	mg/L	20.0	3.5	80	90-110			QM-05

Matrix Spike Dup (4K21005-MSD1) Prepared: 11/21/2014 09:08 Analyzed: 11/24/2014 20:18

Source: C414319-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	20		5.0	mg/L	20.0	3.1	86	90-110	3	10	QM-05
Sulfate as SO4	20		5.0	mg/L	20.0	3.5	83	90-110	3	10	QM-05

Batch 4K25010 - NO PREP

Blank (4K25010-BLK1) Prepared: 11/25/2014 08:44 Analyzed: 11/25/2014 11:05

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4K25010 - NO PREP - Continued

LCS (4K25010-BS1) Prepared: 11/25/2014 08:44 Analyzed: 11/25/2014 11:06

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	100		15	mg/L	100		102	80-120			

Matrix Spike (4K25010-MS1) Prepared: 11/25/2014 08:44 Analyzed: 11/25/2014 11:07

Source: C414111-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	43		15	mg/L	37.8	14 U	112	80-120			

Matrix Spike Dup (4K25010-MSD1) Prepared: 11/25/2014 08:44 Analyzed: 11/25/2014 11:08

Source: C414111-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	38		15	mg/L	37.8	14 U	101	80-120	11	25	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 4K21035 - NO PREP

Blank (4K21035-BLK1) Prepared: 11/21/2014 14:06 Analyzed: 11/21/2014 16:57

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.32	U	1.0	mg/L							

LCS (4K21035-BS1) Prepared: 11/21/2014 14:06 Analyzed: 11/21/2014 16:57

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	45		1.0	mg/L	40.0		112	85-115			

Matrix Spike (4K21035-MS1) Prepared: 11/21/2014 14:06 Analyzed: 11/21/2014 16:57

Source: A406381-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	53		1.0	mg/L	40.0	6.7	115	85-115			

Matrix Spike Dup (4K21035-MSD1) Prepared: 11/21/2014 14:06 Analyzed: 11/21/2014 16:57

Source: A406381-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	45		1.0	mg/L	40.0	6.7	96	85-115	16	21	

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

10775 Central Port Dr.
Orlando, FL 32824
(407) 826-5314 Fax (407) 850-6945

4810 Executive Park Court, Suite 211
Jacksonville, FL 32216-6069
(904) 296-3007 Fax (904) 296-6210

102-A Woodwinds Industrial Ct.
Cary, NC 27511
(919) 467-3090 Fax (919) 467-3515

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Page ____ of ____

Client Name: The Catena Group	Project Number:
Address: 410-B Millstone Drive	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough, NC 27278	PO # / Billing Info:
Tel: 919 732-1300 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print): Nancy Scott	Billing Contact: Nancy Scott
Sampler(s) Signature:	Site Location / Time Zone:

Requested Analyses: Amonia; Cadmium Dissolved; Copper; Turbidity; TOC Dissolved

Requested Turnaround Times
Note : Rush requests subject to acceptance by the facility
___ Standard
___ Expedited
Due ___/___/___

Lab Workorder: C414195

Preservation (See Codes) (Combine as necessary)

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Amonia	Cadmium Dissolved	Copper	Turbidity	TOC Dissolved	Sample Comments
	NC-210	11/19/14	9:45									
	SR-1555	11/19/14	10:15									
	NC-50	11/19/14	10:50									

<-- Total # of Containers

Sample Kit Prepared By:	Date/Time:	Relinquished By: N Scott	Date/Time: 11/19/14	Received By: [signature]	Date/Time: 11/19/14 1120
Comments/Special Reporting Requirements: repeat last		Relinquished By:	Date/Time:	Received By:	Date/Time:
		Relinquished By:	Date/Time:	Received By:	Date/Time:
		Cooler #'s & Temps on Receipt: 3.0c		Condition Upon Receipt: ✓ Acceptable ___ Unacceptable	

atrix : GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments) Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

ENCO Laboratories

Accurate. Timely. Responsive. Innovative.

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Wednesday, December 31, 2014
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C416681

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Tuesday, December 16, 2014.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: SR-1555 **Lab ID: C416681-01** **Sampled: 12/16/14 10:00** **Received: 12/16/14 15:42**

Parameter	Hold Date/Time(s)		Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	01/13/15		12/17/14	09:44	12/17/14 14:45
EPA 310.2	12/30/14		12/26/14	10:07	12/26/14 12:00
EPA 350.1	01/13/15		12/19/14	09:26	12/19/14 13:16
EPA 6010C	06/14/15		12/23/14	14:27	12/24/14 14:29
SM 2130B-2001	12/18/14	10:00	12/17/14	18:24	12/17/14 18:24
SM 5310B-2000	01/13/15		12/22/14	12:18	12/22/14 14:31

Client ID: SR-1555 **Lab ID: C416681-01RE1** **Sampled: 12/16/14 10:00** **Received: 12/16/14 15:42**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	06/14/15	12/23/14	14:27	12/29/14 10:59

Client ID: SR-1555 Dissolved **Lab ID: C416681-02** **Sampled: 12/16/14 10:00** **Received: 12/16/14 15:42**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	06/14/15	12/23/14	14:27	12/24/14 14:33

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SAMPLE DETECTION SUMMARY

Client ID: SR-1555 **Lab ID: C416681-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Chloride	6.1		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2030		23.0	100	ug/L	EPA 6010C	
Potassium - Total	2880		150	500	ug/L	EPA 6010C	
Sodium - Total	6910		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.0	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	20		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.2		0.32	1.0	mg/L	SM 5310B-2000	
Turbidity	1.5		0.50	1.0	NTU	SM 2130B-2001	

Client ID: SR-1555 **Lab ID: C416681-01RE1**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	5940		39.0	100	ug/L	EPA 6010C	

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ANALYTICAL RESULTS

Description: SR-1555 **Lab Sample ID:** C416681-01 **Received:** 12/16/14 15:42
Matrix: Water **Sampled:** 12/16/14 10:00 **Work Order:** C416681
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Calcium [7440-70-2]^	**5940**		ug/L	1	39.0	100	4L23025	EPA 6010C	12/29/14 10:59	VLO	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Magnesium [7439-95-4]^	**2030**		ug/L	1	23.0	100	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Potassium [7440-09-7]^	**2880**		ug/L	1	150	500	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Sodium [7440-23-5]^	**6910**		ug/L	1	400	500	4L23025	EPA 6010C	12/24/14 14:29	VLO	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	4L23025	EPA 6010C	12/24/14 14:29	VLO	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4L23025	EPA 6010C	12/24/14 14:29	VLO	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	4L19023	EPA 350.1	12/19/14 13:16	AJB	
Chloride [16887-00-6]^	**6.1**		mg/L	1	2.2	5.0	4L17013	EPA 300.0	12/17/14 14:45	AJB	
Sulfate as SO4 [14808-79-8]^	**4.0**	J	mg/L	1	2.9	5.0	4L17013	EPA 300.0	12/17/14 14:45	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**20**		mg/L	1	14	15	4L26014	EPA 310.2	12/26/14 12:00	SHA	
Turbidity^	**1.5**		NTU	1	0.50	1.0	4L17045	SM 2130B-2001	12/17/14 18:24	JOC	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.2**		mg/L	1	0.32	1.0	4L22035	SM 5310B-2000	12/22/14 14:31	RSA	

Description: SR-1555 Dissolved **Lab Sample ID:** C416681-02 **Received:** 12/16/14 15:42
Matrix: Water **Sampled:** 12/16/14 10:00 **Work Order:** C416681
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	4L23025	EPA 6010C	12/24/14 14:33	VLO	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4L23025 - EPA 3005A

Blank (4L23025-BLK1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	2.10	U	10.0	ug/L							
Magnesium	23.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

Blank (4L23025-BLK3) Prepared: 12/23/2014 14:27 Analyzed: 12/29/2014 10:36

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	2.10	U	10.0	ug/L							
Magnesium	23.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (4L23025-BS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:25

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	22.3		1.00	ug/L	20.0		111	80-120			
Copper	206		10.0	ug/L	200		103	80-120			
Lead	213		10.0	ug/L	200		107	80-120			
Magnesium	2070		100	ug/L	2000		104	80-120			
Nickel	221		10.0	ug/L	200		110	80-120			
Potassium	10300		500	ug/L	10000		103	80-120			
Sodium	10400		500	ug/L	10000		104	80-120			
Zinc	222		10.0	ug/L	200		111	80-120			

LCS (4L23025-BS2) Prepared: 12/23/2014 14:27 Analyzed: 12/29/2014 10:39

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.9		1.00	ug/L	20.0		104	80-120			
Calcium	2090		100	ug/L	2000		105	80-120			
Copper	195		10.0	ug/L	200		97	80-120			
Lead	199		10.0	ug/L	200		99	80-120			
Magnesium	1990		100	ug/L	2000		100	80-120			
Nickel	206		10.0	ug/L	200		103	80-120			
Potassium	10100		500	ug/L	10000		101	80-120			
Sodium	10300		500	ug/L	10000		103	80-120			
Zinc	208		10.0	ug/L	200		104	80-120			

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4L23025 - EPA 3005A - Continued

Matrix Spike (4L23025-MS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:30

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.3		1.00	ug/L	20.0	0.360 U	107	75-125			
Copper	203		10.0	ug/L	200	1.60 U	102	75-125			
Lead	207		10.0	ug/L	200	2.10 U	103	75-125			
Magnesium	6150		100	ug/L	2000	4750	70	75-125			QM-05
Nickel	221		10.0	ug/L	200	8.89	106	75-125			
Potassium	11700		500	ug/L	10000	1790	99	75-125			
Sodium	45500		500	ug/L	10000	40500	51	75-125			QM-05
Zinc	246		10.0	ug/L	200	32.2	107	75-125			

Matrix Spike (4L23025-MS2) Prepared: 12/23/2014 14:27 Analyzed: 12/29/2014 10:44

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.8		1.00	ug/L	20.0	0.360 U	104	75-125			
Calcium	4840		100	ug/L	2000	3140	85	75-125			
Copper	196		10.0	ug/L	200	1.60 U	98	75-125			
Lead	198		10.0	ug/L	200	2.10 U	99	75-125			
Magnesium	5990		100	ug/L	2000	4750	62	75-125			QM-05
Nickel	215		10.0	ug/L	200	8.89	103	75-125			
Potassium	11900		500	ug/L	10000	1790	102	75-125			
Sodium	46700		500	ug/L	10000	40500	62	75-125			QM-05
Zinc	238		10.0	ug/L	200	32.2	103	75-125			

Matrix Spike Dup (4L23025-MSD1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:33

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.5		1.00	ug/L	20.0	0.360 U	108	75-125	0.9	20	
Copper	205		10.0	ug/L	200	1.60 U	103	75-125	1	20	
Lead	208		10.0	ug/L	200	2.10 U	104	75-125	0.7	20	
Magnesium	6460		100	ug/L	2000	4750	85	75-125	5	20	
Nickel	223		10.0	ug/L	200	8.89	107	75-125	0.7	20	
Potassium	12000		500	ug/L	10000	1790	102	75-125	3	20	
Sodium	47500		500	ug/L	10000	40500	70	75-125	4	20	QM-05
Zinc	247		10.0	ug/L	200	32.2	107	75-125	0.5	20	

Matrix Spike Dup (4L23025-MSD2) Prepared: 12/23/2014 14:27 Analyzed: 12/29/2014 10:46

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.6		1.00	ug/L	20.0	0.360 U	103	75-125	0.7	20	
Calcium	4860		100	ug/L	2000	3140	86	75-125	0.4	20	
Copper	196		10.0	ug/L	200	1.60 U	98	75-125	0.005	20	
Lead	198		10.0	ug/L	200	2.10 U	99	75-125	0.1	20	
Magnesium	6190		100	ug/L	2000	4750	72	75-125	3	20	QM-05
Nickel	214		10.0	ug/L	200	8.89	103	75-125	0.3	20	
Potassium	11800		500	ug/L	10000	1790	100	75-125	2	20	
Sodium	46700		500	ug/L	10000	40500	62	75-125	0.2	20	QM-05
Zinc	238		10.0	ug/L	200	32.2	103	75-125	0.04	20	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 4L23025 - EPA 3005A - Continued

Post Spike (4L23025-PS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:35

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0211		0.00100	mg/L	0.0200	0.000120	105	80-120			
Copper	0.202		0.0100	mg/L	0.200	0.000714	100	80-120			
Lead	0.205		0.0100	mg/L	0.200	-2.00E-5	102	80-120			
Magnesium	6.34		0.100	mg/L	2.00	4.75	80	80-120			
Nickel	0.219		0.0100	mg/L	0.200	0.00889	105	80-120			
Potassium	12.0		0.500	mg/L	10.0	1.79	102	80-120			
Sodium	47.5		0.500	mg/L	10.0	40.5	70	80-120			QM-08
Zinc	0.245		0.0100	mg/L	0.200	0.0322	106	80-120			

Post Spike (4L23025-PS2) Prepared: 12/23/2014 14:27 Analyzed: 12/29/2014 10:49

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0216		0.00100	mg/L	0.0200	0.000120	108	80-120			
Calcium	5.37		0.100	mg/L	2.00	3.14	112	80-120			
Copper	0.212		0.0100	mg/L	0.200	0.000714	105	80-120			
Lead	0.207		0.0100	mg/L	0.200	-2.00E-5	104	80-120			
Magnesium	6.65		0.100	mg/L	2.00	4.75	95	80-120			
Nickel	0.225		0.0100	mg/L	0.200	0.00889	108	80-120			
Potassium	12.8		0.500	mg/L	10.0	1.79	110	80-120			
Sodium	51.3		0.500	mg/L	10.0	40.5	109	80-120			
Zinc	0.252		0.0100	mg/L	0.200	0.0322	110	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 4L23025 - EPA 3005A

Blank (4L23025-BLK1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

Blank (4L23025-BLK2) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:23

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (4L23025-BS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:25

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	206		10.0	ug/L	200		103	80-120			

Matrix Spike (4L23025-MS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:30

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	203		10.0	ug/L	200	1.60 U	102	75-125			

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QUALITY CONTROL DATA

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 4L23025 - EPA 3005A - Continued

Matrix Spike Dup (4L23025-MSD1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:33

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	205		10.0	ug/L	200	1.60 U	103	75-125	1	20	

Post Spike (4L23025-PS1) Prepared: 12/23/2014 14:27 Analyzed: 12/24/2014 13:35

Source: C415919-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.202		0.0100	mg/L	0.200	0.000714	100	80-120			

Classical Chemistry Parameters - Quality Control

Batch 4L17013 - NO PREP

Blank (4L17013-BLK1) Prepared: 12/17/2014 09:44 Analyzed: 12/17/2014 11:04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (4L17013-BS1) Prepared: 12/17/2014 09:44 Analyzed: 12/17/2014 11:21

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	48		5.0	mg/L	50.0		95	90-110			
Sulfate as SO4	47		5.0	mg/L	50.0		94	90-110			

Matrix Spike (4L17013-MS1) Prepared: 12/17/2014 09:44 Analyzed: 12/17/2014 13:37

Source: C414995-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	23		5.0	mg/L	20.0	5.4	89	90-110			QM-05
Sulfate as SO4	32		5.0	mg/L	20.0	13	91	90-110			

Matrix Spike Dup (4L17013-MSD1) Prepared: 12/17/2014 09:44 Analyzed: 12/17/2014 13:54

Source: C414995-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	23		5.0	mg/L	20.0	5.4	87	90-110	2	10	QM-05
Sulfate as SO4	31		5.0	mg/L	20.0	13	89	90-110	1	10	QM-05

Batch 4L17045 - NO PREP

Blank (4L17045-BLK1) Prepared & Analyzed: 12/17/2014 18:24

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Turbidity	0.50	U	1.0	NTU							

LCS (4L17045-BS1) Prepared & Analyzed: 12/17/2014 18:24

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Turbidity	19		1.0	NTU	20.0		96	90-110			

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4L17045 - NO PREP - Continued

Duplicate (4L17045-DUP1) Prepared & Analyzed: 12/17/2014 18:24

Source: C414671-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Turbidity	3.1		1.0	NTU		3.1			1	25	

Duplicate (4L17045-DUP2) Prepared & Analyzed: 12/17/2014 18:24

Source: C414671-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Turbidity	6.6		1.0	NTU		6.7			2	25	

Batch 4L19023 - NO PREP

Blank (4L19023-BLK1) Prepared: 12/19/2014 09:26 Analyzed: 12/19/2014 12:22

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (4L19023-BS1) Prepared: 12/19/2014 09:26 Analyzed: 12/19/2014 12:24

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.92		0.10	mg/L	0.997		92	90-110			

Matrix Spike (4L19023-MS1) Prepared: 12/19/2014 09:26 Analyzed: 12/19/2014 12:28

Source: C406162-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.36		0.10	mg/L	0.387	0.045 U	94	90-110			

Matrix Spike Dup (4L19023-MSD1) Prepared: 12/19/2014 09:26 Analyzed: 12/19/2014 12:30

Source: C406162-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.37		0.10	mg/L	0.387	0.045 U	96	90-110	2	10	

Batch 4L26014 - NO PREP

Blank (4L26014-BLK1) Prepared: 12/26/2014 10:07 Analyzed: 12/26/2014 11:38

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (4L26014-BS1) Prepared: 12/26/2014 10:07 Analyzed: 12/26/2014 11:38

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	99		15	mg/L	100		99	80-120			

Matrix Spike (4L26014-MS1) Prepared: 12/26/2014 10:07 Analyzed: 12/26/2014 11:40

Source: C415213-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	560		75	mg/L	200	320	121	80-120			QM-05

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 4L26014 - NO PREP - Continued

Matrix Spike Dup (4L26014-MSD1) Prepared: 12/26/2014 10:07 Analyzed: 12/26/2014 11:41

Source: C415213-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	540		75	mg/L	200	320	109	80-120	5	25	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 4L22035 - NO PREP

Blank (4L22035-BLK1) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.32	U	1.0	mg/L							

LCS (4L22035-BS1) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	37		1.0	mg/L	40.0		92	85-115			

Matrix Spike (4L22035-MS1) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Source: A407446-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	42		1.0	mg/L	40.0	0.32 U	106	85-115			

Matrix Spike (4L22035-MS2) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Source: A407540-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	42		1.0	mg/L	40.0	0.32 U	106	85-115			

Matrix Spike Dup (4L22035-MSD1) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Source: A407446-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	40		1.0	mg/L	40.0	0.32 U	100	85-115	6	21	

Matrix Spike Dup (4L22035-MSD2) Prepared: 12/22/2014 12:18 Analyzed: 12/22/2014 14:31

Source: A407540-03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	42		1.0	mg/L	40.0	0.32 U	106	85-115	0.1	21	

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-08	Post-digestion spike did not meet method requirements due to confirmed matrix effects (dilution test).

ENCO

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

10775 Central Port Dr.
Orlando, FL 32824

Cary, NC 27511

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Page ___ of ___

Client Name	The Catena Group
Address	410-B Millstone Drive
City/ST/Zip	Hillsborough, NC 27278
Tel	(919) 732-1300
Fax	
Sampler(s) Name, Affiliation (Print)	
Sampler(s) Signature	
Project Number	
Project Name/Desc	Swift Creek Water Qual
PO # / Billing Info	
Reporting Contact	Nancy Scott
Billing Contact	
Site Location / Time Zone	

Requested Analyses: Alkalinity 310.2, Chloride 300; Ammonia 350.1; Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn; CA/F; Sulfate 300; TOC SM5310B Dissolved

Requested Turnaround Times

Note: Rush requests subject to acceptance by the facility

___ Standard

___ Expedited

Due ___/___/___

Lab Workorder: C416681

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2, Chloride 300	Ammonia 350.1	Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn	CA/F	Sulfate 300	TOC SM5310B Dissolved	Sample Comments
	SR 1555	12/16/14	1pm		WA	6	X	X	X	X	X	X	

Preservation (See Codes) (Combine as necessary)

← Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
		[signature]	12-16-14 15:42	[signature]	12/16/14 1542
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By	Date/Time
		Cooler #'s & Temps on Receipt: 2.5°		Condition Upon Receipt: X Acceptable	Unacceptable

Matrix: GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments)

Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note: All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist.

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Friday, February 20, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C501626

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Friday, February 6, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC-50 | **Lab ID: C501626-01** | **Sampled: 02/06/15 11:15** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	03/06/15	02/10/15	08:50	02/10/15 12:08
EPA 310.2	02/20/15	02/19/15	07:58	02/19/15 11:06
EPA 350.1	03/06/15	02/11/15	07:06	02/11/15 09:33
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:14
SM 5310B-2000	03/06/15	02/20/15	10:00	02/20/15 18:10

Client ID: NC-50 | **Lab ID: C501626-02** | **Sampled: 02/06/15 11:15** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:17

Client ID: SR 1555 | **Lab ID: C501626-03** | **Sampled: 02/06/15 10:30** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	03/06/15	02/10/15	08:50	02/10/15 12:25
EPA 310.2	02/20/15	02/19/15	07:58	02/19/15 11:07
EPA 350.1	03/06/15	02/11/15	07:06	02/11/15 09:35
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:19
SM 5310B-2000	03/06/15	02/20/15	10:00	02/20/15 18:10

Client ID: SR 1555 | **Lab ID: C501626-04** | **Sampled: 02/06/15 10:30** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:22

Client ID: NC 210 | **Lab ID: C501626-05** | **Sampled: 02/06/15 09:45** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	03/06/15	02/10/15	08:50	02/10/15 12:42
EPA 310.2	02/20/15	02/19/15	07:58	02/19/15 11:10
EPA 350.1	03/06/15	02/11/15	07:06	02/11/15 09:37
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:24
SM 5310B-2000	03/06/15	02/20/15	10:00	02/20/15 18:10

Client ID: NC 210 | **Lab ID: C501626-06** | **Sampled: 02/06/15 09:45** | **Received: 02/06/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	08/05/15	02/10/15	16:04	02/11/15 11:27

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SAMPLE DETECTION SUMMARY

Client ID: NC-50 **Lab ID: C501626-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	5010		39.0	100	ug/L	EPA 6010C	
Chloride	4.9	J	2.2	5.0	mg/L	EPA 300.0	
Copper - Total	2.46	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	1740		23.0	100	ug/L	EPA 6010C	
Potassium - Total	2420		150	500	ug/L	EPA 6010C	
Sodium - Total	4290		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.5	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	20		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.1		0.32	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C501626-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	2.24	J	1.60	10.0	ug/L	EPA 6010C	

Client ID: SR 1555 **Lab ID: C501626-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	5170		39.0	100	ug/L	EPA 6010C	
Chloride	5.3		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	2.75	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	1820		23.0	100	ug/L	EPA 6010C	
Potassium - Total	2190		150	500	ug/L	EPA 6010C	
Sodium - Total	5500		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.4	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	22		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.3		0.32	1.0	mg/L	SM 5310B-2000	

Client ID: NC 210 **Lab ID: C501626-05**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	5050		39.0	100	ug/L	EPA 6010C	
Chloride	6.0		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	1950		23.0	100	ug/L	EPA 6010C	
Potassium - Total	2110		150	500	ug/L	EPA 6010C	
Sodium - Total	5390		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.6	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	22		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.4		0.32	1.0	mg/L	SM 5310B-2000	

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ANALYTICAL RESULTS

Description: NC-50 **Lab Sample ID:** C501626-01 **Received:** 02/06/15 15:30

Matrix: Water **Sampled:** 02/06/15 11:15 **Work Order:** C501626

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Calcium [7440-70-2]^	**5010**		ug/L	1	39.0	100	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Copper [7440-50-8]^	**2.46**	J	ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Magnesium [7439-95-4]^	**1740**		ug/L	1	23.0	100	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Potassium [7440-09-7]^	**2420**		ug/L	1	150	500	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Sodium [7440-23-5]^	**4290**		ug/L	1	400	500	5B10032	EPA 6010C	02/11/15 11:14	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5B10032	EPA 6010C	02/11/15 11:14	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5B11001	EPA 350.1	02/11/15 09:33	SHA	
Chloride [16887-00-6]^	**4.9**	J	mg/L	1	2.2	5.0	5B10013	EPA 300.0	02/10/15 12:08	AJB	
Sulfate as SO4 [14808-79-8]^	**4.5**	J	mg/L	1	2.9	5.0	5B10013	EPA 300.0	02/10/15 12:08	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**20**		mg/L	1	14	15	5B19002	EPA 310.2	02/19/15 11:06	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.1**		mg/L	1	0.32	1.0	5B19003	SM 5310B-2000	02/20/15 18:10	RSA	

Description: NC-50 **Lab Sample ID:** C501626-02 **Received:** 02/06/15 15:30

Matrix: Water **Sampled:** 02/06/15 11:15 **Work Order:** C501626

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**2.24**	J	ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:17	JDH	

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ANALYTICAL RESULTS

Description: SR 1555 | **Lab Sample ID:** C501626-03 | **Received:** 02/06/15 15:30
Matrix: Water | **Sampled:** 02/06/15 10:30 | **Work Order:** C501626
Project: Swift Creek Water Quality | **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Calcium [7440-70-2]^	**5170**		ug/L	1	39.0	100	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Copper [7440-50-8]^	**2.75**	J	ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Magnesium [7439-95-4]^	**1820**		ug/L	1	23.0	100	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Potassium [7440-09-7]^	**2190**		ug/L	1	150	500	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Sodium [7440-23-5]^	**5500**		ug/L	1	400	500	5B10032	EPA 6010C	02/11/15 11:19	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5B10032	EPA 6010C	02/11/15 11:19	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5B11001	EPA 350.1	02/11/15 09:35	SHA	
Chloride [16887-00-6]^	**5.3**		mg/L	1	2.2	5.0	5B10013	EPA 300.0	02/10/15 12:25	AJB	
Sulfate as SO4 [14808-79-8]^	**4.4**	J	mg/L	1	2.9	5.0	5B10013	EPA 300.0	02/10/15 12:25	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**22**		mg/L	1	14	15	5B19002	EPA 310.2	02/19/15 11:07	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.3**		mg/L	1	0.32	1.0	5B19003	SM 5310B-2000	02/20/15 18:10	RSA	

Description: SR 1555 | **Lab Sample ID:** C501626-04 | **Received:** 02/06/15 15:30
Matrix: Water | **Sampled:** 02/06/15 10:30 | **Work Order:** C501626
Project: Swift Creek Water Quality | **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:22	JDH	

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ANALYTICAL RESULTS

Description: NC 210 **Lab Sample ID:** C501626-05 **Received:** 02/06/15 15:30
Matrix: Water **Sampled:** 02/06/15 09:45 **Work Order:** C501626
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Calcium [7440-70-2]^	**5050**		ug/L	1	39.0	100	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Lead [7439-92-1]^	ND		ug/L	1	2.10	10.0	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Magnesium [7439-95-4]^	**1950**		ug/L	1	23.0	100	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Potassium [7440-09-7]^	**2110**		ug/L	1	150	500	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Sodium [7440-23-5]^	**5390**		ug/L	1	400	500	5B10032	EPA 6010C	02/11/15 11:24	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5B10032	EPA 6010C	02/11/15 11:24	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5B11001	EPA 350.1	02/11/15 09:37	SHA	
Chloride [16887-00-6]^	**6.0**		mg/L	1	2.2	5.0	5B10013	EPA 300.0	02/10/15 12:42	AJB	
Sulfate as SO4 [14808-79-8]^	**4.6**	J	mg/L	1	2.9	5.0	5B10013	EPA 300.0	02/10/15 12:42	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**22**		mg/L	1	14	15	5B19002	EPA 310.2	02/19/15 11:10	AJB	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.4**		mg/L	1	0.32	1.0	5B19003	SM 5310B-2000	02/20/15 18:10	RSA	

Description: NC 210 **Lab Sample ID:** C501626-06 **Received:** 02/06/15 15:30
Matrix: Water **Sampled:** 02/06/15 09:45 **Work Order:** C501626
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5B10032	EPA 6010C	02/11/15 11:27	JDH	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5B10032 - EPA 3005A

Blank (5B10032-BLK1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:07

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	2.10	U	10.0	ug/L							
Magnesium	23.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

Blank (5B10032-BLK2) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							

LCS (5B10032-BS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:13

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.5		1.00	ug/L	20.0		103	80-120			
Calcium	2110		100	ug/L	2000		105	80-120			
Copper	198		10.0	ug/L	200		99	80-120			
Lead	211		10.0	ug/L	200		105	80-120			
Magnesium	2060		100	ug/L	2000		103	80-120			
Nickel	206		10.0	ug/L	200		103	80-120			
Potassium	9950		500	ug/L	10000		100	80-120			
Sodium	10100		500	ug/L	10000		101	80-120			
Zinc	208		10.0	ug/L	200		104	80-120			

Matrix Spike (5B10032-MS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:19

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.3		1.00	ug/L	20.0	0.360 U	106	75-125			
Calcium	38900		100	ug/L	2000	37600	65	75-125			QM-05
Copper	201		10.0	ug/L	200	1.60 U	101	75-125			
Lead	209		10.0	ug/L	200	2.10 U	105	75-125			
Magnesium	9010		100	ug/L	2000	7190	91	75-125			
Nickel	212		10.0	ug/L	200	1.80 U	106	75-125			
Potassium	13200		500	ug/L	10000	3210	100	75-125			
Sodium	24400		500	ug/L	10000	14600	98	75-125			
Zinc	241		10.0	ug/L	200	25.2	108	75-125			

Matrix Spike Dup (5B10032-MSD1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:21

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.7		1.00	ug/L	20.0	0.360 U	104	75-125	3	20	
Calcium	39900		100	ug/L	2000	37600	112	75-125	2	20	
Copper	205		10.0	ug/L	200	1.60 U	102	75-125	2	20	
Lead	213		10.0	ug/L	200	2.10 U	106	75-125	2	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5B10032 - EPA 3005A - Continued

Matrix Spike Dup (5B10032-MSD1) Continued Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:21

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Magnesium	9420		100	ug/L	2000	7190	111	75-125	4	20	
Nickel	206		10.0	ug/L	200	1.80 U	103	75-125	3	20	
Potassium	13700		500	ug/L	10000	3210	105	75-125	3	20	
Sodium	25100		500	ug/L	10000	14600	105	75-125	3	20	
Zinc	235		10.0	ug/L	200	25.2	105	75-125	3	20	

Post Spike (5B10032-PS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:24

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0197		0.00100	mg/L	0.0200	0.000107	98	80-120			
Calcium	38.2		0.100	mg/L	2.00	37.6	26	80-120			QM-08
Copper	0.185		0.0100	mg/L	0.200	0.000744	92	80-120			
Lead	0.192		0.0100	mg/L	0.200	-0.00114	96	80-120			
Magnesium	8.64		0.100	mg/L	2.00	7.19	73	80-120			QM-08
Nickel	0.186		0.0100	mg/L	0.200	-0.000482	93	80-120			
Potassium	12.4		0.500	mg/L	10.0	3.21	92	80-120			
Sodium	23.3		0.500	mg/L	10.0	14.6	87	80-120			
Zinc	0.213		0.0100	mg/L	0.200	0.0252	94	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5B10032 - EPA 3005A

Blank (5B10032-BLK2) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (5B10032-BS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:13

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	198		10.0	ug/L	200		99	80-120			

Matrix Spike (5B10032-MS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:19

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	201		10.0	ug/L	200	1.60 U	101	75-125			

Matrix Spike Dup (5B10032-MSD1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:21

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	205		10.0	ug/L	200	1.60 U	102	75-125	2	20	

Post Spike (5B10032-PS1) Prepared: 02/10/2015 16:04 Analyzed: 02/11/2015 10:24

Source: C417026-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.185		0.0100	mg/L	0.200	0.000744	92	80-120			

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5B10013 - NO PREP

Blank (5B10013-BLK1) Prepared: 02/10/2015 08:50 Analyzed: 02/10/2015 10:11

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (5B10013-BS1) Prepared: 02/10/2015 08:50 Analyzed: 02/10/2015 10:28

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	48		5.0	mg/L	50.0		96	90-110			
Sulfate as SO4	47		5.0	mg/L	50.0		95	90-110			

Matrix Spike (5B10013-MS1) Prepared: 02/10/2015 08:50 Analyzed: 02/10/2015 12:59

Source: C500553-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	36		5.0	mg/L	20.0	17	96	90-110			
Sulfate as SO4	31		5.0	mg/L	20.0	13	89	90-110			QM-05

Matrix Spike Dup (5B10013-MSD1) Prepared: 02/10/2015 08:50 Analyzed: 02/10/2015 13:49

Source: C500553-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	37		5.0	mg/L	20.0	17	100	90-110	2	10	
Sulfate as SO4	32		5.0	mg/L	20.0	13	93	90-110	2	10	

Batch 5B11001 - NO PREP

Blank (5B11001-BLK1) Prepared: 02/11/2015 07:06 Analyzed: 02/11/2015 08:41

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5B11001-BS1) Prepared: 02/11/2015 07:06 Analyzed: 02/11/2015 08:43

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.96		0.10	mg/L	0.997		96	90-110			

Matrix Spike (5B11001-MS1) Prepared: 02/11/2015 07:06 Analyzed: 02/11/2015 08:48

Source: C416551-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	18		2.0	mg/L	7.96	10	96	90-110			

Matrix Spike Dup (5B11001-MSD1) Prepared: 02/11/2015 07:06 Analyzed: 02/11/2015 08:50

Source: C416551-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	18		2.0	mg/L	7.96	10	101	90-110	2	10	

Batch 5B19002 - NO PREP

Blank (5B19002-BLK1) Prepared: 02/19/2015 07:58 Analyzed: 02/19/2015 10:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5B19002 - NO PREP - Continued

Blank (5B19002-BLK1) Continued Prepared: 02/19/2015 07:58 Analyzed: 02/19/2015 10:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5B19002-BS1) Prepared: 02/19/2015 07:58 Analyzed: 02/19/2015 10:49

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	97		15	mg/L	100		97	80-120			

Matrix Spike (5B19002-MS1) Prepared: 02/19/2015 07:58 Analyzed: 02/19/2015 10:51

Source: C501868-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	710		75	mg/L	200	500	104	80-120			

Matrix Spike Dup (5B19002-MSD1) Prepared: 02/19/2015 07:58 Analyzed: 02/19/2015 10:52

Source: C501868-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	710		75	mg/L	200	500	104	80-120	0.01	25	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5B19003 - NO PREP

Blank (5B19003-BLK1) Prepared: 02/20/2015 10:00 Analyzed: 02/20/2015 18:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.32	U	1.0	mg/L							

LCS (5B19003-BS1) Prepared: 02/20/2015 10:00 Analyzed: 02/20/2015 18:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	37		1.0	mg/L	40.0		93	85-115			

Matrix Spike (5B19003-MS1) Prepared: 02/20/2015 10:00 Analyzed: 02/20/2015 18:10

Source: A500757-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	40		1.0	mg/L	40.0	0.39	99	85-115			

Matrix Spike Dup (5B19003-MSD1) Prepared: 02/20/2015 10:00 Analyzed: 02/20/2015 18:10

Source: A500757-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	39		1.0	mg/L	40.0	0.39	97	85-115	2	21	

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FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-08	Post-digestion spike did not meet method requirements due to confirmed matrix effects (dilution test).

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

10775 Central Port Dr. Orlando, FL 32824 (407) 826-5314 Fax (407) 850-6945

4810 Executive Park Court, Suite 211 Jacksonville, FL 32216-6069 (904) 296-3007 Fax (904) 296-6210

102-A Woodwinds Industrial Ct. Cary, NC 27511 (919) 467-3090 Fax (919) 467-3515

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Page ____ of ____

Client Name: Catena Group	Project Number:
Address: 410-B Millstone Drive	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough NC 27278	PO # / Billing Info:
Tel: 919-732-1300 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print): Nancy Scott	Billing Contact: Nancy Scott
Sampler(s) Signature: NScott	Site Location / Time Zone:

Requested Analyses: Alkalinity 310.2, Chloride 300; Ammonia 350.1; Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn; Cu/F; Sulfate 300; TOC SM5310B Dissolved

Preservation (See Codes) (Combine as necessary)

Requested Turnaround Times

Note: Rush requests subject to acceptance by the facility

___ Standard

___ Expedited

Due ___/___/___

Lab Workorder: C501626

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Sample Comments
	NC 50	2/6/15	11:15		WA	6	
	SR 1555	2/6/15	10:30		WA	6	
	NC 210	2/6/15	9:45		WA	6	

<-- Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By: NScott	Date/Time: 2/6/15 3:30	Received By: [signature]	Date/Time: 2-6-15 1530
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By	Date/Time
		Cooler #'s & Temps on Receipt: 3.4°c		Condition Upon Receipt: √ Acceptable ___ Unacceptable	

Matrix: GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments)

Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note: All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist

ENCO Laboratories

Accurate. Timely. Responsive. Innovative.

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Wednesday, April 22, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C504461

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Tuesday, April 7, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC-50 | **Lab ID: C504461-01** | **Sampled: 04/07/15 14:45** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	05/05/15	04/09/15	09:53	04/10/15 18:29
EPA 310.2	04/21/15	04/10/15	07:22	04/10/15 09:32
EPA 350.1	05/05/15	04/10/15	10:02	04/10/15 13:16
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 13:41
SM 5310B-2000	05/05/15	04/15/15	15:00	04/15/15 20:59

Client ID: NC-50 | **Lab ID: C504461-02** | **Sampled: 04/07/15 14:45** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 14:39

Client ID: SR 1555 | **Lab ID: C504461-03** | **Sampled: 04/07/15 14:15** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	05/05/15	04/09/15	09:53	04/10/15 18:47
EPA 310.2	04/21/15	04/10/15	07:22	04/10/15 09:33
EPA 350.1	05/05/15	04/10/15	10:02	04/10/15 13:18
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 14:42
SM 5310B-2000	05/05/15	04/15/15	15:00	04/15/15 20:59

Client ID: SR 1555 | **Lab ID: C504461-04** | **Sampled: 04/07/15 14:15** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 14:44

Client ID: NC 210 | **Lab ID: C504461-05** | **Sampled: 04/07/15 13:45** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	05/05/15	04/09/15	09:53	04/10/15 19:06
EPA 310.2	04/21/15	04/10/15	07:22	04/10/15 09:34
EPA 350.1	05/05/15	04/10/15	10:02	04/10/15 13:19
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 14:47
SM 5310B-2000	05/05/15	04/15/15	15:00	04/15/15 20:59

Client ID: NC 210 | **Lab ID: C504461-06** | **Sampled: 04/07/15 13:45** | **Received: 04/07/15 15:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	10/04/15	04/16/15	11:48	04/17/15 14:49

SAMPLE DETECTION SUMMARY

Client ID: NC-50 **Lab ID: C504461-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	7000		39.0	100	ug/L	EPA 6010C	
Chloride	11		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	5.91	JB	1.60	10.0	ug/L	EPA 6010C	J-01
Magnesium - Total	2290		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2570		150	500	ug/L	EPA 6010C	
Sodium - Total	8620		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.9	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	29		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	6.1		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C504461-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	4.92	JB	1.60	10.0	ug/L	EPA 6010C	J-01

Client ID: SR 1555 **Lab ID: C504461-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	6550		39.0	100	ug/L	EPA 6010C	
Chloride	8.3		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	4.13	JB	1.60	10.0	ug/L	EPA 6010C	J-01
Magnesium - Total	2230		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2330		150	500	ug/L	EPA 6010C	
Sodium - Total	8040		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.0	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	30		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.8		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: SR 1555 **Lab ID: C504461-04**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	4.17	JB	1.60	10.0	ug/L	EPA 6010C	J-01

Client ID: NC 210 **Lab ID: C504461-05**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	6850		39.0	100	ug/L	EPA 6010C	
Chloride	8.5		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	4.65	JB	1.60	10.0	ug/L	EPA 6010C	J-01
Magnesium - Total	2660		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2460		150	500	ug/L	EPA 6010C	
Sodium - Total	8460		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.2	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	26		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.1		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC 210 **Lab ID: C504461-06**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	4.13	JB	1.60	10.0	ug/L	EPA 6010C	J-01

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ANALYTICAL RESULTS

Description: NC-50 **Lab Sample ID:** C504461-01 **Received:** 04/07/15 15:30
Matrix: Water **Sampled:** 04/07/15 14:45 **Work Order:** C504461
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Calcium [7440-70-2]^	**7000**		ug/L	1	39.0	100	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Copper [7440-50-8]^	**5.91**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 13:41	JDH	J-01
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Magnesium [7439-95-4]^	**2290**		ug/L	1	29.0	100	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Potassium [7440-09-7]^	**2570**		ug/L	1	150	500	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Sodium [7440-23-5]^	**8620**		ug/L	1	400	500	5D16018	EPA 6010C	04/17/15 13:41	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5D16018	EPA 6010C	04/17/15 13:41	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5D10011	EPA 350.1	04/10/15 13:16	SHA	
Chloride [16887-00-6]^	**11**		mg/L	1	2.2	5.0	5D09010	EPA 300.0	04/10/15 18:29	SHA	
Sulfate as SO4 [14808-79-8]^	**4.9**	J	mg/L	1	2.9	5.0	5D09010	EPA 300.0	04/10/15 18:29	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**29**		mg/L	1	14	15	5D10001	EPA 310.2	04/10/15 09:32	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**6.1**		mg/L	1	0.34	1.0	5D15005	SM 5310B-2000	04/15/15 20:59	RSA	

Description: NC-50 **Lab Sample ID:** C504461-02 **Received:** 04/07/15 15:30
Matrix: Water **Sampled:** 04/07/15 14:45 **Work Order:** C504461
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**4.92**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 14:39	JDH	J-01

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ANALYTICAL RESULTS

Description: SR 1555 | **Lab Sample ID:** C504461-03 | **Received:** 04/07/15 15:30

Matrix: Water | **Sampled:** 04/07/15 14:15 | **Work Order:** C504461

Project: Swift Creek Water Quality | **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Calcium [7440-70-2]^	**6550**		ug/L	1	39.0	100	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Copper [7440-50-8]^	**4.13**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 14:42	JDH	J-01
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Magnesium [7439-95-4]^	**2230**		ug/L	1	29.0	100	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Potassium [7440-09-7]^	**2330**		ug/L	1	150	500	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Sodium [7440-23-5]^	**8040**		ug/L	1	400	500	5D16018	EPA 6010C	04/17/15 14:42	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5D16018	EPA 6010C	04/17/15 14:42	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5D10011	EPA 350.1	04/10/15 13:18	SHA	
Chloride [16887-00-6]^	**8.3**		mg/L	1	2.2	5.0	5D09010	EPA 300.0	04/10/15 18:47	SHA	
Sulfate as SO4 [14808-79-8]^	**4.0**	J	mg/L	1	2.9	5.0	5D09010	EPA 300.0	04/10/15 18:47	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**30**		mg/L	1	14	15	5D10001	EPA 310.2	04/10/15 09:33	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.8**		mg/L	1	0.34	1.0	5D15005	SM 5310B-2000	04/15/15 20:59	RSA	

Description: SR 1555 | **Lab Sample ID:** C504461-04 | **Received:** 04/07/15 15:30

Matrix: Water | **Sampled:** 04/07/15 14:15 | **Work Order:** C504461

Project: Swift Creek Water Quality | **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**4.17**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 14:44	JDH	J-01

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ANALYTICAL RESULTS

Description: NC 210	**Lab Sample ID:** C504461-05	**Received:** 04/07/15 15:30
Matrix: Water	**Sampled:** 04/07/15 13:45	**Work Order:** C504461
Project: Swift Creek Water Quality	**Sampled By:** Nancy Scott	

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Calcium [7440-70-2]^	**6850**		ug/L	1	39.0	100	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Copper [7440-50-8]^	**4.65**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 14:47	JDH	J-01
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Magnesium [7439-95-4]^	**2660**		ug/L	1	29.0	100	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Potassium [7440-09-7]^	**2460**		ug/L	1	150	500	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Sodium [7440-23-5]^	**8460**		ug/L	1	400	500	5D16018	EPA 6010C	04/17/15 14:47	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5D16018	EPA 6010C	04/17/15 14:47	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5D10011	EPA 350.1	04/10/15 13:19	SHA	
Chloride [16887-00-6]^	**8.5**		mg/L	1	2.2	5.0	5D09010	EPA 300.0	04/10/15 19:06	SHA	
Sulfate as SO4 [14808-79-8]^	**4.2**	J	mg/L	1	2.9	5.0	5D09010	EPA 300.0	04/10/15 19:06	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**26**		mg/L	1	14	15	5D10001	EPA 310.2	04/10/15 09:34	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.1**		mg/L	1	0.34	1.0	5D15005	SM 5310B-2000	04/15/15 20:59	RSA	

Description: NC 210	**Lab Sample ID:** C504461-06	**Received:** 04/07/15 15:30
Matrix: Water	**Sampled:** 04/07/15 13:45	**Work Order:** C504461
Project: Swift Creek Water Quality	**Sampled By:** Nancy Scott	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**4.13**	JB	ug/L	1	1.60	10.0	5D16018	EPA 6010C	04/17/15 14:49	JDH	J-01

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5D16018 - EPA 3005A

Blank (5D16018-BLK1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:28

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	**2.56**	**J**	10.0	ug/L							
Lead	3.10	U	10.0	ug/L							
Magnesium	29.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (5D16018-BS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:38

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	22.3		1.00	ug/L	20.0		112	80-120			
Calcium	2320		100	ug/L	2000		116	80-120			
Copper	216	B	10.0	ug/L	200		108	80-120			
Lead	222		10.0	ug/L	200		111	80-120			
Magnesium	2190		100	ug/L	2000		110	80-120			
Nickel	221		10.0	ug/L	200		110	80-120			
Potassium	11200		500	ug/L	10000		112	80-120			
Sodium	10900		500	ug/L	10000		109	80-120			
Zinc	223		10.0	ug/L	200		111	80-120			

Matrix Spike (5D16018-MS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:43

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	22.6		1.00	ug/L	20.0	0.360 U	113	75-125			
Calcium	9020		100	ug/L	2000	7000	101	75-125			
Copper	223	B	10.0	ug/L	200	5.91	109	75-125			
Lead	223		10.0	ug/L	200	3.10 U	112	75-125			
Magnesium	4420		100	ug/L	2000	2290	106	75-125			
Nickel	224		10.0	ug/L	200	1.80 U	112	75-125			
Potassium	13600		500	ug/L	10000	2570	111	75-125			
Sodium	19300		500	ug/L	10000	8620	107	75-125			
Zinc	229		10.0	ug/L	200	3.80 U	114	75-125			

Matrix Spike Dup (5D16018-MSD1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:46

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	23.3		1.00	ug/L	20.0	0.360 U	116	75-125	3	20	
Calcium	8640		100	ug/L	2000	7000	82	75-125	4	20	
Copper	221	B	10.0	ug/L	200	5.91	107	75-125	1	20	
Lead	223		10.0	ug/L	200	3.10 U	111	75-125	0.1	20	
Magnesium	4290		100	ug/L	2000	2290	100	75-125	3	20	
Nickel	232		10.0	ug/L	200	1.80 U	116	75-125	3	20	
Potassium	13300		500	ug/L	10000	2570	108	75-125	2	20	
Sodium	18800		500	ug/L	10000	8620	102	75-125	3	20	
Zinc	236		10.0	ug/L	200	3.80 U	118	75-125	3	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5D16018 - EPA 3005A - Continued

Post Spike (5D16018-PS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:48

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0219		0.00100	mg/L	0.0200	-7.35E-5	109	80-120			
Calcium	8.61		0.100	mg/L	2.00	7.00	80	80-120			
Copper	0.209	B	0.0100	mg/L	0.200	0.00591	102	80-120			
Lead	0.208		0.0100	mg/L	0.200	2.07E-5	104	80-120			
Magnesium	4.20		0.100	mg/L	2.00	2.29	96	80-120			
Nickel	0.217		0.0100	mg/L	0.200	8.54E-5	108	80-120			
Potassium	12.7		0.500	mg/L	10.0	2.57	102	80-120			
Sodium	18.4		0.500	mg/L	10.0	8.62	98	80-120			
Zinc	0.222		0.0100	mg/L	0.200	0.00209	110	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5D16018 - EPA 3005A

Blank (5D16018-BLK2) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:35

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	**3.11**	**J**	10.0	ug/L							

LCS (5D16018-BS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:38

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	216	B	10.0	ug/L	200		108	80-120			

Matrix Spike (5D16018-MS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:43

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	223	B	10.0	ug/L	200	5.91	109	75-125			

Matrix Spike Dup (5D16018-MSD1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:46

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	221	B	10.0	ug/L	200	5.91	107	75-125	1	20	

Post Spike (5D16018-PS1) Prepared: 04/16/2015 11:48 Analyzed: 04/17/2015 13:48

Source: C504461-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.209	B	0.0100	mg/L	0.200	0.00591	102	80-120			

Classical Chemistry Parameters - Quality Control

Batch 5D09010 - NO PREP

Blank (5D09010-BLK1) Prepared: 04/09/2015 09:53 Analyzed: 04/10/2015 10:08

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5D09010 - NO PREP - Continued

LCS (5D09010-BS1) Prepared: 04/09/2015 09:53 Analyzed: 04/10/2015 12:00

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	53		5.0	mg/L	50.0		105	90-110			
Sulfate as SO4	50		5.0	mg/L	50.0		101	90-110			

Matrix Spike (5D09010-MS1) Prepared: 04/09/2015 09:53 Analyzed: 04/10/2015 12:18

Source: C502700-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	680		50	mg/L	200	450	117	90-110			QM-07
Sulfate as SO4	340		50	mg/L	200	140	100	90-110			

Matrix Spike (5D09010-MS2) Prepared: 04/09/2015 09:53 Analyzed: 04/10/2015 13:14

Source: C502701-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	680		50	mg/L	200	460	109	90-110			
Sulfate as SO4	330		50	mg/L	200	130	97	90-110			

Matrix Spike Dup (5D09010-MSD1) Prepared: 04/09/2015 09:53 Analyzed: 04/10/2015 12:37

Source: C502700-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	370		50	mg/L	200	450	NR	90-110	59	10	QM-07, QM-11
Sulfate as SO4	180		50	mg/L	200	140	19	90-110	62	10	QM-07, QM-11

Batch 5D10001 - NO PREP

Blank (5D10001-BLK1) Prepared: 04/10/2015 07:22 Analyzed: 04/10/2015 09:10

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5D10001-BS1) Prepared: 04/10/2015 07:22 Analyzed: 04/10/2015 09:11

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	100		15	mg/L	100		101	80-120			

Matrix Spike (5D10001-MS1) Prepared: 04/10/2015 07:22 Analyzed: 04/10/2015 09:13

Source: C503561-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	370		75	mg/L	200	170	101	80-120			

Matrix Spike Dup (5D10001-MSD1) Prepared: 04/10/2015 07:22 Analyzed: 04/10/2015 09:13

Source: C503561-04

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	350		75	mg/L	200	170	93	80-120	5	25	

Batch 5D10011 - NO PREP

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5D10011 - NO PREP - Continued

Blank (5D10011-BLK1) Prepared: 04/10/2015 10:02 Analyzed: 04/10/2015 12:23

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5D10011-BS1) Prepared: 04/10/2015 10:02 Analyzed: 04/10/2015 12:25

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.97		0.10	mg/L	0.997		97	90-110			

Matrix Spike (5D10011-MS1) Prepared: 04/10/2015 10:02 Analyzed: 04/10/2015 12:30

Source: C502640-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.35		0.10	mg/L	0.387	0.045 U	91	90-110			

Matrix Spike (5D10011-MS2) Prepared: 04/10/2015 10:02 Analyzed: 04/10/2015 12:36

Source: C502681-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	150		10	mg/L	39.8	100	112	90-110			QM-05

Matrix Spike Dup (5D10011-MSD1) Prepared: 04/10/2015 10:02 Analyzed: 04/10/2015 12:32

Source: C502640-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.36		0.10	mg/L	0.387	0.045 U	94	90-110	4	10	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5D15005 - NO PREP

Blank (5D15005-BLK1) Prepared: 04/15/2015 15:00 Analyzed: 04/15/2015 20:59

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.34	U	1.0	mg/L							

LCS (5D15005-BS1) Prepared: 04/15/2015 15:00 Analyzed: 04/15/2015 20:59

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	41		1.0	mg/L	40.0		103	85-115			

Matrix Spike (5D15005-MS1) Prepared: 04/15/2015 15:00 Analyzed: 04/15/2015 20:59

Source: A502188-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	68		1.0	mg/L	40.0	30	94	85-115			

Matrix Spike Dup (5D15005-MSD1) Prepared: 04/15/2015 15:00 Analyzed: 04/15/2015 20:59

Source: A502188-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	72		1.0	mg/L	40.0	30	106	85-115	7	21	

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
J-01	Result is estimated due to positive results in the associated method blank.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-07	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
QM-11	Precision between duplicate matrix spikes of the same sample was outside acceptance limits.

ENCO

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

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10775 Central Port Dr. Orlando, FL 32824 (407) 826-5314 Fax (407) 850-6945
4810 Executive Park Court, Suite 211 Jacksonville, FL 32216-6069 (904) 296-3007 Fax (904) 296-6210
102-A Woodwinds Industrial Ct Cary, NC 27511 (919) 467-3090 Fax (919) 467-3515

Client Name: The Catena Group	Project Number:
Address: 1000 Corporate Drive, Suite 101	Project Name/Desc: Swift Creek
City/ST/Zip: Hillsborough NC 27278	PO # / Billing Info:
Tel: 919-732-1300 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print):	Billing Contact:
Sampler(s) Signature:	Site Location / Time Zone:

Requested Analyses: Alkalinity 310.2, Chloride 300 | Ammonia 350.1 | Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn | Cu/F | Sulfate 300 | TOC SM5310B Dissolved

Preservation (See Codes) (Combine as necessary)

Requested Turnaround Times
Note: Rush requests subject to acceptance by the facility
___ Standard
___ Expedited
Due ___/___/___

Lab Workorder: C504461

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2, Chloride 300	Ammonia 350.1	Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn	Cu/F	Sulfate 300	TOC SM5310B Dissolved					Sample Comments
	NC 50	4/7/15	2:45			6											
	SR 1555	4/7/15	2:15			6											
	NC 210	4/7/15	1:45			6											

<-- Total # of Containers

Sample Kit Prepared By:	Date/Time:	Relinquished By: Sarah Burton	Date/Time: 4/7/15 3:30	Received By: [signature]	Date/Time: 4/7/15 1530
Comments/Special Reporting Requirements:		Relinquished By:	Date/Time:	Received By:	Date/Time:
		Relinquished By:	Date/Time:	Received By:	Date/Time:
		Cooler #'s & Temps on Receipt: 4.6C		Condition Upon Receipt: X Acceptable ___ Unacceptable	

Matrix: GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments)
Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note: All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist.

ENCO Laboratories

Accurate. Timely. Responsive. Innovative.

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Thursday, May 21, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C505742

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Thursday, May 7, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC 210 | **Lab ID: C505742-01** | **Sampled: 05/07/15 13:25** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	06/04/15	05/13/15 22:01	05/13/15 22:01
EPA 310.2	05/21/15	05/08/15 09:38	05/08/15 13:10
EPA 350.1	06/04/15	05/13/15 07:21	05/13/15 09:57
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 11:06
SM 5310B-2000	06/04/15	05/19/15 08:25	05/19/15 16:44

Client ID: SR 1555 | **Lab ID: C505742-02** | **Sampled: 05/07/15 13:55** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	06/04/15	05/13/15 22:19	05/13/15 22:19
EPA 310.2	05/21/15	05/08/15 09:38	05/08/15 13:10
EPA 350.1	06/04/15	05/13/15 07:21	05/13/15 09:59
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 12:03
SM 5310B-2000	06/04/15	05/19/15 08:25	05/19/15 16:44

Client ID: NC-50 | **Lab ID: C505742-03** | **Sampled: 05/07/15 14:30** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	06/04/15	05/13/15 22:36	05/13/15 22:36
EPA 310.2	05/21/15	05/08/15 09:38	05/08/15 13:11
EPA 350.1	06/04/15	05/13/15 07:21	05/13/15 10:01
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 12:06
SM 5310B-2000	06/04/15	05/19/15 08:25	05/19/15 16:44

Client ID: NC 210 Dissolved | **Lab ID: C505742-04** | **Sampled: 05/07/15 13:25** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 12:08

Client ID: SR 1555 Dissolved | **Lab ID: C505742-05** | **Sampled: 05/07/15 13:55** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 12:11

Client ID: NC 50 Dissolved | **Lab ID: C505742-06** | **Sampled: 05/07/15 14:30** | **Received: 05/07/15 15:17**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	11/03/15	05/18/15 16:30	05/20/15 12:13

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SAMPLE DETECTION SUMMARY

Client ID: NC 210 **Lab ID: C505742-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.060	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	5790		39.0	100	ug/L	EPA 6010C	
Chloride	7.1		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	2.01	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	2270		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2360		150	500	ug/L	EPA 6010C	
Sodium - Total	7070		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.8	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	25		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.3		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: SR 1555 **Lab ID: C505742-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.078	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	5460		39.0	100	ug/L	EPA 6010C	
Chloride	7.3		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2030		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2160		150	500	ug/L	EPA 6010C	
Sodium - Total	7500		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.8	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	21		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.9		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C505742-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.051	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6310		39.0	100	ug/L	EPA 6010C	
Chloride	8.8		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	2.03	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	1970		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2500		150	500	ug/L	EPA 6010C	
Sodium - Total	7010		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.2	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	19		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	6.0		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC 50 Dissolved **Lab ID: C505742-06**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	1.75	J	1.60	10.0	ug/L	EPA 6010C	

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ANALYTICAL RESULTS

Description:	NC 210	**Lab Sample ID:**	C505742-01	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 13:25	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Calcium [7440-70-2]^	**5790**		ug/L	1	39.0	100	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Copper [7440-50-8]^	**2.01**	J	ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Magnesium [7439-95-4]^	**2270**		ug/L	1	29.0	100	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Potassium [7440-09-7]^	**2360**		ug/L	1	150	500	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Sodium [7440-23-5]^	**7070**		ug/L	1	400	500	5E18026	EPA 6010C	05/20/15 11:06	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5E18026	EPA 6010C	05/20/15 11:06	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.060**	J	mg/L	1	0.045	0.10	5E13001	EPA 350.1	05/13/15 09:57	SHA	
Chloride [16887-00-6]^	**7.1**		mg/L	1	2.2	5.0	5E13007	EPA 300.0	05/13/15 22:01	AJB	
Sulfate as SO4 [14808-79-8]^	**3.8**	J	mg/L	1	2.9	5.0	5E13007	EPA 300.0	05/13/15 22:01	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**25**		mg/L	1	14	15	5E08009	EPA 310.2	05/08/15 13:10	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.3**		mg/L	1	0.34	1.0	5E19004	SM 5310B-2000	05/19/15 16:44	RSA	

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ANALYTICAL RESULTS

Description:	SR 1555	**Lab Sample ID:**	C505742-02	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 13:55	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Calcium [7440-70-2]^	**5460**		ug/L	1	39.0	100	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Magnesium [7439-95-4]^	**2030**		ug/L	1	29.0	100	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Potassium [7440-09-7]^	**2160**		ug/L	1	150	500	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Sodium [7440-23-5]^	**7500**		ug/L	1	400	500	5E18026	EPA 6010C	05/20/15 12:03	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5E18026	EPA 6010C	05/20/15 12:03	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.078**	J	mg/L	1	0.045	0.10	5E13001	EPA 350.1	05/13/15 09:59	SHA	
Chloride [16887-00-6]^	**7.3**		mg/L	1	2.2	5.0	5E13007	EPA 300.0	05/13/15 22:19	AJB	
Sulfate as SO4 [14808-79-8]^	**3.8**	J	mg/L	1	2.9	5.0	5E13007	EPA 300.0	05/13/15 22:19	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**21**		mg/L	1	14	15	5E08009	EPA 310.2	05/08/15 13:10	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.9**		mg/L	1	0.34	1.0	5E19004	SM 5310B-2000	05/19/15 16:44	RSA	

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ANALYTICAL RESULTS

Description:	NC-50	**Lab Sample ID:**	C505742-03	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 14:30	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Calcium [7440-70-2]^	**6310**		ug/L	1	39.0	100	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Copper [7440-50-8]^	**2.03**	J	ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Magnesium [7439-95-4]^	**1970**		ug/L	1	29.0	100	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Potassium [7440-09-7]^	**2500**		ug/L	1	150	500	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Sodium [7440-23-5]^	**7010**		ug/L	1	400	500	5E18026	EPA 6010C	05/20/15 12:06	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5E18026	EPA 6010C	05/20/15 12:06	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.051**	J	mg/L	1	0.045	0.10	5E13001	EPA 350.1	05/13/15 10:01	SHA	
Chloride [16887-00-6]^	**8.8**		mg/L	1	2.2	5.0	5E13007	EPA 300.0	05/13/15 22:36	AJB	
Sulfate as SO4 [14808-79-8]^	**4.2**	J	mg/L	1	2.9	5.0	5E13007	EPA 300.0	05/13/15 22:36	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**19**		mg/L	1	14	15	5E08009	EPA 310.2	05/08/15 13:11	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**6.0**		mg/L	1	0.34	1.0	5E19004	SM 5310B-2000	05/19/15 16:44	RSA	

Description:	NC 210 Dissolved	**Lab Sample ID:**	C505742-04	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 13:25	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 12:08	JDH	

Description:	SR 1555 Dissolved	**Lab Sample ID:**	C505742-05	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 13:55	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 12:11	JDH	

Description:	NC 50 Dissolved	**Lab Sample ID:**	C505742-06	**Received:**	05/07/15 15:17
Matrix:	Water	**Sampled:**	05/07/15 14:30	**Work Order:**	C505742
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**1.75**	J	ug/L	1	1.60	10.0	5E18026	EPA 6010C	05/20/15 12:13	JDH	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5E18026 - EPA 3005A

Blank (5E18026-BLK1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 10:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	3.10	U	10.0	ug/L							
Magnesium	29.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (5E18026-BS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.6		1.00	ug/L	20.0		98	80-120			
Calcium	2180		100	ug/L	2000		109	80-120			
Copper	198		10.0	ug/L	200		99	80-120			
Lead	208		10.0	ug/L	200		104	80-120			
Magnesium	2020		100	ug/L	2000		101	80-120			
Nickel	202		10.0	ug/L	200		101	80-120			
Potassium	10400		500	ug/L	10000		104	80-120			
Sodium	9990		500	ug/L	10000		100	80-120			
Zinc	207		10.0	ug/L	200		104	80-120			

Matrix Spike (5E18026-MS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:09

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	18.8		1.00	ug/L	20.0	0.360 U	94	75-125			
Calcium	7640		100	ug/L	2000	5790	93	75-125			
Copper	190		10.0	ug/L	200	2.01	94	75-125			
Lead	198		10.0	ug/L	200	3.10 U	99	75-125			
Magnesium	4200		100	ug/L	2000	2270	97	75-125			
Nickel	193		10.0	ug/L	200	1.80 U	96	75-125			
Potassium	12100		500	ug/L	10000	2360	98	75-125			
Sodium	16900		500	ug/L	10000	7070	98	75-125			
Zinc	199		10.0	ug/L	200	3.80 U	100	75-125			

Matrix Spike Dup (5E18026-MSD1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:11

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	18.7		1.00	ug/L	20.0	0.360 U	94	75-125	0.6	20	
Calcium	7600		100	ug/L	2000	5790	91	75-125	0.6	20	
Copper	190		10.0	ug/L	200	2.01	94	75-125	0.09	20	
Lead	197		10.0	ug/L	200	3.10 U	99	75-125	0.4	20	
Magnesium	4180		100	ug/L	2000	2270	96	75-125	0.4	20	
Nickel	193		10.0	ug/L	200	1.80 U	97	75-125	0.2	20	
Potassium	12100		500	ug/L	10000	2360	97	75-125	0.5	20	
Sodium	16700		500	ug/L	10000	7070	96	75-125	1	20	
Zinc	200		10.0	ug/L	200	3.80 U	100	75-125	0.5	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5E18026 - EPA 3005A - Continued

Post Spike (5E18026-PS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:14

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0187		0.00100	mg/L	0.0200	-0.000124	93	80-120			
Calcium	7.63		0.100	mg/L	2.00	5.79	92	80-120			
Copper	0.190		0.0100	mg/L	0.200	0.00201	94	80-120			
Lead	0.198		0.0100	mg/L	0.200	-0.000677	99	80-120			
Magnesium	4.16		0.100	mg/L	2.00	2.27	95	80-120			
Nickel	0.192		0.0100	mg/L	0.200	0.000347	96	80-120			
Potassium	12.0		0.500	mg/L	10.0	2.36	97	80-120			
Sodium	16.5		0.500	mg/L	10.0	7.07	95	80-120			
Zinc	0.200		0.0100	mg/L	0.200	0.00366	98	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5E18026 - EPA 3005A

Blank (5E18026-BLK1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 10:48

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

Blank (5E18026-BLK2) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 10:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (5E18026-BS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:03

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	198		10.0	ug/L	200		99	80-120			

Matrix Spike (5E18026-MS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:09

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	190		10.0	ug/L	200	2.01	94	75-125			

Matrix Spike Dup (5E18026-MSD1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:11

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	190		10.0	ug/L	200	2.01	94	75-125	0.09	20	

Post Spike (5E18026-PS1) Prepared: 05/18/2015 16:30 Analyzed: 05/20/2015 11:14

Source: C505742-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.190		0.0100	mg/L	0.200	0.00201	94	80-120			

Classical Chemistry Parameters - Quality Control

Batch 5E08009 - NO PREP

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5E08009 - NO PREP - Continued

Blank (5E08009-BLK1) Prepared: 05/08/2015 09:38 Analyzed: 05/08/2015 12:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5E08009-BS1) Prepared: 05/08/2015 09:38 Analyzed: 05/08/2015 12:55

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	100		15	mg/L	100		101	80-120			

Matrix Spike (5E08009-MS1) Prepared: 05/08/2015 09:38 Analyzed: 05/08/2015 12:56

Source: C504821-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	J	15	mg/L	37.8	14 U		80-120			QM-05

Matrix Spike Dup (5E08009-MSD1) Prepared: 05/08/2015 09:38 Analyzed: 05/08/2015 12:58

Source: C504821-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	15		15	mg/L	37.8	14 U	39	80-120		25	QM-05

Batch 5E13001 - NO PREP

Blank (5E13001-BLK1) Prepared: 05/13/2015 07:21 Analyzed: 05/13/2015 09:05

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5E13001-BS1) Prepared: 05/13/2015 07:21 Analyzed: 05/13/2015 09:07

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.98		0.10	mg/L	0.997		99	90-110			

Matrix Spike (5E13001-MS1) Prepared: 05/13/2015 07:21 Analyzed: 05/13/2015 09:09

Source: C402499-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.58		0.10	mg/L	0.387	0.23	91	90-110			

Matrix Spike (5E13001-MS2) Prepared: 05/13/2015 07:21 Analyzed: 05/13/2015 09:17

Source: C503988-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	150		10	mg/L	39.8	120	85	90-110			QM-05

Matrix Spike Dup (5E13001-MSD1) Prepared: 05/13/2015 07:21 Analyzed: 05/13/2015 09:13

Source: C402499-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.57		0.10	mg/L	0.387	0.23	88	90-110	2	10	QM-05

Batch 5E13007 - NO PREP

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5E13007 - NO PREP - Continued

Blank (5E13007-BLK1) Prepared & Analyzed: 05/13/2015 13:15

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (5E13007-BS1) Prepared & Analyzed: 05/13/2015 12:58

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	53		5.0	mg/L	50.0		106	90-110			
Sulfate as SO4	51		5.0	mg/L	50.0		101	90-110			

Matrix Spike (5E13007-MS2) Prepared & Analyzed: 05/14/2015 05:19

Source: C505175-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	73		5.0	mg/L	20.0	51	112	90-110			QM-05

Matrix Spike (5E13007-MS3) Prepared & Analyzed: 05/13/2015 14:43

Source: C504888-02RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	710		50	mg/L	200	480	119	90-110			QM-05
Sulfate as SO4	340		50	mg/L	200	130	102	90-110			

Matrix Spike (5E13007-MS4) Prepared & Analyzed: 05/13/2015 15:18

Source: C505175-01RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Sulfate as SO4	1600		100	mg/L	400	1100	114	90-110			QM-05

Matrix Spike Dup (5E13007-MSD3) Prepared & Analyzed: 05/13/2015 15:01

Source: C504888-02RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	700		50	mg/L	200	480	112	90-110	2	10	QM-05
Sulfate as SO4	330		50	mg/L	200	130	100	90-110	1	10	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5E19004 - NO PREP

Blank (5E19004-BLK1) Prepared: 05/19/2015 08:25 Analyzed: 05/19/2015 16:44

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.34	U	1.0	mg/L							

LCS (5E19004-BS1) Prepared: 05/19/2015 08:25 Analyzed: 05/19/2015 16:44

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	38		1.0	mg/L	40.0		96	85-115			

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QUALITY CONTROL DATA

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5E19004 - NO PREP - Continued

Matrix Spike (5E19004-MS1) Prepared: 05/19/2015 08:25 Analyzed: 05/19/2015 16:44

Source: A502833-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	54		1.0	mg/L	40.0	6.9	119	85-115			QM-07

Matrix Spike Dup (5E19004-MSD1) Prepared: 05/19/2015 08:25 Analyzed: 05/19/2015 16:44

Source: A502833-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	56		1.0	mg/L	40.0	6.9	124	85-115	3	21	QM-07

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FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-07	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.

ENCO ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

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10775 Central Port Dr. Orlando, FL 32824 (407) 826-5314 Fax (407) 850-6945

4810 Executive Park Court, Suite 211 Jacksonville, FL 32216-6069 (904) 296-3007 Fax (904) 296-6210

102-A Woodwinds Industrial Ct. Cary, NC 27511 (919) 467-3090 Fax (919) 467-3515

Page ___ of ___

Client Name: The Catena Group	Project Number:
Address: 1000 Corporate Drive, Suite 101	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough, NC 27278	PO # / Billing Info:
Tel: (919) 732-1300 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print):	Billing Contact:
Sampler(s) Signature: NScott	Site Location / Time Zone:

Requested Analyses: Alkalinity 310.2, Chloride 300 | Ammonia 350.1 | Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn | Cu/F | Sulfate 300 | TOC SM310B Dissolved

Preservation (See Codes) (Combine as necessary)

Requested Turnaround Times

Note : Rush requests subject to acceptance by the facility

___ Standard

___ Expedited

Due ___/___/___

Lab Workorder: C505742

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2, Chloride 300	Ammonia 350.1	Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn	Cu/F	Sulfate 300	TOC SM310B Dissolved					Sample Comments
	NC 210	5/7/15	13:25		SW	6	/	/	/	/	/	/					
	SR 1555	5/7/15	13:55		SW	6	/	/	/	/	/	/					
	NC 50	5/7/15	14:30		SW	6	/	/	/	/	/	/					

<-- Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By: NScott	Date/Time: 5/7/15 3:17	Received By:	Date/Time: 5-7-15 1517
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By	Date/Time
		Cooler #'s & Temps on Receipt: 4.0°		Condition Upon Receipt: ✓ Acceptable ___ Unacceptable	

Matrix : **GW**-Groundwater **SO**-Soil **DW**-Drinking Water **SE**-Sediment **SW**-Surface Water **WW**-Wastewater **A**-Air **O**-Other (detail in comments) **Preservation: I**-Ice **H**-HCl **N**-HNO3 **S**-H2SO4 **NO**-NaOH **O**-Other (detail in comments)

Note : All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist

Sample Preservation Verification

ENCO Cary

Work Order:	C505742	Project:	Swift Creek Water Quality
Client:	The Catena Group (TH015)	Project #:	[none]
Logged In:	07-May-15 15:55	Logged By:	Andrew S Coons

C505742-01

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C505742-02

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C505742-03

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

	Reagent Name	ID
1		
2		

	Reagent Name	ID
3		
4		

	Reagent Name	ID
5		
6		

ENCO Laboratories

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102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Tuesday, June 23, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C505697

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Tuesday, June 9, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC-210 | **Lab ID: C505697-01** | **Sampled: 06/09/15 12:05** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	07/07/15	06/11/15 08:53	06/11/15 14:29
EPA 310.2	06/23/15	06/15/15 07:48	06/15/15 09:22
EPA 350.1	07/07/15	06/17/15 10:24	06/17/15 12:43
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:46
SM 5310B-2000	07/07/15	06/18/15 11:15	06/18/15 12:09

Client ID: SR-1555 | **Lab ID: C505697-02** | **Sampled: 06/09/15 12:45** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	07/07/15	06/11/15 08:53	06/11/15 14:46
EPA 310.2	06/23/15	06/15/15 07:48	06/15/15 08:54
EPA 350.1	07/07/15	06/17/15 10:24	06/17/15 12:45
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:49
SM 5310B-2000	07/07/15	06/18/15 11:15	06/18/15 12:09

Client ID: NC-50 | **Lab ID: C505697-03** | **Sampled: 06/09/15 13:25** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 300.0	07/07/15	06/11/15 08:53	06/11/15 15:03
EPA 310.2	06/23/15	06/15/15 07:48	06/15/15 08:57
EPA 350.1	07/07/15	06/17/15 10:24	06/17/15 12:47
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:51
SM 5310B-2000	07/07/15	06/18/15 11:15	06/18/15 12:09

Client ID: NC-210 Dissolved | **Lab ID: C505697-04** | **Sampled: 06/09/15 12:05** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:54

Client ID: SR-1555 Dissolved | **Lab ID: C505697-05** | **Sampled: 06/09/15 12:45** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:56

Client ID: NC-50 Dissolved | **Lab ID: C505697-06** | **Sampled: 06/09/15 13:25** | **Received: 06/09/15 14:30**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)	Analysis Date/Time(s)
EPA 6010C	12/06/15	06/15/15 11:10	06/18/15 13:59

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SAMPLE DETECTION SUMMARY

Client ID: NC-210 **Lab ID: C505697-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Cadmium - Total	0.360	J	0.360	1.00	ug/L	EPA 6010C	
Calcium - Total	7030	B	39.0	100	ug/L	EPA 6010C	QB-01
Chloride	7.5		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	1.74	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	2490		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2310		150	500	ug/L	EPA 6010C	
Sodium - Total	8030		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.3	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	23		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.3		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: SR-1555 **Lab ID: C505697-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	6870	B	39.0	100	ug/L	EPA 6010C	QB-01
Chloride	7.2		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	1.69	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	2180		29.0	100	ug/L	EPA 6010C	
Nickel - Total	2.02	J	1.80	10.0	ug/L	EPA 6010C	
Potassium - Total	2080		150	500	ug/L	EPA 6010C	
Sodium - Total	8520		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.2	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	32		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	4.2		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C505697-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.072	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	8180	B	39.0	100	ug/L	EPA 6010C	QB-01
Chloride	9.9		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	5.53	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	2400		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2990		150	500	ug/L	EPA 6010C	
Sodium - Total	8240		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.1	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	30		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.9		0.34	1.0	mg/L	SM 5310B-2000	
Zinc - Total	16.7		3.80	10.0	ug/L	EPA 6010C	

Client ID: NC-210 Dissolved **Lab ID: C505697-04**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	1.66	J	1.60	10.0	ug/L	EPA 6010C	

Client ID: NC-50 Dissolved **Lab ID: C505697-06**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Copper - Dissolved	2.79	J	1.60	10.0	ug/L	EPA 6010C	

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ANALYTICAL RESULTS

Description: NC-210 **Lab Sample ID:** C505697-01 **Received:** 06/09/15 14:30

Matrix: Water **Sampled:** 06/09/15 12:05 **Work Order:** C505697

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	**0.360**	J	ug/L	1	0.360	1.00	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Calcium [7440-70-2]^	**7030**	B	ug/L	1	39.0	100	5F15026	EPA 6010C	06/18/15 13:46	JDH	QB-01
Copper [7440-50-8]^	**1.74**	J	ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Magnesium [7439-95-4]^	**2490**		ug/L	1	29.0	100	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Potassium [7440-09-7]^	**2310**		ug/L	1	150	500	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Sodium [7440-23-5]^	**8030**		ug/L	1	400	500	5F15026	EPA 6010C	06/18/15 13:46	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5F15026	EPA 6010C	06/18/15 13:46	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5F17014	EPA 350.1	06/17/15 12:43	SHA	
Chloride [16887-00-6]^	**7.5**		mg/L	1	2.2	5.0	5F11013	EPA 300.0	06/11/15 14:29	AJB	
Sulfate as SO4 [14808-79-8]^	**3.3**	J	mg/L	1	2.9	5.0	5F11013	EPA 300.0	06/11/15 14:29	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**23**		mg/L	1	14	15	5F15009	EPA 310.2	06/15/15 09:22	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.3**		mg/L	1	0.34	1.0	5F18004	SM 5310B-2000	06/18/15 12:09	RSA	

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ANALYTICAL RESULTS

Description: SR-1555 **Lab Sample ID:** C505697-02 **Received:** 06/09/15 14:30

Matrix: Water **Sampled:** 06/09/15 12:45 **Work Order:** C505697

Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Calcium [7440-70-2]^	**6870**	B	ug/L	1	39.0	100	5F15026	EPA 6010C	06/18/15 13:49	JDH	QB-01
Copper [7440-50-8]^	**1.69**	J	ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Magnesium [7439-95-4]^	**2180**		ug/L	1	29.0	100	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Nickel [7440-02-0]^	**2.02**	J	ug/L	1	1.80	10.0	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Potassium [7440-09-7]^	**2080**		ug/L	1	150	500	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Sodium [7440-23-5]^	**8520**		ug/L	1	400	500	5F15026	EPA 6010C	06/18/15 13:49	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5F15026	EPA 6010C	06/18/15 13:49	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5F17014	EPA 350.1	06/17/15 12:45	SHA	
Chloride [16887-00-6]^	**7.2**		mg/L	1	2.2	5.0	5F11013	EPA 300.0	06/11/15 14:46	AJB	
Sulfate as SO4 [14808-79-8]^	**3.2**	J	mg/L	1	2.9	5.0	5F11013	EPA 300.0	06/11/15 14:46	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**32**		mg/L	1	14	15	5F15008	EPA 310.2	06/15/15 08:54	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**4.2**		mg/L	1	0.34	1.0	5F18004	SM 5310B-2000	06/18/15 12:09	RSA	

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ANALYTICAL RESULTS

Description: NC-50 **Lab Sample ID:** C505697-03 **Received:** 06/09/15 14:30
Matrix: Water **Sampled:** 06/09/15 13:25 **Work Order:** C505697
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Calcium [7440-70-2]^	**8180**	B	ug/L	1	39.0	100	5F15026	EPA 6010C	06/18/15 13:51	JDH	QB-01
Copper [7440-50-8]^	**5.53**	J	ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Magnesium [7439-95-4]^	**2400**		ug/L	1	29.0	100	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Potassium [7440-09-7]^	**2990**		ug/L	1	150	500	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Sodium [7440-23-5]^	**8240**		ug/L	1	400	500	5F15026	EPA 6010C	06/18/15 13:51	JDH	
Zinc [7440-66-6]^	**16.7**		ug/L	1	3.80	10.0	5F15026	EPA 6010C	06/18/15 13:51	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.072**	J	mg/L	1	0.045	0.10	5F17014	EPA 350.1	06/17/15 12:47	SHA	
Chloride [16887-00-6]^	**9.9**		mg/L	1	2.2	5.0	5F11013	EPA 300.0	06/11/15 15:03	AJB	
Sulfate as SO4 [14808-79-8]^	**4.1**	J	mg/L	1	2.9	5.0	5F11013	EPA 300.0	06/11/15 15:03	AJB	
Total Alkalinity as CaCO3 [471-34-1]^	**30**		mg/L	1	14	15	5F15008	EPA 310.2	06/15/15 08:57	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.9**		mg/L	1	0.34	1.0	5F18004	SM 5310B-2000	06/18/15 12:09	RSA	

Description: NC-210 Dissolved **Lab Sample ID:** C505697-04 **Received:** 06/09/15 14:30
Matrix: Water **Sampled:** 06/09/15 12:05 **Work Order:** C505697
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**1.66**	J	ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:54	JDH	

Description: SR-1555 Dissolved **Lab Sample ID:** C505697-05 **Received:** 06/09/15 14:30
Matrix: Water **Sampled:** 06/09/15 12:45 **Work Order:** C505697
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:56	JDH	

Description: NC-50 Dissolved **Lab Sample ID:** C505697-06 **Received:** 06/09/15 14:30
Matrix: Water **Sampled:** 06/09/15 13:25 **Work Order:** C505697
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	**2.79**	J	ug/L	1	1.60	10.0	5F15026	EPA 6010C	06/18/15 13:59	JDH	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5F15026 - EPA 3005A

Blank (5F15026-BLK1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 12:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	**42.7**	**J**	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	3.10	U	10.0	ug/L							
Magnesium	29.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (5F15026-BS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.6		1.00	ug/L	20.0		98	80-120			
Calcium	2180	B	100	ug/L	2000		109	80-120			
Copper	193		10.0	ug/L	200		97	80-120			
Lead	200		10.0	ug/L	200		100	80-120			
Magnesium	2020		100	ug/L	2000		101	80-120			
Nickel	198		10.0	ug/L	200		99	80-120			
Potassium	10500		500	ug/L	10000		105	80-120			
Sodium	9740		500	ug/L	10000		97	80-120			
Zinc	199		10.0	ug/L	200		100	80-120			

Matrix Spike (5F15026-MS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:14

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.2		1.00	ug/L	20.0	0.360 U	96	75-125			
Calcium	21900	B	100	ug/L	2000	19800	105	75-125			
Copper	197		10.0	ug/L	200	1.60 U	99	75-125			
Lead	201		10.0	ug/L	200	3.10 U	101	75-125			
Magnesium	7200		100	ug/L	2000	5090	105	75-125			
Nickel	204		10.0	ug/L	200	5.00	100	75-125			
Potassium	13400		500	ug/L	10000	3080	103	75-125			
Sodium	42600		500	ug/L	10000	31200	114	75-125			
Zinc	201		10.0	ug/L	200	3.80 U	101	75-125			

Matrix Spike Dup (5F15026-MSD1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:17

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.3		1.00	ug/L	20.0	0.360 U	96	75-125	0.1	20	
Calcium	21700	B	100	ug/L	2000	19800	91	75-125	1	20	
Copper	195		10.0	ug/L	200	1.60 U	97	75-125	1	20	
Lead	202		10.0	ug/L	200	3.10 U	101	75-125	0.1	20	
Magnesium	7000		100	ug/L	2000	5090	96	75-125	3	20	
Nickel	201		10.0	ug/L	200	5.00	98	75-125	1	20	
Potassium	13200		500	ug/L	10000	3080	101	75-125	2	20	
Sodium	41600		500	ug/L	10000	31200	104	75-125	2	20	
Zinc	200		10.0	ug/L	200	3.80 U	100	75-125	0.6	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5F15026 - EPA 3005A - Continued

Post Spike (5F15026-PS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:41

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0190		0.00100	mg/L	0.0200	-0.000294	95	80-120			
Calcium	21.3	B	0.100	mg/L	2.00	19.8	71	80-120			QM-08
Copper	0.196		0.0100	mg/L	0.200	0.00137	97	80-120			
Lead	0.196		0.0100	mg/L	0.200	0.000683	98	80-120			
Magnesium	6.66		0.100	mg/L	2.00	5.09	79	80-120			QM-08
Nickel	0.199		0.0100	mg/L	0.200	0.00500	97	80-120			
Potassium	14.1		0.500	mg/L	10.0	3.08	110	80-120			
Sodium	42.8		0.500	mg/L	10.0	31.2	117	80-120			
Zinc	0.198		0.0100	mg/L	0.200	0.00284	98	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5F15026 - EPA 3005A

Blank (5F15026-BLK2) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 12:58

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (5F15026-BS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	193		10.0	ug/L	200		97	80-120			

Matrix Spike (5F15026-MS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:14

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	197		10.0	ug/L	200	1.60 U	99	75-125			

Matrix Spike Dup (5F15026-MSD1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:17

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	195		10.0	ug/L	200	1.60 U	97	75-125	1	20	

Post Spike (5F15026-PS1) Prepared: 06/15/2015 11:10 Analyzed: 06/18/2015 13:41

Source: C506306-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.196		0.0100	mg/L	0.200	0.00137	97	80-120			

Classical Chemistry Parameters - Quality Control

Batch 5F11013 - NO PREP

Blank (5F11013-BLK1) Prepared: 06/11/2015 08:53 Analyzed: 06/11/2015 11:12

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5F11013 - NO PREP - Continued

LCS (5F11013-BS1) Prepared: 06/11/2015 08:53 Analyzed: 06/11/2015 12:30

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	53		5.0	mg/L	50.0		106	90-110			
Sulfate as SO4	51		5.0	mg/L	50.0		101	90-110			

Matrix Spike (5F11013-MS1) Prepared: 06/11/2015 08:53 Analyzed: 06/12/2015 00:36

Source: C506986-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	45		5.0	mg/L	20.0	23	112	90-110			QM-05
Sulfate as SO4	57		5.0	mg/L	20.0	35	109	90-110			

Matrix Spike (5F11013-MS2) Prepared: 06/11/2015 08:53 Analyzed: 06/11/2015 13:21

Source: C502650-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	41		5.0	mg/L	20.0	19	109	90-110			
Sulfate as SO4	68		5.0	mg/L	20.0	46	112	90-110			QM-05

Matrix Spike Dup (5F11013-MSD1) Prepared: 06/11/2015 08:53 Analyzed: 06/11/2015 13:04

Source: C506986-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	45		5.0	mg/L	20.0	23	111	90-110	0.09	10	QM-05
Sulfate as SO4	57		5.0	mg/L	20.0	35	108	90-110	0.1	10	

Batch 5F15008 - NO PREP

Blank (5F15008-BLK1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 08:00

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5F15008-BS1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 08:11

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	97		15	mg/L	100		97	80-120			

Matrix Spike (5F15008-MS1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 08:54

Source: C506986-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	26		15	mg/L	37.8	14 U	68	80-120			QM-05

Matrix Spike Dup (5F15008-MSD1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 08:56

Source: C506986-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	23		15	mg/L	37.8	14 U	61	80-120	11	25	QM-05

Batch 5F15009 - NO PREP

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5F15009 - NO PREP - Continued

Blank (5F15009-BLK1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 09:17

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5F15009-BS1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 09:18

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	95		15	mg/L	100		95	80-120			

Matrix Spike (5F15009-MS1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 10:01

Source: C504935-01RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	25		15	mg/L	37.8	14 U	66	80-120			QM-05

Matrix Spike Dup (5F15009-MSD1) Prepared: 06/15/2015 07:48 Analyzed: 06/15/2015 10:03

Source: C504935-01RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	27		15	mg/L	37.8	14 U	72	80-120	9	25	QM-05

Batch 5F17014 - NO PREP

Blank (5F17014-BLK1) Prepared: 06/17/2015 10:24 Analyzed: 06/17/2015 12:28

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5F17014-BS1) Prepared: 06/17/2015 10:24 Analyzed: 06/17/2015 12:30

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	1.1		0.10	mg/L	0.997		105	90-110			

Matrix Spike (5F17014-MS1) Prepared: 06/17/2015 10:24 Analyzed: 06/17/2015 12:32

Source: C402500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.41		0.10	mg/L	0.387	0.070	87	90-110			QM-05

Matrix Spike (5F17014-MS2) Prepared: 06/17/2015 10:24 Analyzed: 06/17/2015 12:40

Source: C502677-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.93		0.10	mg/L	0.387	0.62	79	90-110			QM-05

Matrix Spike Dup (5F17014-MSD1) Prepared: 06/17/2015 10:24 Analyzed: 06/17/2015 12:36

Source: C402500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.33		0.10	mg/L	0.387	0.070	66	90-110	22	10	QM-05, QM-11

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5F18004 - NO PREP

QUALITY CONTROL DATA

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5F18004 - NO PREP - Continued

Blank (5F18004-BLK1) Prepared: 06/18/2015 11:15 Analyzed: 06/18/2015 12:09

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.34	U	1.0	mg/L							

LCS (5F18004-BS1) Prepared: 06/18/2015 11:15 Analyzed: 06/18/2015 12:09

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	37		1.0	mg/L	40.0		93	85-115			

Matrix Spike (5F18004-MS1) Prepared: 06/18/2015 11:15 Analyzed: 06/18/2015 12:09

Source: A503583-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	49		1.0	mg/L	40.0	8.9	101	85-115			

Matrix Spike Dup (5F18004-MSD1) Prepared: 06/18/2015 11:15 Analyzed: 06/18/2015 12:09

Source: A503583-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	49		1.0	mg/L	40.0	8.9	101	85-115	0.2	21	

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FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QB-01	The method blank had a positive result for the analyte; however, the concentration in the method blank is less than 10% of the sample result, which minimizes the impact of the deviation.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-08	Post-digestion spike did not meet method requirements due to confirmed matrix effects (dilution test).
QM-11	Precision between duplicate matrix spikes of the same sample was outside acceptance limits.

ENCO

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(407) 826-5314 Fax (407) 850-6945	(904) 296-3007 Fax (904) 296-6210	(919) 467-3090 Fax (919) 467-3515

Client Name: The Catena Group (TH015)	Project Number: [none]
Address: 1000 Corporate Dr. Suite 101 ~~410-B Millstone Drive~~	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough, NC 27278	PO # / Billing Info:
Tel: (919) 417-2732 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print): N. Scott	Billing Contact: Nancy Scott
Sampler(s) Signature: NScott	Site Location / Time Zone:

Requested Analyses: Alkalinity 310.2,Chloride 300; Ammonia 350.1; Ca,Cd,Cu,K,Mg,Na,Ni,Pb,Zn; Cu/F; Sulfate 300; TOC SM5310B Dissolved

Preservation (See Codes) (Combine as necessary)

Requested Turnaround Times

Note : Rush requests subject acceptance by the facility

___ Standard

___ Expedited

Due __/__/__

Lab Workorder: C505697

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2,Chloride 300	Ammonia 350.1	Ca,Cd,Cu,K,Mg,Na,Ni,Pb,Zn	Cu/F	Sulfate 300	TOC SM5310B Dissolved					Sample Comments
	NC-210	6/9/15	12:05		WA	6	X	X	X	X	X	X					
	SR-1555		12:45		WA	6	X	X	X	X	X	X					
	NC-50		1:25		WA	6	X	X	X	X	X	X					
					WA	6	X	X	X	X	X	X					
					WA	6	X	X	X	X	X	X					
					WA	6	X	X	X	X	X	X					
					WA	6	X	X	X	X	X	X					
					WA	6	X	X	X	X	X	X					

<-- Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By: NScott	Date/Time: 6/9/15 2:30	Received By	Date/Time
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By: [signature]	Date/Time: 6/9/15 230
		Cooler #'s & Temps on Receipt: 2°C		Condition Upon Receipt: ✓ Acceptable ___ Unacceptable	

Matrix : GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments) Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note : All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist

Sample Preservation Verification

ENCO Cary

Work Order:	C505697	Project:	Swift Creek Water Quality
Client:	The Catena Group (TH015)	Project #:	[none]
Logged In:	09-Jun-15 15:13	Logged By:	John C King

C505697-01

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
B	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C505697-02

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
B	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C505697-03

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
B	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

	Reagent Name	ID
1		
2		

	Reagent Name	ID
3		
4		

	Reagent Name	ID
5		
6		

102-A Woodwinds Industrial Court
Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Thursday, July 16, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C508411

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Wednesday, July 1, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

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SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC 210 | **Lab ID: C508411-01** | **Sampled: 07/01/15 09:10** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	07/29/15	07/07/15	09:00	07/07/15 19:53
EPA 310.2	07/15/15	07/02/15	12:24	07/02/15 14:10
EPA 350.1	07/29/15	07/08/15	09:12	07/08/15 11:09
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 14:02
SM 5310B-2000	07/29/15	07/15/15	10:00	07/15/15 11:20

Client ID: SR1555 | **Lab ID: C508411-02** | **Sampled: 07/01/15 11:20** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	07/29/15	07/07/15	09:00	07/07/15 20:10
EPA 310.2	07/15/15	07/02/15	12:24	07/02/15 14:11
EPA 350.1	07/29/15	07/08/15	09:12	07/08/15 11:11
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 15:02
SM 5310B-2000	07/29/15	07/15/15	10:00	07/15/15 11:20

Client ID: NC 50 | **Lab ID: C508411-03** | **Sampled: 07/01/15 13:15** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	07/29/15	07/07/15	09:00	07/07/15 21:01
EPA 310.2	07/15/15	07/02/15	12:24	07/02/15 14:11
EPA 350.1	07/29/15	07/08/15	09:12	07/08/15 11:14
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 15:05
SM 5310B-2000	07/29/15	07/15/15	10:00	07/15/15 11:20

Client ID: NC 210 Dissolved | **Lab ID: C508411-04** | **Sampled: 07/01/15 09:10** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 15:08

Client ID: SR 1555 Dissolved | **Lab ID: C508411-05** | **Sampled: 07/01/15 11:20** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 15:10

Client ID: NC 50 Dissolved | **Lab ID: C508411-06** | **Sampled: 07/01/15 13:15** | **Received: 07/01/15 14:36**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	12/28/15	07/02/15	08:40	07/06/15 15:13

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SAMPLE DETECTION SUMMARY

Client ID: NC 210 **Lab ID: C508411-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	7000		39.0	100	ug/L	EPA 6010C	
Chloride	8.5		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2420	B	29.0	100	ug/L	EPA 6010C	QB-01
Potassium - Total	2650		150	500	ug/L	EPA 6010C	
Sodium - Total	7640		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.9	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	23		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.7		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: SR1555 **Lab ID: C508411-02**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.073	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6890		39.0	100	ug/L	EPA 6010C	
Chloride	8.5		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2350	B	29.0	100	ug/L	EPA 6010C	QB-01
Potassium - Total	2550		150	500	ug/L	EPA 6010C	
Sodium - Total	7550		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.8	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	29		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.3		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC 50 **Lab ID: C508411-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	7470		39.0	100	ug/L	EPA 6010C	
Chloride	9.7		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2400	B	29.0	100	ug/L	EPA 6010C	QB-01
Potassium - Total	2720		150	500	ug/L	EPA 6010C	
Sodium - Total	7800		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.1	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	27		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.9		0.34	1.0	mg/L	SM 5310B-2000	
Zinc - Total	4.09	J	3.80	10.0	ug/L	EPA 6010C	

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ANALYTICAL RESULTS

Description: NC 210 | **Lab Sample ID:** C508411-01 | **Received:** 07/01/15 14:36
Matrix: Water | **Sampled:** 07/01/15 09:10 | **Work Order:** C508411
Project: Swift Creek Water Quality | **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Calcium [7440-70-2]^	**7000**		ug/L	1	39.0	100	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Magnesium [7439-95-4]^	**2420**	B	ug/L	1	29.0	100	5G02007	EPA 6010C	07/06/15 14:02	JDH	QB-01
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Potassium [7440-09-7]^	**2650**		ug/L	1	150	500	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Sodium [7440-23-5]^	**7640**		ug/L	1	400	500	5G02007	EPA 6010C	07/06/15 14:02	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5G02007	EPA 6010C	07/06/15 14:02	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5G08004	EPA 350.1	07/08/15 11:09	SHA	
Chloride [16887-00-6]^	**8.5**		mg/L	1	2.2	5.0	5G07010	EPA 300.0	07/07/15 19:53	SHA	
Sulfate as SO4 [14808-79-8]^	**3.9**	J	mg/L	1	2.9	5.0	5G07010	EPA 300.0	07/07/15 19:53	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**23**		mg/L	1	14	15	5G02027	EPA 310.2	07/02/15 14:10	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.7**		mg/L	1	0.34	1.0	5G15018	SM 5310B-2000	07/15/15 11:20	RSA	

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ANALYTICAL RESULTS

Description:	SR1555	**Lab Sample ID:**	C508411-02	**Received:**	07/01/15 14:36
Matrix:	Water	**Sampled:**	07/01/15 11:20	**Work Order:**	C508411
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Calcium [7440-70-2]^	**6890**		ug/L	1	39.0	100	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Magnesium [7439-95-4]^	**2350**	B	ug/L	1	29.0	100	5G02007	EPA 6010C	07/06/15 15:02	JDH	QB-01
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Potassium [7440-09-7]^	**2550**		ug/L	1	150	500	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Sodium [7440-23-5]^	**7550**		ug/L	1	400	500	5G02007	EPA 6010C	07/06/15 15:02	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5G02007	EPA 6010C	07/06/15 15:02	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.073**	J	mg/L	1	0.045	0.10	5G08004	EPA 350.1	07/08/15 11:11	SHA	
Chloride [16887-00-6]^	**8.5**		mg/L	1	2.2	5.0	5G07010	EPA 300.0	07/07/15 20:10	SHA	
Sulfate as SO4 [14808-79-8]^	**3.8**	J	mg/L	1	2.9	5.0	5G07010	EPA 300.0	07/07/15 20:10	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**29**		mg/L	1	14	15	5G02027	EPA 310.2	07/02/15 14:11	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.3**		mg/L	1	0.34	1.0	5G15018	SM 5310B-2000	07/15/15 11:20	RSA	

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ANALYTICAL RESULTS

Description: NC 50 **Lab Sample ID:** C508411-03 **Received:** 07/01/15 14:36
Matrix: Water **Sampled:** 07/01/15 13:15 **Work Order:** C508411
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Calcium [7440-70-2]^	**7470**		ug/L	1	39.0	100	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Magnesium [7439-95-4]^	**2400**	B	ug/L	1	29.0	100	5G02007	EPA 6010C	07/06/15 15:05	JDH	QB-01
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Potassium [7440-09-7]^	**2720**		ug/L	1	150	500	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Sodium [7440-23-5]^	**7800**		ug/L	1	400	500	5G02007	EPA 6010C	07/06/15 15:05	JDH	
Zinc [7440-66-6]^	**4.09**	J	ug/L	1	3.80	10.0	5G02007	EPA 6010C	07/06/15 15:05	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5G08004	EPA 350.1	07/08/15 11:14	SHA	
Chloride [16887-00-6]^	**9.7**		mg/L	1	2.2	5.0	5G07010	EPA 300.0	07/07/15 21:01	SHA	
Sulfate as SO4 [14808-79-8]^	**4.1**	J	mg/L	1	2.9	5.0	5G07010	EPA 300.0	07/07/15 21:01	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**27**		mg/L	1	14	15	5G02027	EPA 310.2	07/02/15 14:11	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.9**		mg/L	1	0.34	1.0	5G15018	SM 5310B-2000	07/15/15 11:20	RSA	

Description: NC 210 Dissolved **Lab Sample ID:** C508411-04 **Received:** 07/01/15 14:36
Matrix: Water **Sampled:** 07/01/15 09:10 **Work Order:** C508411
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 15:08	JDH	

Description: SR 1555 Dissolved **Lab Sample ID:** C508411-05 **Received:** 07/01/15 14:36
Matrix: Water **Sampled:** 07/01/15 11:20 **Work Order:** C508411
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 15:10	JDH	

Description: NC 50 Dissolved **Lab Sample ID:** C508411-06 **Received:** 07/01/15 14:36
Matrix: Water **Sampled:** 07/01/15 13:15 **Work Order:** C508411
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G02007	EPA 6010C	07/06/15 15:13	JDH	

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QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G02007 - EPA 3005A

Blank (5G02007-BLK1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 13:45

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	3.10	U	10.0	ug/L							
Magnesium	**38.9**	**J**	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (5G02007-BS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 13:58

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	21.2		1.00	ug/L	20.0		106	80-120			
Calcium	2270		100	ug/L	2000		113	80-120			
Copper	215		10.0	ug/L	200		108	80-120			
Lead	212		10.0	ug/L	200		106	80-120			
Magnesium	2120	B	100	ug/L	2000		106	80-120			
Nickel	213		10.0	ug/L	200		106	80-120			
Potassium	11100		500	ug/L	10000		111	80-120			
Sodium	10100		500	ug/L	10000		101	80-120			
Zinc	212		10.0	ug/L	200		106	80-120			

Matrix Spike (5G02007-MS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:04

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.4		1.00	ug/L	20.0	0.360 U	102	75-125			
Calcium	9000		100	ug/L	2000	7000	100	75-125			
Copper	210		10.0	ug/L	200	1.60 U	105	75-125			
Lead	204		10.0	ug/L	200	3.10 U	102	75-125			
Magnesium	4490	B	100	ug/L	2000	2420	103	75-125			
Nickel	205		10.0	ug/L	200	1.80 U	103	75-125			
Potassium	13300		500	ug/L	10000	2650	107	75-125			
Sodium	18100		500	ug/L	10000	7640	105	75-125			
Zinc	206		10.0	ug/L	200	3.80 U	103	75-125			

Matrix Spike Dup (5G02007-MSD1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:07

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.5		1.00	ug/L	20.0	0.360 U	102	75-125	0.3	20	
Calcium	8840		100	ug/L	2000	7000	92	75-125	2	20	
Copper	210		10.0	ug/L	200	1.60 U	105	75-125	0.2	20	
Lead	206		10.0	ug/L	200	3.10 U	103	75-125	1	20	
Magnesium	4430	B	100	ug/L	2000	2420	100	75-125	1	20	
Nickel	205		10.0	ug/L	200	1.80 U	102	75-125	0.1	20	
Potassium	13000		500	ug/L	10000	2650	103	75-125	2	20	
Sodium	18100		500	ug/L	10000	7640	104	75-125	0.3	20	
Zinc	205		10.0	ug/L	200	3.80 U	102	75-125	0.4	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G02007 - EPA 3005A - Continued

Post Spike (5G02007-PS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:10

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0193		0.00100	mg/L	0.0200	-6.72E-5	97	80-120			
Calcium	8.80		0.100	mg/L	2.00	7.00	90	80-120			
Copper	0.199		0.0100	mg/L	0.200	0.000951	99	80-120			
Lead	0.196		0.0100	mg/L	0.200	0.00116	98	80-120			
Magnesium	4.29	B	0.100	mg/L	2.00	2.42	94	80-120			
Nickel	0.195		0.0100	mg/L	0.200	-0.000109	97	80-120			
Potassium	12.7		0.500	mg/L	10.0	2.65	100	80-120			
Sodium	17.3		0.500	mg/L	10.0	7.64	97	80-120			
Zinc	0.195		0.0100	mg/L	0.200	0.00142	97	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G02007 - EPA 3005A

Blank (5G02007-BLK2) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 13:49

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (5G02007-BS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 13:58

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	215		10.0	ug/L	200		108	80-120			

Matrix Spike (5G02007-MS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:04

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	210		10.0	ug/L	200	1.60 U	105	75-125			

Matrix Spike Dup (5G02007-MSD1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:07

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	210		10.0	ug/L	200	1.60 U	105	75-125	0.2	20	

Post Spike (5G02007-PS1) Prepared: 07/02/2015 08:41 Analyzed: 07/06/2015 14:10

Source: C508411-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.199		0.0100	mg/L	0.200	0.000951	99	80-120			

Classical Chemistry Parameters - Quality Control

Batch 5G02027 - NO PREP

Blank (5G02027-BLK1) Prepared: 07/02/2015 12:24 Analyzed: 07/02/2015 13:57

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5G02027 - NO PREP - Continued

LCS (5G02027-BS1) Prepared: 07/02/2015 12:24 Analyzed: 07/02/2015 13:57

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	98		15	mg/L	100		98	80-120			

Matrix Spike (5G02027-MS1) Prepared: 07/02/2015 12:24 Analyzed: 07/02/2015 13:58

Source: C504934-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L	37.8	14 U		80-120			QM-05

Matrix Spike Dup (5G02027-MSD1) Prepared: 07/02/2015 12:24 Analyzed: 07/02/2015 14:00

Source: C504934-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L	37.8	14 U		80-120		25	QM-05

Batch 5G07010 - NO PREP

Blank (5G07010-BLK1) Prepared: 07/07/2015 09:00 Analyzed: 07/07/2015 10:32

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

LCS (5G07010-BS1) Prepared: 07/07/2015 09:00 Analyzed: 07/07/2015 10:49

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	54		5.0	mg/L	50.0		109	90-110			
Sulfate as SO4	52		5.0	mg/L	50.0		104	90-110			

Matrix Spike (5G07010-MS1) Prepared: 07/07/2015 09:00 Analyzed: 07/07/2015 11:06

Source: C502337-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	25		5.0	mg/L	20.0	5.5	97	90-110			
Sulfate as SO4	33		5.0	mg/L	20.0	14	99	90-110			

Matrix Spike (5G07010-MS3) Prepared: 07/07/2015 09:00 Analyzed: 07/07/2015 12:31

Source: C502337-02RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	180		20	mg/L	80.0	92	113	90-110			QM-05
Sulfate as SO4	220		20	mg/L	80.0	130	112	90-110			QM-05

Matrix Spike Dup (5G07010-MSD1) Prepared: 07/07/2015 09:00 Analyzed: 07/07/2015 11:23

Source: C502337-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	26		5.0	mg/L	20.0	5.5	101	90-110	3	10	
Sulfate as SO4	34		5.0	mg/L	20.0	14	103	90-110	2	10	

Batch 5G08004 - NO PREP

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QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5G08004 - NO PREP - Continued

Blank (5G08004-BLK1) Prepared: 07/08/2015 09:12 Analyzed: 07/08/2015 10:18

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5G08004-BS1) Prepared: 07/08/2015 09:12 Analyzed: 07/08/2015 10:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	1.0		0.10	mg/L	0.997		104	90-110			

Matrix Spike (5G08004-MS1) Prepared: 07/08/2015 09:12 Analyzed: 07/08/2015 10:22

Source: C505857-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	54		5.0	mg/L	19.9	35	91	90-110			

Matrix Spike (5G08004-MS2) Prepared: 07/08/2015 09:12 Analyzed: 07/08/2015 10:30

Source: C505857-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	11		1.0	mg/L	3.98	7.1	90	90-110			

Matrix Spike Dup (5G08004-MSD1) Prepared: 07/08/2015 09:12 Analyzed: 07/08/2015 10:26

Source: C505857-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	53		5.0	mg/L	19.9	35	87	90-110	2	10	QM-05

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5G15018 - NO PREP

Blank (5G15018-BLK1) Prepared: 07/15/2015 10:00 Analyzed: 07/15/2015 11:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.34	U	1.0	mg/L							

LCS (5G15018-BS1) Prepared: 07/15/2015 10:00 Analyzed: 07/15/2015 11:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	39		1.0	mg/L	40.0		98	85-115			

LCS Dup (5G15018-BSD1) Prepared: 07/15/2015 10:00 Analyzed: 07/15/2015 11:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	44		1.0	mg/L	40.0		111	85-115	12	21	

Matrix Spike (5G15018-MS1) Prepared: 07/15/2015 10:00 Analyzed: 07/15/2015 11:20

Source: A504277-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	46		1.0	mg/L	40.0	5.4	103	85-115			

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QUALITY CONTROL DATA

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5G15018 - NO PREP - Continued

Matrix Spike Dup (5G15018-MSD1) Prepared: 07/15/2015 10:00 Analyzed: 07/15/2015 11:20

Source: A504277-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	44		1.0	mg/L	40.0	5.4	97	85-115	5	21	

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QB-01	The method blank had a positive result for the analyte; however, the concentration in the method blank is less than 10% of the sample result, which minimizes the impact of the deviation.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

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102-A Woodwinds Industrial Ct.
Cary, NC 27511
(919) 467-3090 Fax (919) 467-3515

Page ___ of ___

Client Name: The Catena Group	Project Number:
Address: 1000 Corporate Dr. Suite 101	Project Name/Desc: Swift Creek Water Quality
City/ST/Zip: Hillsborough NC 27278	PO # / Billing Info:
Tel: 919 732 1300 Fax:	Reporting Contact: Nancy Scott
Sampler(s) Name, Affiliation (Print): Nancy Scott	Billing Contact:
Sampler(s) Signature: NScott	Site Location / Time Zone:

Requested Analyses: Alk 310.2, Chloride 300 / Ammonia 350.1 / Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn / Cu/F / Sulfate 300 / TOC SM310B Dissolved

Requested Turnaround Times
Note : Rush requests subject to acceptance by the facility
___ Standard
___ Expedited
Due ___/___/___

Lab Workorder: C508411

Preservation (See Codes) (Combine as necessary)

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alk 310.2, Chloride 300	Ammonia 350.1	Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn	Cu/F	Sulfate 300	TOC SM310B Dissolved					Sample Comments
	NC 210	7/1/15	9:10		SW	6	X	X	X	X	X	X					
	SR 1555	↓	11:20		↓	↓	X	X	↓	↓	↓	↓					
	NC 50		1:15				X	X									

<-- Total # of Containers

Sample Kit Prepared By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
		[signature]	7 236 pm	[signature]	7/1/15 1436
Comments/Special Reporting Requirements		Relinquished By	Date/Time	Received By	Date/Time
		Relinquished By	Date/Time	Received By	Date/Time
		Cooler #'s & Temps on Receipt: 4.2°c		Condition Upon Receipt: ✓ Acceptable ___ Unacceptable	

Matrix : GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments)

Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note : All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist.

SIR SPEEDY #5800 (407) 847-3928

Ref. No. G 847/00150

Sample Preservation Verification

ENCO Cary

Work Order:	C508411	Project:	Swift Creek Water Quality
Client:	The Catena Group (TH015)	Project #:	[none]
Logged In:	01-Jul-15 15:06	Logged By:	John C King

C508411-01

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508411-02

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508411-03

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508411-04

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

C508411-05

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

C508411-06

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

	Reagent Name	ID
1		
2		

	Reagent Name	ID
3		
4		

	Reagent Name	ID
5		
6		

ENCO Laboratories

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Cary NC, 27511
Phone: 919.467.3090 FAX: 919.467.3515

Thursday, July 23, 2015
The Catena Group (TH015)
Attn: Nancy Scott
410-B Millstone Drive
Hillsborough, NC 27278

RE: Laboratory Results for
Project Number: [none], Project Name/Desc: Swift Creek Water Quality
ENCO Workorder(s): C508904

Dear Nancy Scott,

Enclosed is a copy of your laboratory report for test samples received by our laboratory on Friday, July 10, 2015.

Unless otherwise noted in an attached project narrative, all samples were received in acceptable condition and processed in accordance with the referenced methods/procedures. Results for these procedures apply only to the samples as submitted.

The analytical results contained in this report are in compliance with NELAC standards, except as noted in the project narrative. This report shall not be reproduced except in full, without the written approval of the Laboratory.

This report contains only those analyses performed by Environmental Conservation Laboratories. Unless otherwise noted, all analyses were performed at ENCO Cary. Data from outside organizations will be reported under separate cover.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Bill Scott

Bill Scott
Project Manager
Enclosure(s)

SAMPLE SUMMARY/LABORATORY CHRONICLE

Client ID: NC 210 | **Lab ID: C508904-01** | **Sampled: 07/10/15 09:05** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	08/07/15	07/13/15	09:00	07/14/15 02:47
EPA 310.2	07/24/15	07/13/15	11:10	07/13/15 13:44
EPA 350.1	08/07/15	07/15/15	07:37	07/15/15 10:56
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 10:44
SM 5310B-2000	08/07/15	07/21/15	13:00	07/21/15 15:19

Client ID: NC 210 Dissolved | **Lab ID: C508904-02** | **Sampled: 07/10/15 09:05** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 10:46

Client ID: SR 1555 | **Lab ID: C508904-03** | **Sampled: 07/10/15 09:45** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	08/07/15	07/13/15	09:00	07/14/15 03:04
EPA 310.2	07/24/15	07/13/15	11:10	07/13/15 13:44
EPA 350.1	08/07/15	07/15/15	07:37	07/15/15 10:58
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 10:49
SM 5310B-2000	08/07/15	07/21/15	13:00	07/21/15 15:19

Client ID: SR 1555 Dissolved | **Lab ID: C508904-04** | **Sampled: 07/10/15 09:45** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 11:00

Client ID: NC-50 | **Lab ID: C508904-05** | **Sampled: 07/10/15 10:15** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 300.0	08/07/15	07/13/15	09:00	07/14/15 03:22
EPA 310.2	07/24/15	07/13/15	11:10	07/13/15 13:45
EPA 350.1	08/07/15	07/15/15	07:37	07/15/15 11:00
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 11:03
SM 5310B-2000	08/07/15	07/21/15	13:00	07/21/15 15:19

Client ID: NC-50 Dissolved | **Lab ID: C508904-06** | **Sampled: 07/10/15 10:15** | **Received: 07/10/15 11:10**

Parameter	Hold Date/Time(s)	Prep Date/Time(s)		Analysis Date/Time(s)
EPA 6010C	01/06/16	07/13/15	14:19	07/17/15 11:06

SAMPLE DETECTION SUMMARY

Client ID: NC 210 **Lab ID: C508904-01**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Calcium - Total	5590		39.0	100	ug/L	EPA 6010C	
Chloride	7.0		2.2	5.0	mg/L	EPA 300.0	
Copper - Total	1.61	J	1.60	10.0	ug/L	EPA 6010C	
Magnesium - Total	2150		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2500		150	500	ug/L	EPA 6010C	
Sodium - Total	6620		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.7	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	22		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.3		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: SR 1555 **Lab ID: C508904-03**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.060	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	6020		39.0	100	ug/L	EPA 6010C	
Chloride	8.0		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2130		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2400		150	500	ug/L	EPA 6010C	
Sodium - Total	7340		400	500	ug/L	EPA 6010C	
Sulfate as SO4	3.8	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	22		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.2		0.34	1.0	mg/L	SM 5310B-2000	

Client ID: NC-50 **Lab ID: C508904-05**

Analyte	Results	Flag	MDL	PQL	Units	Method	Notes
Ammonia as N	0.069	J	0.045	0.10	mg/L	EPA 350.1	
Calcium - Total	7370		39.0	100	ug/L	EPA 6010C	
Chloride	9.3		2.2	5.0	mg/L	EPA 300.0	
Magnesium - Total	2370		29.0	100	ug/L	EPA 6010C	
Potassium - Total	2480		150	500	ug/L	EPA 6010C	
Sodium - Total	7760		400	500	ug/L	EPA 6010C	
Sulfate as SO4	4.0	J	2.9	5.0	mg/L	EPA 300.0	
Total Alkalinity as CaCO3	23		14	15	mg/L	EPA 310.2	
Total Organic Carbon - Dissolved	5.9		0.34	1.0	mg/L	SM 5310B-2000	

ANALYTICAL RESULTS

Description: NC 210 **Lab Sample ID:** C508904-01 **Received:** 07/10/15 11:10
Matrix: Water **Sampled:** 07/10/15 09:05 **Work Order:** C508904
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Calcium [7440-70-2]^	**5590**		ug/L	1	39.0	100	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Copper [7440-50-8]^	**1.61**	J	ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Magnesium [7439-95-4]^	**2150**		ug/L	1	29.0	100	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Potassium [7440-09-7]^	**2500**		ug/L	1	150	500	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Sodium [7440-23-5]^	**6620**		ug/L	1	400	500	5G13040	EPA 6010C	07/17/15 10:44	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5G13040	EPA 6010C	07/17/15 10:44	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	ND		mg/L	1	0.045	0.10	5G15003	EPA 350.1	07/15/15 10:56	SHA	
Chloride [16887-00-6]^	**7.0**		mg/L	1	2.2	5.0	5G13017	EPA 300.0	07/14/15 02:47	SHA	
Sulfate as SO4 [14808-79-8]^	**3.7**	J	mg/L	1	2.9	5.0	5G13017	EPA 300.0	07/14/15 02:47	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**22**		mg/L	1	14	15	5G13030	EPA 310.2	07/13/15 13:44	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.3**		mg/L	1	0.34	1.0	5G21008	SM 5310B-2000	07/21/15 15:19	RSA	

Description: NC 210 Dissolved **Lab Sample ID:** C508904-02 **Received:** 07/10/15 11:10
Matrix: Water **Sampled:** 07/10/15 09:05 **Work Order:** C508904
Project: Swift Creek Water Quality **Sampled By:** Nancy Scott

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 10:46	JDH	

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ANALYTICAL RESULTS

Description:	SR 1555	**Lab Sample ID:**	C508904-03	**Received:**	07/10/15 11:10
Matrix:	Water	**Sampled:**	07/10/15 09:45	**Work Order:**	C508904
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Calcium [7440-70-2]^	**6020**		ug/L	1	39.0	100	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Magnesium [7439-95-4]^	**2130**		ug/L	1	29.0	100	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Potassium [7440-09-7]^	**2400**		ug/L	1	150	500	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Sodium [7440-23-5]^	**7340**		ug/L	1	400	500	5G13040	EPA 6010C	07/17/15 10:49	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5G13040	EPA 6010C	07/17/15 10:49	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.060**	J	mg/L	1	0.045	0.10	5G15003	EPA 350.1	07/15/15 10:58	SHA	
Chloride [16887-00-6]^	**8.0**		mg/L	1	2.2	5.0	5G13017	EPA 300.0	07/14/15 03:04	SHA	
Sulfate as SO4 [14808-79-8]^	**3.8**	J	mg/L	1	2.9	5.0	5G13017	EPA 300.0	07/14/15 03:04	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**22**		mg/L	1	14	15	5G13030	EPA 310.2	07/13/15 13:44	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.2**		mg/L	1	0.34	1.0	5G21008	SM 5310B-2000	07/21/15 15:19	RSA	

Description:	SR 1555 Dissolved	**Lab Sample ID:**	C508904-04	**Received:**	07/10/15 11:10
Matrix:	Water	**Sampled:**	07/10/15 09:45	**Work Order:**	C508904
Project:	Swift Creek Water Quality	**Sampled By:**	Nancy Scott		

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 11:00	JDH	

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ANALYTICAL RESULTS

Description: NC-50	**Lab Sample ID:** C508904-05	**Received:** 07/10/15 11:10
Matrix: Water	**Sampled:** 07/10/15 10:15	**Work Order:** C508904
Project: Swift Creek Water Quality	**Sampled By:** Nancy Scott	

Metals (total recoverable) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Cadmium [7440-43-9]^	ND		ug/L	1	0.360	1.00	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Calcium [7440-70-2]^	**7370**		ug/L	1	39.0	100	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Lead [7439-92-1]^	ND		ug/L	1	3.10	10.0	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Magnesium [7439-95-4]^	**2370**		ug/L	1	29.0	100	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Nickel [7440-02-0]^	ND		ug/L	1	1.80	10.0	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Potassium [7440-09-7]^	**2480**		ug/L	1	150	500	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Sodium [7440-23-5]^	**7760**		ug/L	1	400	500	5G13040	EPA 6010C	07/17/15 11:03	JDH	
Zinc [7440-66-6]^	ND		ug/L	1	3.80	10.0	5G13040	EPA 6010C	07/17/15 11:03	JDH	

Classical Chemistry Parameters

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Ammonia as N [7664-41-7]^	**0.069**	J	mg/L	1	0.045	0.10	5G15003	EPA 350.1	07/15/15 11:00	SHA	
Chloride [16887-00-6]^	**9.3**		mg/L	1	2.2	5.0	5G13017	EPA 300.0	07/14/15 03:22	SHA	
Sulfate as SO4 [14808-79-8]^	**4.0**	J	mg/L	1	2.9	5.0	5G13017	EPA 300.0	07/14/15 03:22	SHA	
Total Alkalinity as CaCO3 [471-34-1]^	**23**		mg/L	1	14	15	5G13030	EPA 310.2	07/13/15 13:45	SHA	

Classical Chemistry Parameters (Dissolved)

^ - ENCO Orlando certified analyte [NC 424]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Total Organic Carbon^	**5.9**		mg/L	1	0.34	1.0	5G21008	SM 5310B-2000	07/21/15 15:19	RSA	

Description: NC-50 Dissolved	**Lab Sample ID:** C508904-06	**Received:** 07/10/15 11:10
Matrix: Water	**Sampled:** 07/10/15 10:15	**Work Order:** C508904
Project: Swift Creek Water Quality	**Sampled By:** Nancy Scott	

Metals (Dissolved) by EPA 6000/7000 Series Methods

^ - ENCO Cary certified analyte [NC 591]

Analyte [CAS Number]	Results	Flag	Units	DF	MDL	PQL	Batch	Method	Analyzed	By	Notes
Copper [7440-50-8]^	ND		ug/L	1	1.60	10.0	5G13040	EPA 6010C	07/17/15 11:06	JDH	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G13040 - EPA 3005A

Blank (5G13040-BLK1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 09:47

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.360	U	1.00	ug/L							
Calcium	39.0	U	100	ug/L							
Copper	1.60	U	10.0	ug/L							
Lead	3.10	U	10.0	ug/L							
Magnesium	29.0	U	100	ug/L							
Nickel	1.80	U	10.0	ug/L							
Potassium	150	U	500	ug/L							
Sodium	400	U	500	ug/L							
Zinc	3.80	U	10.0	ug/L							

LCS (5G13040-BS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 09:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.4		1.00	ug/L	20.0		97	80-120			
Calcium	2150		100	ug/L	2000		107	80-120			
Copper	194		10.0	ug/L	200		97	80-120			
Lead	206		10.0	ug/L	200		103	80-120			
Magnesium	2030		100	ug/L	2000		102	80-120			
Nickel	201		10.0	ug/L	200		100	80-120			
Potassium	10200		500	ug/L	10000		102	80-120			
Sodium	10200		500	ug/L	10000		102	80-120			
Zinc	200		10.0	ug/L	200		100	80-120			

Matrix Spike (5G13040-MS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:00

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	20.2		1.00	ug/L	20.0	0.360 U	101	75-125			
Calcium	23800		100	ug/L	2000	22300	76	75-125			
Copper	206		10.0	ug/L	200	1.60 U	103	75-125			
Lead	210		10.0	ug/L	200	3.10 U	105	75-125			
Magnesium	7620		100	ug/L	2000	5640	99	75-125			
Nickel	208		10.0	ug/L	200	1.80 U	104	75-125			
Potassium	13800		500	ug/L	10000	3240	105	75-125			
Sodium	16800		500	ug/L	10000	6330	105	75-125			
Zinc	224		10.0	ug/L	200	14.3	105	75-125			

Matrix Spike Dup (5G13040-MSD1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:03

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	19.3		1.00	ug/L	20.0	0.360 U	97	75-125	4	20	
Calcium	23400		100	ug/L	2000	22300	56	75-125	2	20	QM-05
Copper	196		10.0	ug/L	200	1.60 U	98	75-125	5	20	
Lead	207		10.0	ug/L	200	3.10 U	103	75-125	2	20	
Magnesium	7420		100	ug/L	2000	5640	89	75-125	3	20	
Nickel	200		10.0	ug/L	200	1.80 U	100	75-125	4	20	
Potassium	13400		500	ug/L	10000	3240	102	75-125	3	20	
Sodium	16500		500	ug/L	10000	6330	102	75-125	2	20	
Zinc	216		10.0	ug/L	200	14.3	101	75-125	4	20	

QUALITY CONTROL DATA

Metals (total recoverable) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G13040 - EPA 3005A - Continued

Post Spike (5G13040-PS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:06

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Cadmium	0.0194		0.00100	mg/L	0.0200	-0.000121	97	80-120			
Calcium	23.1		0.100	mg/L	2.00	22.3	41	80-120			QM-08
Copper	0.198		0.0100	mg/L	0.200	0.000135	99	80-120			
Lead	0.201		0.0100	mg/L	0.200	-0.00206	101	80-120			
Magnesium	7.21		0.100	mg/L	2.00	5.64	78	80-120			QM-08
Nickel	0.202		0.0100	mg/L	0.200	-0.000361	101	80-120			
Potassium	13.0		0.500	mg/L	10.0	3.24	98	80-120			
Sodium	15.9		0.500	mg/L	10.0	6.33	96	80-120			
Zinc	0.221		0.0100	mg/L	0.200	0.0143	103	80-120			

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

Batch 5G13040 - EPA 3005A

Blank (5G13040-BLK2) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 09:51

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	1.60	U	10.0	ug/L							

LCS (5G13040-BS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 09:54

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	194		10.0	ug/L	200		97	80-120			

Matrix Spike (5G13040-MS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:00

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	206		10.0	ug/L	200	1.60 U	103	75-125			

Matrix Spike Dup (5G13040-MSD1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:03

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	196		10.0	ug/L	200	1.60 U	98	75-125	5	20	

Post Spike (5G13040-PS1) Prepared: 07/13/2015 14:19 Analyzed: 07/17/2015 10:06

Source: C508500-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Copper	0.198		0.0100	mg/L	0.200	0.000135	99	80-120			

Classical Chemistry Parameters - Quality Control

Batch 5G13017 - NO PREP

Blank (5G13017-BLK1) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 14:32

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	2.2	U	5.0	mg/L							
Sulfate as SO4	2.9	U	5.0	mg/L							

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Batch 5G13017 - NO PREP - Continued

LCS (5G13017-BS1) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 15:27

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	54		5.0	mg/L	50.0		108	90-110			
Sulfate as SO4	52		5.0	mg/L	50.0		104	90-110			

Matrix Spike (5G13017-MS1) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 15:44

Source: C508205-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	25		5.0	mg/L	20.0	5.4	100	90-110			
Sulfate as SO4	29		5.0	mg/L	20.0	9.5	97	90-110			

Matrix Spike (5G13017-MS2) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 16:35

Source: C508205-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	77		5.0	mg/L	20.0	53	118	90-110			QM-05

Matrix Spike (5G13017-MS3) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 17:09

Source: C508205-02RE1

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Sulfate as SO4	320		50	mg/L	200	120	100	90-110			

Matrix Spike Dup (5G13017-MSD1) Prepared: 07/13/2015 09:00 Analyzed: 07/13/2015 16:01

Source: C508205-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Chloride	26		5.0	mg/L	20.0	5.4	101	90-110	0.8	10	
Sulfate as SO4	29		5.0	mg/L	20.0	9.5	98	90-110	0.6	10	

Batch 5G13030 - NO PREP

Blank (5G13030-BLK1) Prepared: 07/13/2015 11:10 Analyzed: 07/13/2015 13:20

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L							

LCS (5G13030-BS1) Prepared: 07/13/2015 11:10 Analyzed: 07/13/2015 13:21

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	100		15	mg/L	100		104	80-120			

Matrix Spike (5G13030-MS1) Prepared: 07/13/2015 11:10 Analyzed: 07/13/2015 13:22

Source: C508205-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	18		15	mg/L	37.8	14 U	46	80-120			QM-05

Matrix Spike Dup (5G13030-MSD1) Prepared: 07/13/2015 11:10 Analyzed: 07/13/2015 13:24

Source: C508205-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity as CaCO3	14	U	15	mg/L	37.8	14 U		80-120		25	QM-05

Batch 5G15003 - NO PREP

QUALITY CONTROL DATA

Classical Chemistry Parameters - Quality Control

Blank (5G15003-BLK1) Prepared: 07/15/2015 07:37 Analyzed: 07/15/2015 10:06

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.045	U	0.10	mg/L							

LCS (5G15003-BS1) Prepared: 07/15/2015 07:37 Analyzed: 07/15/2015 10:08

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	1.0		0.10	mg/L	0.997		102	90-110			

Matrix Spike (5G15003-MS1) Prepared: 07/15/2015 07:37 Analyzed: 07/15/2015 10:10

Source: C508051-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.37		0.10	mg/L	0.387	0.045 U	95	90-110			

Matrix Spike (5G15003-MS2) Prepared: 07/15/2015 07:37 Analyzed: 07/15/2015 10:23

Source: C508123-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.77		0.10	mg/L	0.387	0.42	91	90-110			

Matrix Spike Dup (5G15003-MSD1) Prepared: 07/15/2015 07:37 Analyzed: 07/15/2015 10:15

Source: C508051-02

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Ammonia as N	0.37		0.10	mg/L	0.387	0.045 U	95	90-110	0.05	10	

Classical Chemistry Parameters (Dissolved) - Quality Control

Batch 5G21008 - NO PREP

Blank (5G21008-BLK1) Prepared: 07/21/2015 13:00 Analyzed: 07/21/2015 15:19

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	0.34	U	1.0	mg/L							

LCS (5G21008-BS1) Prepared: 07/21/2015 13:00 Analyzed: 07/21/2015 15:19

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	44		1.0	mg/L	40.0		111	85-115			

Matrix Spike (5G21008-MS1) Prepared: 07/21/2015 13:00 Analyzed: 07/21/2015 15:19

Source: A504272-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	45		1.0	mg/L	40.0	1.0	109	85-115			

Matrix Spike Dup (5G21008-MSD1) Prepared: 07/21/2015 13:00 Analyzed: 07/21/2015 15:19

Source: A504272-01

Analyte	Result	Flag	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Organic Carbon	42		1.0	mg/L	40.0	1.0	103	85-115	6	21	

FLAGS/NOTES AND DEFINITIONS

B	The analyte was detected in the associated method blank.
D	The sample was analyzed at dilution.
J	The reported value is between the laboratory method detection limit (MDL) and the laboratory method reporting limit (MRL), adjusted for actual sample preparation data and moisture content, where applicable.
U	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
E	The concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate.
MRL	Method Reporting Limit. The MRL is roughly equivalent to the practical quantitation limit (PQL) and is based on the low point of the calibration curve, when applicable, sample preparation factor, dilution factor, and, in the case of soil samples, moisture content.
ND	The analyte was analyzed for but not detected to the level shown, adjusted for actual sample preparation data and moisture content, where applicable.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence (85% or greater confidence) to make a "tentative identification".
P	Greater than 25% concentration difference was observed between the primary and secondary GC column. The lower concentration is reported.
QM-05	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
QM-08	Post-digestion spike did not meet method requirements due to confirmed matrix effects (dilution test).

ENVIRONMENTAL CONSERVATION LABORATORIES CHAIN-OF-CUSTODY RECORD

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4810 Executive Park Court, Suite 211 Jacksonville, FL 32216-6069 (904) 296-3007 Fax (904) 296-6210
102-A Woodwinds Industrial Ct. Cary, NC 27511 (919) 467-3090 Fax (919) 467-3515
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Client Name	The Catena Group
Address	1000 Corporate Dr. Suite 101
City/ST/Zip	Hillsborough NC 27278
Tel	919 732 1300
Fax	
Sampler(s) Name, Affiliation (Print)	Nancy Scott
Sampler(s) Signature	NScott
Project Number	
Project Name/Desc	Swift Creek Water Quality
PO # / Billing Info	
Reporting Contact	Nancy Scott
Billing Contact	
Site Location / Time Zone	

Requested Analyses: Alkalinity 310.2, Chloride 300 | Ammonia 350.1 | Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn | Cu/F | Sulfate 300 | TOC SM310B Dissolved

Requested Turnaround Times
Note: Rush requests subject to acceptance by the facility
___ Standard
___ Expedited
Due __/__/__

Lab Workorder: C508904

Preservation (See Codes) (Combine as necessary)

Item #	Sample ID (Field Identification)	Collection Date	Collection Time	Comp / Grab	Matrix (see codes)	Total # of Containers	Alkalinity 310.2, Chloride 300	Ammonia 350.1	Ca, Cd, Cu, K, Mg, Na, Ni, Pb, Zn	Cu/F	Sulfate 300	TOC SM310B Dissolved	Sample Comments
	NC 210	7/10/15	9:05		SW	6	X	X	X	X	X	X	
	SR 1555	↓	9:45		↓	↓	↓	↓	↓	↓	↓	↓	
	NC 50		10:15										

<-- Total # of Containers

Sample Kit Prepared By	
Date/Time	
Comments/Special Reporting Requirements	

Relinquished By	Date/Time	Received By	Date/Time
NScott	7/10/15 11:10	[illegible signature]	7/10/15 1110

Cooler #'s & Temps on Receipt: 2.5 c

Condition Upon Receipt: ✓ Acceptable ___ Unacceptable

Matrix: GW-Groundwater SO-Soil DW-Drinking Water SE-Sediment SW-Surface Water WW-Wastewater A-Air O-Other (detail in comments)

Preservation: I-Ice H-HCl N-HNO3 S-H2SO4 NO-NaOH O-Other (detail in comments)

Note: All samples submitted to ENCO Labs are in accordance with the terms and conditions listed on the reverse of this form, unless prior written agreements exist

Sample Preservation Verification

ENCO Cary

Work Order:	C508904	Project:	Swift Creek Water Quality
Client:	The Catena Group (TH015)	Project #:	[none]
Logged In:	10-Jul-15 12:54	Logged By:	Jennifer L. Jackson

C508904-01

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508904-02

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

C508904-03

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508904-04

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

C508904-05

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
C	250mLP+H2SO4	<2	Y / N / NA	Y / N / NA		
D	250mLP+HNO3	<2	Y / N / NA	Y / N / NA		

C508904-06

Cont	Type	Pres (pH) Requirement	pH Checked / In Control	pH Adjusted	Date/Time Adjusted	Reagent Used/Comments
A	250mLP+HNO3 [F]	<2	Y / N / NA	Y / N / NA		

	Reagent Name	ID		Reagent Name	ID		Reagent Name	ID
1			3			5		
2			4			6		

Appendix C – Historical Water Quality Analysis

Table 1. Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at City of Raleigh monitoring station J4500000.

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/19/2009	25.2	7.1	0.08	9.86	1.29
9/2/2009	21.7	7.1	0.42	13.18	1.62
10/28/2009	16.1	7.3	0.02	16.68	2.08
11/24/2009	13.3	6.7	0.14	29.76	3.17
12/31/2009	4.9	6.4	0.03	33.74	5.70
1/22/2010	7.1	6.5	0.07	32.61	4.89
2/26/2010	5.4	7	0.01	24.10	4.84
3/31/2010	13.8	6.6	0.06	31.28	3.13
4/8/2010	20.1	7.1	0.13	15.05	1.80
5/27/2010	20.5	6.9	0.08	17.39	1.89
6/24/2010	26.7	7.1	0.23	8.71	1.17
7/23/2010	26.3	6.7	0.26	12.25	1.37
8/27/2010	24.4	7	0.17	11.59	1.42
9/10/2010	21.8	7.2	0.12	11.74	1.53
10/22/2010	13.5	7	0.08	24.10	2.87
11/19/2010	9.8	7.2	0.35	19.73	3.32
12/22/2010	5.3	7	0.01	24.10	4.87
1/20/2011	4.3	6.8	3.73	28.05	5.53
2/10/2011	6	7.1	0.22	21.94	4.46
3/3/2011	10.3	6.9	0.05	26.15	3.65
5/17/2011	20.4	7	0.11	16.15	1.84
6/10/2011	25.1	7	0.11	10.94	1.36
7/29/2011	26.8	7.3	0.51	6.87	1.05
8/11/2011	26.1	7.1	0.14	9.16	1.22
9/12/2011	22.5	7.3	0.14	9.81	1.38
10/21/2011	15.1	7.2	0.08	19.73	2.36
11/10/2011	11.8	7.3	0.05	17.51	2.75
12/30/2011	7.8	7.2	0.05	19.73	3.78
1/12/2012	7.6	7.1	0.07	21.94	4.03
2/23/2012	5.8	7.2	0.06	19.73	4.30
3/8/2012	8	7.1	0.04	21.94	3.92
4/26/2012	15.4	7.2	0.06	19.73	2.32
5/10/2012	18.9	7.2	0.05	14.93	1.85
7/31/2012	25.1	6.8	0.27	12.75	1.45
8/16/2012	22.8	6.9	0.19	14.37	1.63
9/11/2012	22.1	6.8	0.08	16.34	1.76
10/4/2012	21.6	7	1.88	14.62	1.70
11/12/2012	10.6	6.7	0.03	29.76	3.77
12/12/2012	11.5	6.9	0.07	26.15	3.38
1/23/2013	6.2	6.5	0.06	32.61	5.18
2/14/2013	9	6.8	0.10	28.05	4.08
3/14/2013	9.4	7.1	0.08	21.94	3.58
4/8/2013	14.5	6.9	0.05	26.15	2.79
5/7/2013	17.8	7.4	0.09	12.67	1.74
6/13/2013	25.1	7.1	0.11	9.95	1.30
7/10/2013	26.4	6.8	0.12	11.44	1.33

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/6/2013	25.6	6.8	0.11	12.23	1.40
9/10/2013	26.4	7.1	0.05	8.93	1.20
10/24/2013	12.9	7	0.10	24.10	2.98
11/7/2013	14.2	6.9	0.05	26.15	2.84
12/5/2013	10.4	7.2	0.08	19.73	3.20
1/16/2014	7.5	6.7	0.02	29.76	4.61
2/14/2014	2.7	6.9	0.02	26.15	5.96
3/10/2014	8.4	6.8	0.04	28.05	4.25
4/10/2014	15.4	6.9	0.04	26.15	2.63
5/13/2014	22.1	7	0.15	14.02	1.65
6/26/2014	27.3	7	0.13	9.11	1.18
7/24/2014	25.8	7.1	0.11	9.39	1.25
8/6/2014	25.2	7.1	0.08	9.86	1.29
9/3/2014	26.1	7.1	0.09	9.16	1.22
10/16/2014	20.2	7	0.08	16.42	1.86
11/17/2014	8.9	7.3	0.05	17.51	3.32
12/30/2014	9.9	7.4	0.03	15.34	2.90
1/12/2015	7	6.9	0.12	26.15	4.52
2/3/2015	7.5	7.2	0.05	19.73	3.85
3/3/2015	7.1	7.3	0.03	17.51	3.72
4/7/2015	17.1	7.4	0.06	13.42	1.82

Table 2. Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at City of Raleigh monitoring station J4510000.

Date	Temp(°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/19/2009	26.0	7.2	0.08	8.29	1.17
9/2/2009	22.9	7.1	0.20	11.94	1.50
10/28/2009	16.9	7.2	0.01	17.62	2.10
11/24/2009	13.5	6.6	0.18	31.28	3.19
12/31/2009	5.3	6.5	0.04	32.61	5.49
1/22/2010	7.5	6.6	0.41	31.28	4.69
2/26/2010	6.0	6.8	0.02	28.05	4.96
3/31/2010	14.4	6.6	0.05	31.28	3.01
4/8/2010	20.4	7.0	0.16	16.15	1.84
5/27/2010	21.0	6.9	0.11	16.68	1.83
6/24/2010	26.8	7.0	0.10	9.50	1.22
7/23/2010	26.4	7.0	0.09	9.82	1.25
8/27/2010	24.5	6.9	0.16	12.48	1.46
9/10/2010	22.1	7.1	0.13	12.75	1.58
10/22/2010	13.6	7.1	0.08	21.94	2.73
11/19/2010	10.2	7.2	0.18	19.73	3.24
12/22/2010	5.5	7.0	0.02	24.10	4.81
1/20/2011	4.4	7.0	0.40	24.10	5.16
2/10/2011	6.1	7.0	0.12	24.10	4.62
3/3/2011	10.6	6.9	0.07	26.15	3.58
5/17/2011	20.9	7.2	0.09	12.65	1.62
6/10/2011	25.0	6.9	0.11	11.97	1.42
7/29/2011	26.7	7.2	0.28	7.82	1.12
8/11/2011	26.4	7.0	0.10	9.82	1.25
9/12/2011	22.3	7.2	0.07	11.26	1.48
10/21/2011	14.8	7.1	0.04	21.94	2.53
11/10/2011	10.7	6.8	0.02	28.05	3.66
12/30/2011	7.3	6.9	0.04	26.15	4.43
1/12/2012	7.7	7.3	0.05	17.51	3.58
2/23/2012	5.9	7.2	0.09	19.73	4.27
3/8/2012	8	7.3	0.07	17.51	3.51
4/26/2012	15.3	7.1	0.11	21.94	2.45
5/10/2012	18.8	7.2	0.05	15.05	1.86
7/31/2012	24.9	6.9	0.1	12.07	1.42
8/16/2012	22.5	6.9	0.09	14.73	1.66
9/11/2012	21.2	6.8	0.06	17.61	1.86
10/4/2012	20.6	6.9	0.09	17.24	1.88
11/12/2012	10	6.9	0.09	26.15	3.72
12/12/2012	10.8	6.9	0.03	26.15	3.54
1/23/2013	4	6.9	0.07	26.15	5.48
2/14/2013	8.4	7	0.26	24.10	3.99
3/14/2013	9	6.9	0.05	26.15	3.97
4/8/2013	13.6	6.7	0.03	29.76	3.11
5/7/2013	17.3	6.9	0.15	22.67	2.33
6/13/2013	24.7	6.8	0.08	13.17	1.48
7/10/2013	24.3	6.8	0.12	13.62	1.52

Date	**Temp(°C)**	**pH (SU)**	**NH3 as N (mg/L)**	**CMC**	**CCC**
8/6/2013	24.4	6.9	0.05	12.59	1.47
9/10/2013	24.7	6.8	0.03	13.17	1.48
10/24/2013	12.2	6.7	0.03	29.76	3.40
11/7/2013	14	6.7	0.04	29.76	3.03
12/5/2013	10.4	7.2	0.05	19.73	3.20
1/16/2014	7.1	6.6	0.04	31.28	4.82
2/14/2014	2.1	6.9	0.03	26.15	6.19
3/10/2014	8.1	6.8	0.09	28.05	4.33
4/10/2014	14.6	6.7	0.05	29.76	2.91
5/13/2014	21.4	7	0.09	14.86	1.72
6/26/2014	25	6.8	0.09	12.85	1.46
7/24/2014	24.1	6.9	0.08	12.90	1.50
8/6/2014	24.2	6.8	0.09	13.73	1.53
9/3/2014	24.4	6.9	0.08	12.59	1.47
10/16/2014	18.8	6.9	0.03	20.02	2.11
11/17/2014	7.8	7.2	0.07	19.73	3.78
12/30/2014	9.3	7.1	0.02	21.94	3.61
1/12/2015	5.4	7	0.1	24.10	4.84
2/3/2015	6.6	7.3	0.08	17.51	3.85
3/3/2015	6.6	7.2	0.03	19.73	4.08
4/7/2015	16	7.2	0.07	18.98	2.23

Table 3 Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at City of Raleigh monitoring station J4511000.

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/19/2009	26.3	7.1	0.27	9.01	1.21
9/2/2009	23.3	7.1	0.21	11.55	1.46
10/28/2009	17.2	7.1	0.01	19.14	2.17
11/24/2009	14.0	6.8	0.23	28.05	2.96
12/31/2009	5.9	6.6	0.05	31.28	5.20
1/22/2010	8.0	6.5	0.09	32.61	4.61
2/26/2010	6.2	6.7	0.01	29.76	5.01
3/31/2010	14.8	6.7	0.64	29.76	2.88
4/8/2010	21.1	7.1	0.04	13.86	1.69
5/27/2010	21.5	6.8	0.09	17.18	1.82
6/24/2010	27.3	6.8	0.20	10.62	1.26
7/23/2010	27.0	6.7	0.42	11.56	1.31
8/27/2010	24.2	7.0	0.18	11.78	1.44
9/10/2010	21.7	7.1	0.20	13.18	1.62
10/22/2010	13.1	7.0	0.10	24.10	2.94
11/19/2010	9.7	7.1	0.04	21.94	3.52
12/22/2010	5.1	7.2	0.02	19.73	4.50
1/20/2011	4.6	7.1	0.32	21.94	4.88
2/10/2011	6.3	7.1	0.10	21.94	4.38
3/3/2011	11.0	7.1	0.09	21.94	3.23
5/17/2011	20.7	6.9	0.10	17.10	1.87
6/10/2011	25.2	6.8	0.13	12.64	1.44
7/29/2011	27.0	7.1	0.86	8.50	1.15
8/11/2011	26.6	7.1	0.20	8.78	1.18
9/12/2011	22.5	7.2	0.18	11.08	1.46
10/21/2011	14.7	7.2	0.07	19.73	2.42
11/10/2011	13.2	7.0	0.05	24.10	2.93
12/30/2011	8.3	7.1	0.02	21.94	3.85
1/12/2012	8.1	7.2	0.02	19.73	3.71
2/23/2012	6.0	7.1	0.05	21.94	4.46
3/8/2012	8.4	7	0.02	24.10	3.99
4/26/2012	15.1	7.3	0.07	17.51	2.22
5/10/2012	19	7	0.05	18.13	2.01
7/31/2012	25.2	6.9	0.05	11.78	1.40
8/16/2012	22.3	6.8	0.28	16.07	1.73
9/11/2012	21.3	6.9	0.09	16.27	1.80
10/4/2012	20.6	6.9	0.04	17.24	1.88
11/12/2012	9.9	6.8	0.09	28.05	3.85
12/12/2012	10.9	6.8	0.03	28.05	3.61
1/23/2013	6.6	6.8	0.07	28.05	4.77
2/14/2013	8.9	7.1	0.09	21.94	3.70
3/14/2013	9.2	6.8	0.04	28.05	4.03
4/8/2013	13.4	6.9	0.09	26.15	2.99
5/7/2013	16.9	7	0.11	21.58	2.30
6/13/2013	24.5	6.8	0.28	13.39	1.50
7/10/2013	24.2	6.9	0.07	12.80	1.49

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/6/2013	24.3	6.9	0.06	12.69	1.48
9/10/2013	24.6	6.9	0.09	12.38	1.45
10/24/2013	12.3	6.8	0.02	28.05	3.30
11/7/2013	13.9	6.9	0.02	26.15	2.89
12/5/2013	8.8	7.1	0.08	21.94	3.73
1/16/2014	7	6.8	0.05	28.05	4.65
2/14/2014	2.2	6.9	0.02	26.15	6.16
3/10/2014	8.2	6.9	0.08	26.15	4.18
4/10/2014	14.7	6.8	0.02	28.05	2.83
5/13/2014	21.3	6.9	0.07	16.27	1.80
6/26/2014	25	6.9	0.09	11.97	1.42
7/24/2014	24.3	7	0.09	11.69	1.43
8/6/2014	24.4	6.8	0.07	13.51	1.51
9/3/2014	24.9	6.9	0.05	12.07	1.42
10/16/2014	19	6.8	0.09	21.13	2.14
11/17/2014	8.2	7.1	0.11	21.94	3.87
12/30/2014	9.7	6.9	0.05	26.15	3.80
1/12/2015	5.5	6.8	0.08	28.05	5.12
2/3/2015	6.7	7	0.1	24.10	4.45
3/3/2015	6.8	7	0.03	24.10	4.42
4/7/2015	16.2	7.1	0.04	20.80	2.31

Table 4 Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at City of Raleigh monitoring station J4520000.

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/19/2009	27.3	6.9	0.13	9.90	1.22
9/2/2009	23.8	7.0	0.23	12.18	1.48
10/28/2009	17.6	7.2	0.01	16.62	2.01
11/24/2009	14.2	6.7	0.22	29.76	2.99
12/31/2009	6.0	6.5	0.02	32.61	5.25
1/22/2010	8.2	6.6	0.08	31.28	4.49
2/26/2010	6.3	6.9	0.01	26.15	4.73
3/31/2010	15.1	6.8	0.04	28.05	2.76
4/8/2010	21.5	7.0	0.20	14.74	1.71
5/27/2010	21.7	6.9	0.09	15.74	1.75
6/24/2010	26.7	6.8	0.11	11.16	1.30
7/23/2010	26.2	6.8	0.13	11.63	1.35
8/27/2010	24.9	7.1	0.12	10.11	1.32
9/10/2010	22.4	7.0	0.15	13.68	1.62
10/22/2010	13.7	7.2	0.07	19.73	2.58
11/19/2010	10.3	7.2	0.06	19.73	3.22
12/22/2010	5.5	7.1	0.03	21.94	4.61
1/20/2011	4.9	7.0	0.45	24.10	5.00
2/10/2011	6.0	7.2	0.10	19.73	4.24
3/3/2011	11.3	7.1	0.05	21.94	3.17
5/17/2011	21.1	6.9	0.09	16.54	1.82
6/10/2011	25.4	6.7	0.08	13.20	1.45
7/29/2011	27.4	7.0	0.17	9.04	1.17
8/11/2011	26.3	7.0	0.09	9.90	1.26
9/12/2011	22.4	7.1	0.08	12.44	1.55
10/21/2011	15.1	7.0	0.05	24.10	2.59
11/10/2011	11.3	6.9	0.03	26.15	3.42
12/30/2011	7.6	7.0	0.05	24.10	4.20
1/12/2012	7.7	7.1	0.05	21.94	4.00
2/23/2012	5.9	7.3	0.07	17.51	4.02
3/8/2012	8.1	7.2	0.04	19.73	3.71
4/26/2012	15.6	7	0.24	24.03	2.51
5/10/2012	19.2	7	0.05	17.83	1.99
7/31/2012	25.5	6.8	0.08	12.33	1.41
8/16/2012	22.8	6.9	0.08	14.37	1.63
9/11/2012	21.4	6.6	0.05	19.34	1.92
10/4/2012	21	6.8	0.04	17.90	1.88
11/12/2012	10	6.7	0.02	29.76	3.92
12/12/2012	10.8	6.7	0.05	29.76	3.72
1/23/2013	4.3	6.8	0.05	28.05	5.53
2/14/2013	9.3	7.1	0.11	21.94	3.61
3/14/2013	9.5	6.7	0.07	29.76	4.05
4/8/2013	13.7	7	0.04	24.10	2.83
5/7/2013	17.4	7.1	0.1	18.83	2.14
6/13/2013	25.3	6.8	0.17	12.54	1.43
7/10/2013	24.5	6.9	0.1	12.48	1.46

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
8/6/2013	24.9	6.8	0.05	12.96	1.47
9/10/2013	25.3	7	0.02	10.76	1.34
10/24/2013	12.2	6.9	0.02	26.15	3.23
11/7/2013	14.2	7	0.05	24.10	2.74
12/5/2013	9.9	6.8	0.04	28.05	3.85
1/16/2014	7.2	6.9	0.07	26.15	4.46
2/14/2014	1.9	6.8	0.06	28.05	6.46
3/10/2014	8.4	6.8	0.07	28.05	4.25
4/10/2014	14.5	6.7	0.03	29.76	2.93
5/13/2014	21	7.1	0.07	13.97	1.70
6/26/2014	24.8	7.1	0.07	10.20	1.33
7/24/2014	24	7.1	0.05	10.90	1.40
8/6/2014	23.4	6.9	0.09	13.67	1.57
9/3/2014	24.3	7	0.06	11.69	1.43
10/16/2014	18.8	6.9	0.06	20.02	2.11
11/17/2014	7.8	7.3	0.03	17.51	3.56
12/30/2014	9.9	6.9	0.05	26.15	3.75
1/12/2015	5.3	6.8	0.11	28.05	5.19
2/3/2015	6.3	6.8	0.08	28.05	4.86
3/3/2015	6.4	7.1	0.14	21.94	4.35
4/7/2015	15.9	7	0.05	23.44	2.46

Table 5 Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at City of Raleigh monitoring station J4580000.

Date	Temp (°C	pH (SU)	NH3 as N (mg/L)	CMC	CCC
5/2/2012	21.50	6.9	0.07	16.00	1.77
7/19/2012	26.2	6.9	0.05	10.84	1.31
8/2/2012	25.60	6.9	0.07	11.39	1.36
9/13/2012	20.20	6.9	0.06	17.83	1.93
10/3/2012	21.20	6.9	0.07	16.41	1.81
11/28/2012	6.10	6.8	0.04	28.05	4.92
12/20/2012	8.60	6.7	0.02	29.76	4.29
1/11/2013	9.70	6.8	0.05	28.05	3.90
2/7/2013	7.00	7.0	0.06	24.10	4.36
3/13/2013	10.10	7.1	0.07	21.94	3.43
4/4/2013	10.80	6.9	0.03	26.15	3.54
5/8/2013	16.00	7.2	0.10	18.98	2.23
6/19/2013	22.10	7.2	0.05	11.45	1.50
7/2/2013	23.90	7.1	0.08	10.99	1.41
8/5/2013	24.10	7.1	0.05	10.81	1.39
9/9/2013	22.50	7.1	0.04	12.34	1.54
10/17/2013	17.90	6.7	0.02	24.58	2.36
11/6/2013	12.90	7.1	0.16	21.94	2.86
12/4/2013	8.20	6.7	0.08	29.76	4.40
1/8/2014	1.70	6.8	0.08	28.05	6.54
2/6/2014	6.60	6.9	0.07	26.15	4.63
3/6/2014	4.40	6.9	0.05	26.15	5.34
4/7/2014	14.10	6.8	0.02	28.05	2.94
5/12/2014	20.60	7.0	0.05	15.88	1.82
6/12/2014	22.70	7.1	0.04	12.14	1.52
7/17/2014	23.00	7.0	0.06	13.02	1.56
8/5/2014	23.10	6.9	0.10	14.02	1.60
9/2/2014	26.00	6.9	0.05	11.02	1.33
10/9/2014	19.20	7.2	0.02	14.56	1.81
11/6/2014	15.90	7.1	0.10	21.32	2.36
12/4/2014	10.20	7.1	0.04	21.94	3.40
1/14/2015	5.80	7.2	0.08	19.73	4.30
2/12/2015	6.10	7.3	0.06	17.51	3.97
3/18/2015	12.40	7.1	0.03	21.94	2.95
4/6/2015	14.10	7.2	0.02	19.73	2.52

Table 6. Ammonia measurements and event-specific acute and chronic criteria (USEPA 2013) at USGS monitoring station 02087701.

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
10/18/1989	22	6.6	0.05	18.43	1.84
4/4/1990	15	6.7	0.04	29.76	2.84
6/20/1990	28	7.2	0.02	7.07	1.03
8/14/1990	30	8.3	0.03	0.96	0.26
9/5/1990	27.6	7.8	0.01	3.00	0.62
10/24/1990	22	6.9	0.02	15.41	1.72
4/25/1991	18	6.7	0.06	24.43	2.34
6/11/1991	25	8.6	0.02	0.81	0.21
7/23/1991	33	7.3	0.04	4.14	0.70
8/6/1991	28	7.1	0.2	7.86	1.08
9/17/1991	27	7.2	0.02	7.68	1.10
11/13/1991	10	6.5	0.07	32.61	4.06
4/16/1992	16	7.2	0.02	19.11	2.23
6/2/1992	22	7	0.02	14.20	1.66
8/13/1992	30	6.5	0.14	9.90	1.12
10/15/1992	21	7.2	0.06	12.63	1.61
4/26/1993	18	7.2	0.03	16.19	1.96
6/25/1993	27.1	6.7	0.04	11.49	1.30
8/4/1993	28.8	7	0.05	8.08	1.07
10/14/1993	17.3	7	0.11	20.96	2.25
11/15/1993	14.3	7.1	0.01	21.94	2.61
4/22/1994	20.9	7	0.03	15.56	1.78
6/21/1994	28.8	7.2	0.02	6.61	0.98
8/2/1994	28.1	6.9	0.04	9.29	1.16
9/21/1994	23.3	6.6	0.19	16.55	1.69
6/16/1995	23.6	6.5	0.02	16.82	1.69
8/5/2005	29	6.9	0.015	8.62	1.09
8/5/2005	27.6	6.9	0.158	9.68	1.20
10/19/2005	19.9	6.7	0.044	20.87	2.07
4/20/2006	17.5	6.3	0.09	29.69	2.56
7/5/2006	29.6	6.7	0.012	9.34	1.11
7/5/2006	22.7	6.1	0.055	20.11	1.85
8/30/2006	31.7	8.5	0.014	0.56	0.16
8/30/2006	28.2	6.3	0.027	12.23	1.28
8/30/2006	23.8	6.7	1.74	15.10	1.61
4/26/2007	15.5	5.5	0.047	38.25	3.01
6/21/2007	26.2	6.4	0.042	14.03	1.44
6/21/2007	23.2	6.7	0.625	15.87	1.67
11/1/2007	16.7	6.8	0.067	25.64	2.49

Date	Temp (°C)	pH (SU)	NH3 as N (mg/L)	CMC	CCC
11/1/2007	16.5	6.7	0.075	27.66	2.58
11/1/2007	16.4	6.8	0.088	26.28	2.54
4/28/2008	17.5	6.6	0.029	26.76	2.46
6/25/2008	25.5	7	0.131	10.62	1.32
8/21/2008	25.9	6.9	0.07	11.15	1.34
6/25/2009	22.3	6.6	0.208	17.98	1.81
8/20/2009	28.2	6.6	0.155	11.02	1.24
8/20/2009	24.7	7	2.1	11.35	1.39
10/15/2009	19.4	6.8	0.048	20.50	2.09
10/15/2009	19.4	6.9	0.06	19.11	2.03
4/15/2010	17.5	6.5	0.118	27.90	2.50
6/10/2010	28.1	6.9	0.027	9.29	1.16
6/10/2010	20.8	7.2	1.28	12.84	1.63
8/12/2010	31.5	7.2	0.099	5.29	0.82
8/12/2010	29.6	6.8	0.195	8.80	1.08
10/14/2010	21.2	7	0.078	15.17	1.75
10/14/2010	21.1	6.8	0.079	17.80	1.87
4/25/2011	20.8	6.8	0.081	18.25	1.91
4/25/2011	19.4	6.6	0.107	22.86	2.18
6/28/2011	28.5	7	0.123	8.28	1.09
6/28/2011	28.5	6.9	0.137	8.99	1.13

Table 7 Copper measurements and event-specific acute and chronic water quality standards (USEPA 2007, NC Register 2014) at USGS monitoring station 02087701.

Date	Dissolved Cu (ug/L)	Hardness (as mg/L of $CaCO_3$)	CMC	CCC
10/18/1989	0.96	17.7	2.63	2.04
4/4/1990	2.88	22.5	3.30	2.50
6/20/1990	2.88	22.4	3.28	2.49
8/14/1990	2.88	19.6	2.89	2.23
9/5/1990	5.76	19.6	2.89	2.23
9/5/1990	2.88	18.6	2.75	2.13
10/24/1990	1.92	22.2	3.25	2.47
4/25/1991	2.88	22.9	3.35	2.54
6/11/1991	1.92	20.1	2.96	2.27
7/23/1991	1.92	21.6	3.17	2.42
8/6/1991	3.84	19.2	2.84	2.19
9/17/1991	2.88	19	2.81	2.17
4/16/1992	4.8	23.8	3.48	2.63
6/2/1992	0.96	22.9	3.35	2.54
8/13/1992	1.92	16.8	2.50	1.95
10/15/1992	0.96	17.5	2.60	2.02
4/26/1993	1.92	28.2	4.08	3.04
6/25/1993	1.92	30.5	4.39	3.25
8/4/1993	0.96	22.3	3.27	2.48
10/14/1993	0.96	20.5	3.02	2.31
11/15/1993	0.96	20.3	2.99	2.29
4/22/1994	1.92	25.6	3.72	2.80
6/21/1994	1.92	24.2	3.53	2.66
8/2/1994	1.92	19.6	2.89	2.23
12/6/1994	3.84	21.6	3.17	2.42
5/1/1995	1.92	15.9	2.38	1.86
6/16/1995	1.92	20.8	3.06	2.34
10/19/2005	0.768	22.6	3.31	2.51
4/20/2006	1.248	16.7	2.49	1.94
4/26/2007	1.536	26.1	3.79	2.84
10/15/2009	2.592	20.2	2.98	2.28
4/15/2010	8.352	22.1	3.24	2.47
10/14/2010	1.728	18.8	2.78	2.15
4/25/2011	1.344	22.7	3.32	2.52

Appendix D

Dwarf Wedgemussel Viability Study Report

DWARF WEDGEMUSSEL VIABILITY STUDY

Complete 540
Triangle Expressway Southeast Extension

Wake and Johnston Counties

STIP Project Nos. R-2721, R-2828, and R-2829
State Project Nos. 6.401078, 6.401079, and 6.401080
Federal Aid Project Nos. STP-0540(19), STP-0540(20), and STP-0540(21)
WBS Nos. 37673.1.TA2, 35516.1.TA2, and 35517.1.TA1

Prepared for:

North Carolina Department of Transportation
North Carolina Turnpike Authority

Prepared by:

Three Oaks Engineering, Inc. | The Catena Group, Inc.

May 17, 2016

Executive Summary

Swift Creek, a major tributary of the Neuse River Basin located in Wake and Johnston Counties, North Carolina, supports the federally Endangered Dwarf Wedgemussel (DWM), and several other rare aquatic species. The Swift Creek DWM population has been identified as essential for the recovery of the species by the US Fish & Wildlife Service (USFWS).

The NC Department of Transportation (NCDOT) proposes transportation improvements from the NC 55 Bypass in Apex to the US 64/US 264 Bypass in Knightdale. These improvements, known as the Complete 540 - Triangle Expressway Southeast Extension project, would extend the existing Triangle Expressway, effectively completing the 540 Outer Loop around Raleigh. Inevitably, this proposed project would require at least one crossing of Swift Creek.

Before assessing potential project related impacts to the Swift Creek DWM population, a comprehensive update to the environmental baseline of the Swift Creek population was completed as part of a study on the projected population and habitat viability. The purpose of this study is threefold:

- characterize existing conditions of the Swift Creek Watershed (SCW)
- summarize conservation measures that have been implemented to protect DWM in the SCW
- assess historic trends and future viability of the DWM population and habitat conditions.

Population viability attributes that were considered include range of occupied habitat, relative abundance, and evidence of reproduction and recruitment. Habitat viability attributes include general channel stability and micro-habitat characteristics like stream bank conditions and substrate composition.

A number of past studies assessed various aspects of the SCW. This report draws from these studies in order to develop a clearer and more concise picture of the current and projected future conditions of the watershed, with regard to land use and water quality. Data gaps in the watershed baseline information are also identified.

The second part of this study provides an accounting of various conservation measures that have been implemented in the SCW to protect the stream, and more specifically the DWM. A Local Watershed Management Plan was developed for the upper part of the SCW, and various recommendations from that plan have been adopted by participant municipalities. Additionally, recent highway and water treatment projects in the watershed incorporated various conservation measures to offset identified impacts to the species and the watershed. Conservation measures that have been adopted range from development restrictions, and Best Management Practices

(BMPs) that avoid/minimize future impacts, to various measures such as guaranteed low flow releases that were developed to offset impacts from particular projects.

Population trends of the DWM and other freshwater mussel species in Swift Creek were examined to compare current population conditions to the past. The trend analysis measures include relative abundance, age class distribution, and detection probability. Trends of in-stream habitat conditions, flow, channel stability, and substrate composition were also analyzed. Historic hydrograph data was analyzed to assess how often aquatic life is exposed to extreme low flows. Aerial photography was used to illustrate the condition of the stream channel and its movement, or lack thereof, across the landscape, and geomorphology attributes were compared between sites that currently support the DWM and sites that do not.

The results of this study demonstrate that there are numerous stressors to aquatic communities in the SCW, particularly the DWM population. Many of these stressors are directly and indirectly related to the urbanization of the watershed since the early 1990s. It appears that mussel populations have declined in conjunction with these recent changes in the watershed. The declines seem to have leveled off, and there is some indication that mussel recruitment has increased within the last few years. The geomorphology component of the study identified that the heterogeneous distribution of substrate size within a site is important for the DWM.

Based on this analysis, it is apparent that the long term viability of the DWM population in Swift Creek is threatened; however, it can be concluded with some level of uncertainty that there is a chance for this species to persist into the future. This chance of persistence is very tenuous, especially without active management and increased habitat protection. Management recommendations that would help ensure a sustainable DWM population include in-stream habitat monitoring, population augmentation using captive propagation techniques, continued targeted water quality monitoring, and establishing a DWM focused stakeholder group in the Lower SCW.

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Appendices

1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) of the North Carolina Department of Transportation (NCDOT) proposes construction of a new road corridor from NC-55 (Apex) East to US-64 Bypass (Knightdale); thus completing the I-540 outer loop around the City of Raleigh (Figure 1). The Dwarf Wedgemussel (*Alasmidonta heterodon*, DWM), which is listed by the US Fish and Wildlife Service (USFWS) as a federally endangered species, occurs in Swift Creek within the proposed action area of the project. It was first documented to occur in Swift Creek in 1991 (Alderman 1991).

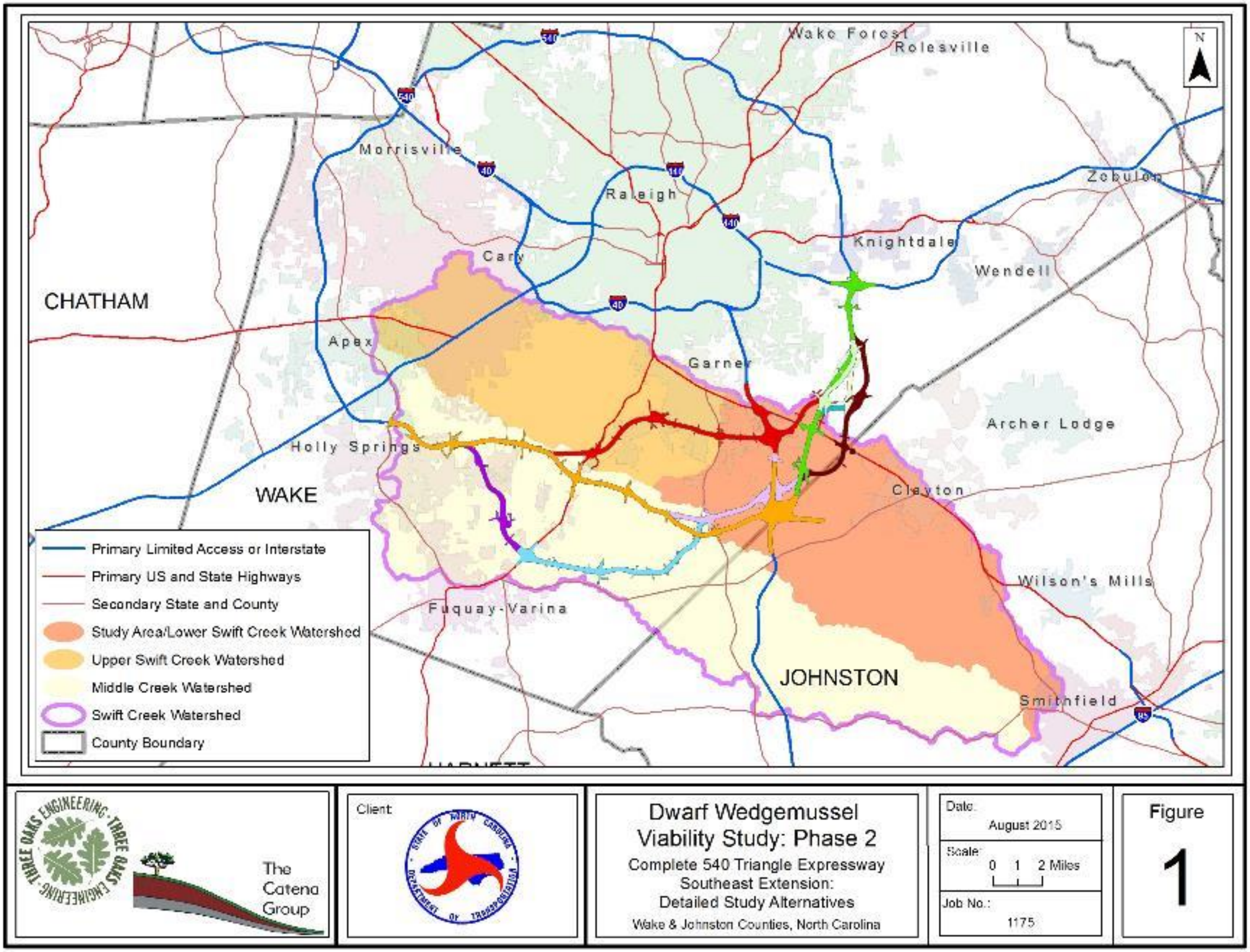
The North Carolina Wildlife Resources Commission (NCWRC) identified the Swift Creek Watershed (SCW) as one of 25 areas in North Carolina considered essential for the continued survival of endangered or threatened aquatic wildlife species (Alderman et al. 1993), as it supports several rare aquatic species (Table 1), including the DWM.

Table 1. Rare Aquatic Species in Swift Creek

Scientific Name	Common Name	NCWRC Status*	Nature Serve Status**	Federal Status
Alasmidonta heterodon	Dwarf Wedgemussel	E	S1	E
Alasmidonta undulata	Triangle Floater	T	S2	~
Anguilla rostrata	American Eel	~	S4	~
Elliptio lanceolata	Yellow Lance	E	S1	~
Elliptio roanokensis	Roanoke Slabshell	T	S1	~
Fusconaia masoni	Atlantic Pigtoe	E	S1	~
Lampsilis radiata	Eastern Lampmussel	T	S1S2	~
Lasmigona subviridis	Green Floater	E	S1	~
Lythrurus matutinus	Pinewoods Shiner	~	S3	~
Necturus lewisi	Neuse River Waterdog	SC	S2	~
Noturus furiosus	Carolina Madtom	T	S2	~
Strophitus undulatus	Creeper	T	S2	~
Villosa constricta	Notched Rainbow	SC	S3	~

*E, T, and SC denote Endangered, Threatened, and Special Concern respectively.
**S-ranks, referring to NC State ranks, range from S1 (imperiled) to S5 (secure), with S1S2 indicating some uncertainty in the appropriate rank.

As required by the Nature Preserves Act (NCGS 113A-164 of Article 9), the North Carolina Natural Heritage Program (NCNHP) compiles the North Carolina Department of Environment and Natural Resources (NCDENR) priority list of "Significant Natural Heritage Areas" (SNHAs). These sites are inventoried and evaluated on the basis of rare plant and animal species, rare or high quality natural communities, and special animal habitats, collectively termed the "Elements" of natural diversity. The sites are rated with regard to national and state significance, and nearly 250 acres of lower Swift Creek are rated as "High", which is the third highest rating, following "Exceptional" and "Very High", then followed by "Moderate", and


Wake Forest
Rolesville
Morrisville
Raleigh
Knightdale
Wendell
Zebulon
Cary
CHATHAM
Apex
Garner
Archer Lodge
Holly Springs
Clayton
WAKE
Wilson's Mills
Fuquay-Varina
JOHNSTON
Smithfield
N
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Middle Creek Watershed
Swift Creek Watershed
County Boundary
The Catena Group
Client
Dwarf Wedgemussel Viability Study: Phase 2
Complete 540 Triangle Expressway Southeast Extension: Detailed Study Alternatives
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 1 2 Miles
Job No.: 1175
Figure
1

“General”. It is noted that sites on the list should be given priority for protection; however, it does not imply that all of the areas currently receive protection (NCNHP 2015).

The Swift Creek population of the DWM was identified in the USFWS 1993 Recovery Plan as essential for the recovery of the species. Since the DWM is within the proposed action area, potential direct, indirect, and cumulative impacts to this species will need to be fully assessed and disclosed as required by Section 7 of the Endangered Species Act of 1973, as amended. This will be accomplished during the planning and environmental studies for the Complete 540 project.

In a letter to NCDOT dated February 17, 2011, the USFWS indicated that an updated Environmental Baseline of the DWM population in Swift Creek will be needed to determine if the proposed action has the potential to jeopardize the continued existence of this species. The USFWS proposed a three-tiered study to be implemented by NCDOT to develop this updated Environmental Baseline:

1. Provide an accounting (compliance/ implementation) of conservation measures that have been implemented in Swift Creek to protect DWM
2. Assess the effectiveness of existing conservation measures and environmental protections in Swift Creek with regard to habitat and population stability
3. Assess historic trends, and current viability of DWM population and habitat conditions in Swift Creek

In response to the correspondence and in coordination with NCDOT and USFWS, this study was initiated in March 2011, beginning with an intensive mussel survey effort that continued at various times of the year through October 2012. However, mussel surveys were also conducted in 2010 within Swift Creek as well as other waterbodies (Middle Creek, Neuse River etc.) within the project study corridors as part of the NEPA studies for the project. These data were gathered as a component of the mussel population viability portion of the third tier of this study. A Phase 1 report of this study was completed March 21, 2014, that compared the results of these surveys with all previous survey data. The other major tasks carried out in Phase 1 included assessing and comparing current and previous watershed and habitat conditions, as well as a gathering of information to provide an account of conservation measures, and what protective measures are in place within the SCW. The DWM Viability Study: Phase 1 Draft Report (Appendix A) served as an interim evaluation of baseline information for the watershed and the Swift Creek DWM population.

After review of the Phase 1 Draft Report by the USFWS and NCDOT, additional analysis was recommended for a second phase of the study (Phase 2) to develop a more complete baseline and meet the objectives of the study. The combined results of the two phases of this study are presented in this report.

1.1.Summary of Phase I Report

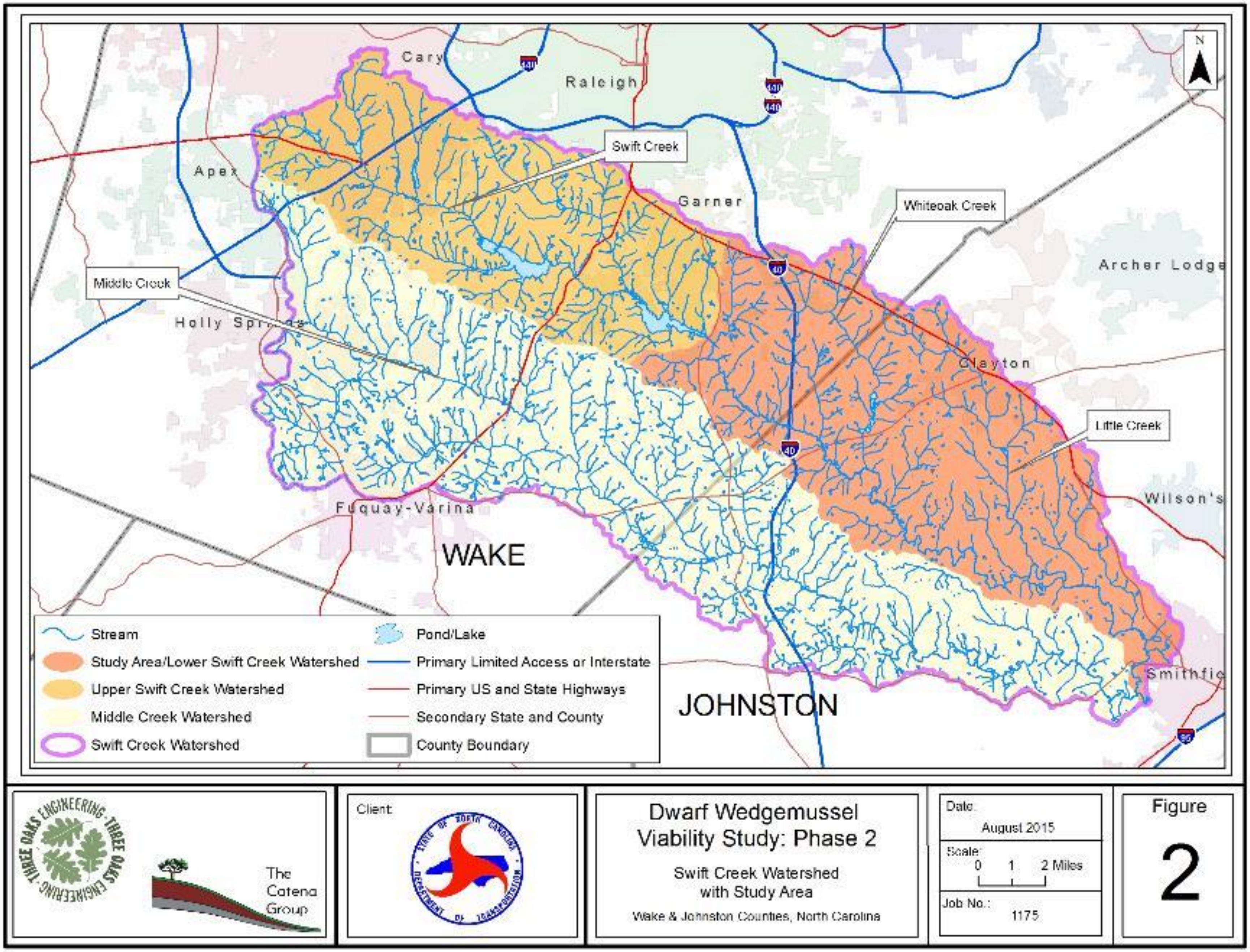
The preliminary results of Phase 1 demonstrated that there are numerous stressors to aquatic communities, particularly the DWM population, in the SCW. Many of these stressors are directly and indirectly related to the rapid urbanization of the watershed since the early 1990s. A number of conservation measures that had been developed and implemented within the SCW were identified in Phase 1. These measures consisted largely of establishing minimum buffer requirements, limiting the amount of imperviousness and nutrient inputs, and providing stormwater and erosion control measures. Additionally, measures associated with the Dempsey Benton Water Treatment Plant provide for maintenance of minimum flows in the Lower SCW. The Phase 1 report concluded that the effectiveness of these measures in providing sufficient protection to the DWM population was unclear. This was due mainly to the short period of time that these measures were in place, the difficulty in evaluating the effectiveness of a particular measure given the number of stressors that occur within the SCW, and the uncertainty of whether or not the measures were implemented to the level they were intended.

It appears that mussel populations have declined in conjunction with these recent changes. The declines seem to have leveled off, and there is some indication that mussel recruitment has increased within the last few years. The geomorphology component of the study identified that the heterogeneous distribution of substrate size within a site may be important for the DWM.

Phase 1 analysis indicated that the long term viability of the DWM population in SCW is threatened, but there was not sufficient information to predict the likelihood the species would continue to persist in Swift Creek into the future. Population augmentation using captive propagation of individuals was identified as a management tool that could enhance the viability of the population.

1.2.Study Area

SCW is located in Wake and Johnston Counties in Central North Carolina and is part of the Neuse River Basin (Figure 2). The watershed is contained entirely within the Piedmont Physiographic Province. The headwaters of Swift Creek are in the towns of Apex and Cary, Wake County; from there, the stream flows southeast for approximately 38 miles until joining the Neuse River near Smithfield in Johnston County. The system includes two major reservoirs, Lake Wheeler and Lake Benson, which serve as water sources for the Triangle Area. The drainage area of SCW is approximately 289 square miles, with a major tributary, Middle Creek accounting for 45% of the drainage area. SCW encompasses several municipalities, including portions of Raleigh, residential areas, forested areas, and agricultural fields. From the headwaters to and including Lake Benson is considered the Upper SCW; below Lake Benson to the convergence with the Neuse River (32 stream miles) is considered the Lower SCW (Figure 2). The DWM population occurs within the Lower SCW, thus it is where the majority of this


Cary
Raleigh
Apex
Garner
Holly Springs
Archer Lodge
Clayton
Wilson's
Fuquay-Varina
Smithfie
WAKE
JOHNSTON
Swift Creek
Whiteoak Creek
Middle Creek
Little Creek
N
Stream
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Middle Creek Watershed
Swift Creek Watershed
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
The Catena Group
Client
Dwarf Wedgemussel Viability Study: Phase 2
Swift Creek Watershed with Study Area
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 1 2 Miles
Job No.: 1175
Figure
2

study is focused, and is defined as the Study Area. However, conditions in the Upper SCW have some influence on the Lower SCW, therefore relevant data from the upper part of the watershed is provided and discussed in this report.

2.0 SPECIES DESCRIPTION

Alasmidonta heterodon (Dwarf Wedgemussel)

Federal Status: Endangered
Family: Unionidae
Listed: March 14, 1990

2.1.Characteristics

DWM was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortman (1919) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900).

The specific epithet *heterodon* refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. DWM is generally small, with a shell length ranging between 25 mm and 38 mm. The largest specimen reported by Clarke (1981) was 56.5 mm long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark and nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. This species is considered to be a long-term brooder, with gravid females reportedly observed in the fall months. Like other freshwater mussels, this species' eggs are fertilized in the female as sperm are taken in through their siphons as they respire. The eggs develop within the female's gills into larvae (glochidia). The females later release the glochidia, which then attaches to the gills or fins of a specific host fish species. Based on anecdotal evidence, such as dates when gravid females are present or absent, it appears that release of glochidia occurs primarily in April in North Carolina (Michaelson and Neves 1995). Recent research has confirmed at least three potential fish host species for DWM to be the Tessellated darter (*Etheostoma olmstedi*), Johnny Darter (*E. nigrum*), and Mottled Sculpin (*Cottus bairdii*) (Michaelson 1993). 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

The historic range of DWM was confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages, in 11 states, and 1 Canadian Province (USFWS 1993). When the recovery plan for this species was written, DWM was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The most recent assessment (2013 5-Year Review) indicates that DWM is currently found in 16 major drainages, comprising approximately 75 “sites” (one site may have multiple occurrences) (USFWS 2013). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the floods of 2005 are still being studied. At a recent USFWS meeting, it was noted that one of the Farmington River populations has been extirpated, possibly lowering the number of occupied “sites” (Sarah McRae USFWS, personal communication).

Strayer et al. (1996) conducted range-wide assessments of remaining DWM populations and assigned a population status to each of the populations. The status rating is based on range size, number of individuals, and evidence of reproduction. Seven of the 20 populations assessed were considered “poor”, and two others were considered “poor to fair” and “fair to poor”, respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however, it is believed to have been extirpated from the main-stem of the Neuse River.

DWM inhabits creeks and rivers of varying sizes (down to approximately two meters [6 ft] wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993). In North Carolina, DWM often occurs within submerged root mats along stable streambanks (USFWS 2007). Two general in-stream habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

2.3. Threats, Particularly the Swift Creek Population

The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, etc.) have contributed to the decline of this species throughout its range. With the exception of the Neversink River population in New York, which has an estimated population of over 80,000 DWM individuals, all of the other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpations from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes. Based on expert opinion of a North Carolina DWM (NC DWM) Work Group assembled by the USFWS Raleigh field office in 2012, the "Allee effect", defined as a high risk of demographic extirpation due to low population abundance and lack of dispersal, was identified as the second highest threat behind "unsuitable physical habitat" to the Swift Creek population (Smith et al. 2014).

2.3.1. *Sedimentation*

Siltation resulting from substandard land-use practices associated with activities such as agriculture, forestry, and land development has been recognized as a major contributing factor to 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 25 mm (one inch) have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the DWM because of accelerated sedimentation and erosion (Smith 1981).

2.3.2. *Habitat Alteration*

The impact of impoundments on freshwater mussels has been well documented (USFWS 1992a; Neves 1993). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia. 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 5.79 meters (19 feet) of muck (USFWS 1992b). Large portions of all of the river basins within the DWM range have been impounded and this is believed to be a major factor contributing to the decline of the species (Master 1986; USFWS 1993).

2.3.3. *Toxic Contaminants*

The presence of toxic contaminants has been shown to contribute to widespread declines of freshwater mussel populations (Havlik and Marking 1987; Bogan 1993; Neves et al. 1997; Richter et al. 1997; Strayer et al. 2004). Toxic contaminants can produce lethal or sub-lethal responses to freshwater mussels. The NC DWM Work Group identified “low water quality due to contaminants” as the third most important threat to the Swift Creek population (Smith et al. 2014). The sensitivities of freshwater mussels to toxic contaminants is variable based on species, life stage (glochidium, juvenile, or adult), and environmental conditions, as well as concentration and exposure route (water column, sediments, etc.), frequency, and duration. Several studies have indicated that early life stages of freshwater mussels are among the most sensitive aquatic organisms to various inorganic toxicants such as copper (Jacobson et al. 1993; Jacobson et al. 1997; Milam et al. 2005; Wang et al. 2007a; Wang et al. 2007b) and ammonia (NH3) (Wade 1992; Augsperger et al. 2003; Bartsch et al. 2003; Newton et al. 2003; Wang et al. 2007a; Wang et al. 2007b; Grabarkiewicz and Davis 2008).

Anthropogenic sources of ammonia and copper in surface waters include sewage treatment effluent, industrial wastewater effluent, and runoff and ground water contamination from agriculture, lawn/turf management, livestock operations, roadways, and faulty septic systems. 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 discharges of chlorinated sewage effluent.

Recent studies indicated that previous federal water quality criteria for many pollutants commonly found in wastewater discharges and stormwater runoff were likely not protective of freshwater mussels; nationwide regulations controlling the discharge or runoff of these pollutants are also not protective (Augspurger et al. 2003). The previous (1999) U.S. Environmental Protection Agency (EPA) recommended ‘freshwater ammonia aquatic life ambient water quality’ criteria were based on the most sensitive endpoints known at the time: the acute criterion was based primarily on effects on salmonids (where present) or other fish, and the chronic criterion was based primarily on reproductive effects on the benthic invertebrate *Hyalella* or on survival and growth of fish early life stages (when present) (USEPA 2009). Research demonstrated that these standards were not protective of freshwater mussel species, which are some of the most sensitive aquatic organisms to ammonia. As a result, the EPA recently revised the freshwater ammonia aquatic life ambient water quality criteria (acute and chronic standards) to reflect freshwater mussel species sensitivity thresholds (USEPA 2013).

Ward et al. (2007) sampled for ammonia, copper and chlorine at five locations within, or draining to, the portion of Swift Creek occupied by DWM, and found that ammonia and chlorine levels rarely exceeded ecological screening values; however, copper levels exceeded ecological screening values for both acute and chronic exposure at all sites. Further discussion of this study, and results of water quality sampling targeting these compounds that were conducted as part of the Phase 2 of this study are discussed in Section 3.5, and in further detail in the Lower Swift Creek Water Quality Report (Three Oaks Engineering/ The Catena Group 2015a), which is included in Appendix B

When publishing the five-year review for the Carolina Heelsplitter (*Lasmigona decorata*), another federally Endangered freshwater mussel species that occurs in North Carolina, the USFWS stated that there were "currently no water quality standards, or monitoring requirements for ammonia, copper and phosphorus in North Carolina" (USFWS 2012).

The Goose Creek Site Specific Management Plan (NCDENR 2009), which was developed to provide protection for the Carolina Heelsplitter, requires that any direct or indirect discharge that may cause ammonia toxicity to the Carolina Heelsplitter implement measures to reduce ammonia inputs to achieve 0.5 milligrams per liter or less of total ammonia based on chronic toxicity defined in 15A NCAC 02B .0202 (NCAC 1998). This level of total ammonia is based on ambient water temperature equal to or greater than 25 degrees Celsius (NCDENR 2009).

While there are still no adopted standards or monitoring requirements for ammonia, and phosphorus in North Carolina, standards have recently been developed for copper, as updated in the Triennial Review of Standards (North Carolina Register 2014). EPA water quality criteria and North Carolina water quality standards are discussed further in Section 3.3.

In addition, studies indicate other toxicants present in wastewater effluent such as pharmaceuticals and personal care products (fluoxitine, estrogenic compounds, opiate derivatives etc.) cause a wide array of neurotoxicological (Gagné et al 2007a), reproductive (Bringolf et al. 2007; Gagné et al 2007b) and behavioral (Hazelton et al. 2013, Heltsley et al. 2006) impacts to freshwater mussels.

Other sources of toxic contaminants in surface waters arise from highway and urban runoff. Numerous pollutants have been identified in highway runoff, including various metals (lead, zinc, iron, copper, etc.), sediment, pesticides, deicing salts, nutrients (nitrogen, phosphorus), and petroleum hydrocarbons (Gupta et al. 1981; Yousef et al. 1985). The sources of these runoff constituents range from construction and maintenance activities to daily vehicular use. Hoffman et al. (1984) concluded that highway runoff can contribute up to 80 percent of the total pollutant loadings to receiving water bodies; identifying, among others, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, lead, and zinc.

The toxicity of highway runoff to aquatic ecosystems is poorly understood. A major reason for this poor understanding is the low number of studies focusing solely on highway runoff. Potential impacts of highway runoff have often been inferred from studies conducted on urban runoff; however, the relative loadings of pollutants are often much greater in urban runoff, because of a larger drainage area and lower receiving water dilution ratios (Dupuis et al. 1985). The negative effects of urban runoff inputs on benthic macroinvertebrate communities have been well documented (Garie and McIntosh 1986; Jones and Clark 1987; Field and Pitt 1990). Lieb (1998) found the macroinvertebrate community of a headwater stream in Pennsylvania to be highly degraded by urban runoff via a detention pond. Improvements were observed at continual distances downstream from the discharge point; however, all sites examined were still impaired compared to a reference community.

The few studies that examined actual highway runoff show that some species demonstrate little sensitivity to highway runoff exposure, while others are much more sensitive (Dupuis et al. 1985). Maltby et al. (1995) found elevated levels of hydrocarbons and metals in both stream sediments and the water column below a heavily traveled British motorway. They demonstrated that the benthic amphipod (*Gammarus pulex*) experienced a decrease in survival when exposed to sediments contaminated with roadway runoff. However, this species showed no increase in mortality when exposed to water contaminated with roadway runoff. Most of these studies only measured acute toxicity to runoff and did not examine long-term effects.

The effects of highway runoff on freshwater bivalves have not been studied extensively. Augspurger (1992) compared sediment samples and soft tissues of three Eastern Elliptio (*Elliptio complanata*), a relatively common species upstream and downstream of the I-95 crossing of Swift Creek of the Tar River Basin in Nash County, North Carolina. The sediment samples as well as the mussels exhibited higher levels of aliphatic hydrocarbons, arsenic, lead, zinc, and other heavy metal contaminants in the downstream samples. Because of the small sample size, the effect on the health of these mussels was not studied. In another study, contaminant analysis of stream sediments showed an increase of polycyclic aromatic hydrocarbons and some metals downstream of road crossings, although there was no direct correlation found between increasing contaminant levels and decreasing mussel abundance at these crossings (Levine et al. 2005). The Eastern Elliptio was the only mussel species that was found in large enough numbers for statistically valid comparisons. The Eastern Elliptio is generally considered more tolerant of water quality degradation than many other mussel species. Further research is needed before the effects of highway runoff on sensitive mussel species such as the DWM can be determined.

In addition, contamination of surface water from toxic spills along roadways is known to have significant impacts to aquatic communities. A toxic spill resulting from a tanker truck accident that was carrying Octocure 554 (a chemical liquid used in the rubber making process) killed several miles of mussel populations in the Clinch River near Cedar Bluff, Virginia (Richmond Times Dispatch 1998). The spill killed thousands of fish and mussels, including three federally protected species. The Clinch River contains one of the most diverse mussel faunas in the United States. The stretch of the river affected by the spill was one of the few remaining areas that contained a reproducing population of the endangered Tan Riffleshell (*Epioblasma florentina walkeri*), which has not been found in the river since.

2.3.4. *Urbanization/Impervious Surface*

The Swift Creek watershed has experienced urbanization in recent years, which is discussed in detail in Section 3.0. The correlation of increasing development within a watershed and decreasing water quality is well documented (Lenat et al. 1979; Garie and McIntosh 1986; Crawford and Lenat 1989; Lieb 1998), and is largely associated with increases in impervious surface area. These increases in impervious surface area can affect water quality in a variety of ways, particularly with regard to changes to stream flow, water temperature, total suspended sediment, and pollutant loadings.

Multiple studies have demonstrated that water quality and stream ecosystem degradation begins to occur in watersheds that have approximately ten percent coverage by impervious surfaces (Schueler 1994; Arnold and Gibbons 1996; Stewart et al. 2000). NCWRC recommendations for management of protected aquatic species watersheds are to limit imperviousness to six percent of the watershed (NCWRC 2002). The amount of impervious surface has increased in the SCW, constituting about 11% of the SCW land area within Wake County (the more developed of the two counties). As a result, Wake County as a whole contributes about 4.29 inches/year of runoff (CDM 2003, Table 3-5). Of all the rainfall that falls onto these impervious surfaces, an estimated 95 percent becomes runoff. Johnston County is less developed than Wake County. As of 2011, the county was approximately 3.6 percent urban development, while the portion in the SCW was approximately 8.6 percent. This is based on the National Land Cover Dataset (NLCD, Homer et al. 2014), and assuming all development is captured in the Low, Medium, and High Intensity Developed categories. The 2009 NCDWQ Neuse River Basinwide Plan indicates the entire SCW is 29.5 percent urbanized, with much of the growth occurring in the last 20 years. Increases in impervious surface area within a watershed can result in extremes (either high or low) in peak discharge, runoff volume, and base flow conditions.

2.3.4.1. Peak Discharge

Peak discharge is the maximum rate of stormwater flow expected from a storm event, measured in cubic feet per second (cfs). Peak discharge is often one metric used in analyzing impacts from development. Peak discharge affects channel stability (or instability), which is one of the identified constituent elements of Critical Habitat for the DWM. Increases in peak discharge equates to higher velocity, which in turn increases the scouring effect (surface erodibility) of the runoff. Accordingly, sedimentation will increase as erosion rates increase. Increases of peak discharge rates, coupled with deforestation, have been shown to result in stream narrowing and incision and subsequent loss of ecosystem function (Sweeney et al. 2004). Increased runoff volume and peak discharge (from typical and atypical storm events) destabilize the stream channel.

2.3.4.2. Runoff Volume

Runoff volume is the amount of stormwater expected from a storm event, measured in acre-feet. Like peak discharge, runoff volume is another metric often used in determining impacts of development, especially on the aquatic environment. For example, increases in the amount of runoff normally equates to increased sediment. While the two indicators are related, when analyzed separately, both are useful in assessing impacts to aquatic systems.

In a stable system, an increase in the velocity may have little impact if volume does not change, provided that measures to slow the increased velocity have been implemented. However, the increased runoff volume may have enough sediment to cause detrimental impacts. Regardless, it is important to consider both the rate (peak discharge) and the amount (runoff volume) when assessing impacts to aquatic systems. Again, sufficient stormwater controls accompanying future development activities in any given watershed are essential for conservation of sensitive aquatic species such as DWM.

2.3.4.3. Decreased Base Flow

Increases of impervious surface lead to decreases in infiltration and base flow (groundwater flow) within adjacent streams. This can result in the following:

- Less water to cover the stream bottom during periods of reduced base flow.
- Increases in water evaporation and temperature in widened streams as a result of reduced overhanging tree cover and increased exposure to sunlight, especially in areas with shallower water.
- Extension of the waste water treatment plant (WWTP) effluent “plume” further downstream, if base flow is reduced and WWTP discharge remains constant or increases, as it takes longer for the stream to dilute the nutrients and other toxins in the effluent.

Permitted and un-permitted water withdrawals for crop and turf/lawn irrigation further exacerbate this effect. In North Carolina, permits are required for water withdrawals of one million gallons or greater. Withdrawals less than this are not regulated, and are often unknown. Numerous small withdrawal operations have been observed in the Lower SCW (Catena personal observations). During summer months withdrawals of up to 188 gallons per minute (gpm), or 0.42 cfs can significantly affect the available dilution for downstream dischargers (Belnick 2001).

In general, soils in the Piedmont portion of the Neuse River Basin are highly erodible and are underlain by fractured rock formations that have limited water storage capacity resulting in the streams that flow through them being naturally susceptible to periods of very low or even interrupted flow. Streams in this area tend to have low summer flows and limited ability to assimilate oxygen-consuming wastes (NCWRC 2005). In addition, the Upper SCW is close to the transitional area between the poorly drained soils of the Triassic basin and the moderately drained soils weathered from granitic rocks underlying the Lower SCW. As such, Swift Creek is even more susceptible to periods of interrupted flow, particularly in the upper reaches, which have almost no potential for sustained 7Q10 low flow discharge; 7Q10 is defined as the minimum average discharge for a consecutive seven day period occurring, on average, once in ten years (Weaver 1998). The natural susceptibility of these watersheds to periods of very low to interrupted flow is further compounded by anthropogenic factors such as water withdrawals and urbanization.

Prolonged periods of drought have been shown to adversely impact mussel species (Johnson et al. 2001; Golladay et al. 2005; USFWS 2012), as mussels may face increased water temperatures and reduced dissolved oxygen (DO) concentrations (hypoxia, or eventually anoxia), increased predation, and emersion or stranding (Johnson et al. 2001). Thin-shelled species like DWM may be inherently more prone to the consequences of drought than thicker shelled species like *Elliptio* mussels. Prolonged drought has been identified as a major threat to the endangered Carolina Heelsplitter (USFWS 2012). Similarly, based on expert opinion of a NC DWM Work Group assembled by the USFWS Raleigh field office, drought ("unsuitable flow") was identified as one of the top three threats in all of the populations in the Tar River Basin (Smith et al. 2015).

While drought is recognized as a major threat for many mussel species, the actual low flow requirements of mussels is poorly understood. Johnson et al. (2001) and Golladay et al. (2005) assessed drought impacts on mussel assemblages in a number of streams in the Flint River Basin of southwestern Georgia. Flow rate, water temperature, water depth, and DO were monitored throughout the study and sites were classified as flowing or non-flowing during the drought period. Sites that ceased flowing during the drought had significant declines in the abundance of all mussel species, some of which are endangered, as well as declines in species richness. However, sites that maintained some flow during the drought had increases in stable species of mussels and no change in special concern or endangered species through the drought. Mortality of mussels at sites that ceased flowing was attributed to reductions in DO concentration, which was highly correlated with water velocity.

As part of the Section 7 Consultation for the Dempsey E. Benton Water Treatment Plant, a 60-year synthesized hydrologic time series was developed for Swift Creek using a ratio of the drainage area from the nearby, unregulated Middle Creek. The analysis concluded that Swift Creek historically experienced near zero and zero flow conditions (Entrix 2005). Minimum flow releases are now guaranteed as a result of conservation measures developed for the project (see Section 4.2.5).

2.3.4.4. Thermal Pollution

Concerns over effects of thermal pollution from urban runoff on aquatic systems have increased in recent years. Elevation of stream temperature can raise Biochemical Oxygen Demand (BOD), lower DO, and alter faunal composition (Poole et al. 2001, Roa-Espinosa et al. 2003). Typically, runoff from a developed impervious area will have a temperature similar to the temperature of the impervious area. During the hot summer months, this could potentially make the stormwater runoff reach temperatures up to and above 90°F, which could be detrimental to the aquatic life. Traditional structural stormwater controls, such as open storm-water detention ponds/basins that do not allow for infiltration, do not protect receiving water bodies against adverse temperature effects. Various stormwater Best Management Practices (BMPs) have been shown to be effective in ameliorating temperature effects (NC State Cooperative Extension 2006a). For example, bioretention devices were shown to reduce runoff temperature by 5-10°F in Greensboro, NC (NC State Cooperative Extension 2006b). The loss of riparian buffers as well as peak discharge related channel widening can also contribute to stream temperature increases, by increasing sunlight exposure and decreasing water depth.

2.3.5. *Invasive Species*

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 DWM. 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 Widlak 1987; Alderman 1995). The Zebra Mussel, native to the drainage basins of the Black, Caspian, and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The zebra mussel is not currently known from any river supporting DWM populations.

2.3.6. *Loss of Riparian Buffers*

Loss of riparian buffers can lead to degradation of adjacent aquatic habitats. The role of forested riparian buffers in protecting aquatic habitats is well documented (NCWRC 2002). Riparian buffers provide many functions including pollutant reduction and filtration, a primary source of carbon for aquatic food webs, stream channel stability, and maintenance of water and air temperatures. Numerous studies have recommended a range of buffer widths needed to maintain these functions. Recommended widths vary greatly depending on the parameter or function evaluated. Wide contiguous buffers of 100-300 feet are recommended to adequately perform all functions (NCWRC 2002). The NCWRC recommends a minimum 200-foot native, forested buffer on perennial streams and a 100-foot forested buffer on intermittent streams in watersheds that support federally endangered and threatened aquatic species (NCWRC 2002). Although not officially adopted, the USFWS uses the NCWRC recommendations as guidance when addressing federally protected aquatic species in North Carolina.

2.3.7. *Degradation Caused by All-terrain Vehicle Use*

Another human-related factor adversely impacting habitat of the DWM is recreational all-terrain vehicle (ATV) use. ATV tracks have been noted crossing streams as well as traveling stream channels throughout the Swift Creek watershed. In addition to directly running over mussels, ATVs destabilize stream banks and floodplains, causing sedimentation and buffer degradation. While there is no quantitative data available on ATV use, locally, this can have significant impacts. This was identified as a threat to the DWM population in Swift Creek (Smith et al. 2015)

Photo 1. ATV Trails in Swift Creek Channel

3.0 WATERSHED CONDITIONS

An overall assessment of current and past conditions of the watershed is crucial to understanding mussel population viability. Various GIS layers, aerial photography, and publications were consulted to characterize the past and current conditions within the SCW.

GIS data layers utilized include the National Land Cover Database (NLCD) and the National Pollution Discharge Elimination System (NPDES) database. The land cover shapefile is available from the United States Department of Agriculture/Natural Resources Conservation Service GeoSpatial Data Gateway (USDA 2015). The nationwide comprehensive land cover data layer was created through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium using data through 2011. The NPDES shapefile is available online from NC OneMap as updated by the NCDWQ in 2006 (NC OneMap 2006). The file identifies outfall locations and type of individual NPDES permitted wastewater discharges. The NC Division of Water Resources (NCDWR, formerly the NC Division of Water Quality (NCDWQ)) also keeps a more updated list of active NPDES permits. The list, updated September 4, 2015, was used along with the shapefile to locate active permitted dischargers (NCDWR 2013a). **Please note: References to NCDWQ indicate information that was published prior to the agency name change.**

3.1. Land Use and Population Growth

In the last half century, the development within the SCW is concentrated in the towns of Cary and Apex, and along highway corridors (AMEC 2004). Cary's population grew from 7,640 to over 135,000 between 1970 and 2010 (NCDWQ 2003a; US Census 2015). As of 2014, according to the latest US Census Bureau estimates, Cary's population is estimated to be over 155,000 (US Census 2015). Apex's population grew from 2,192 to over 37,000 between 1970 and 2010 (NCDWQ 2003a; US Census 2015). Apex's population is estimated to be nearly 44,000 as of 2014 (US Census 2015). The upper portion of SCW has mostly been built out over the last 20 years, with the remaining forested areas lying almost completely in nature preserves or floodplains (see Section 3.1.1 below). Further development will likely not affect the water quality within the Upper SCW, given the large majority of development that has already taken place (NCDWQ 2003a). However, development is likely to happen in the Lower SCW where more parcels available for development remain.

The trend of development in recent years has occurred throughout much of the Neuse River Basin. Land cover information from the National Resources Inventory (NRI), which is published by the Natural Resource Conservation Service (NRCS), was collected several times between 1982 and 1997 and was presented in the 2009 Neuse River Basinwide Water Quality Plan, Chapter 16 – Community Changes and Challenges (NCDWQ 2009). While the data is outdated and presented at a larger scale than the project study area (the entire Neuse River Basin versus SCW), it demonstrates the development of the Neuse River Basin during the 15-year period for which data is available (Table 2). The most important change with regard to aquatic species is the conversion of agricultural land cover (-17%) and forest cover (-7.2%) to urban and developed land (+89.8%).

Table 2. Land Cover in the Neuse River Basin: 1982 vs. 1997 (NCDWQ, 2009)

Land Cover	1982 % of Total	1997 % of Total	% Change since 1982
Cultivated crop	28.8	23.9	-17.0
Uncultivated crop	0.4	1.5	275
Pasture	3.2	3.7	16.7
Forest	48.4	44.9	-7.2
Urban & built-up	6.9	13.1	89.9
Federal	2.1	2.3	9.5
Other	10.4	10.6	1.9

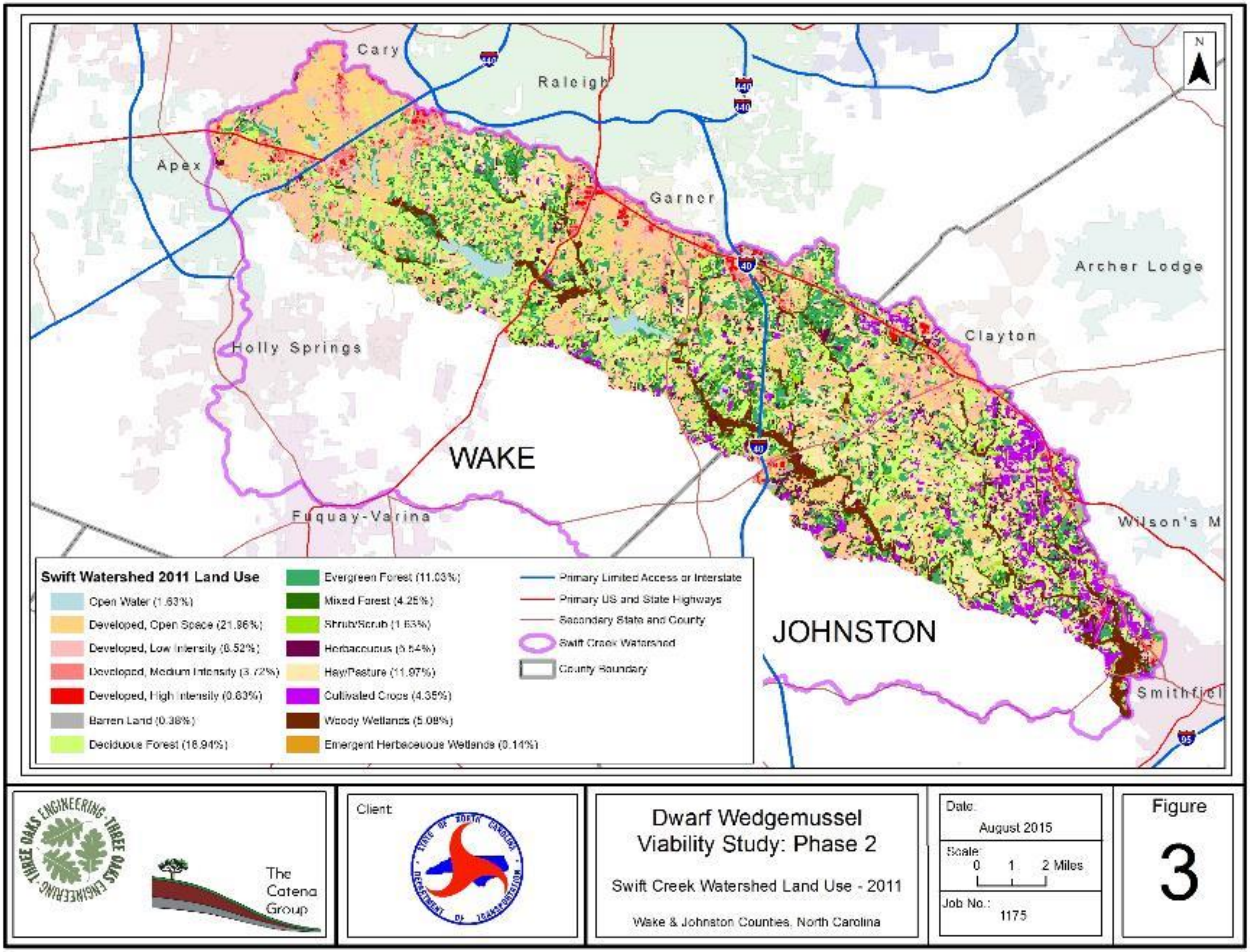
A more recent land cover dataset is available from the NLCD (Figure 3). The 2011 dataset is satellite data with a spatial resolution of 30 meters. The 2011 land use dataset is in a more manageable format, and thus SCW could be examined exclusively. Taken in coordination with the other land use dataset, it is a clearer picture of the amount of developed lands, compared to the amount of agriculture and forestry cover for SCW. The 2011 dataset also divides land use into more categories, such as varying degrees of development and types of forest (Table 3).

Table 3. Land Use cover in Swift Creek Watershed, NLCD 2011

Land Use	Sum of Area (Square Miles)	Percent*
Open water	2.58	1.63
Developed, open space	33.96	21.96
Developed, low intensity	13.17	8.52
Developed, medium intensity	5.75	3.72
Developed, high intensity	1.29	0.83
Barren land	0.59	0.38
Deciduous forest	29.29	18.94
Evergreen forest	17.06	11.03
Mixed forest	6.58	4.25
Shrub/scrub	2.52	1.63
Grassland/herbaceous	8.56	5.54
Pasture/hay	18.51	11.97
Cultivated crops	6.72	4.35
Woody wetlands	7.85	5.08
Emergent herbaceous wetlands	0.22	0.14
Total	154.65	99.97

* Due to rounding, this column does not add to exactly 100%

In the Phase 1 report, the NLCD data set used was from 2006, as that was the most recent dataset available at that time. There has been an increase in the combined "Developed" land use categories from 2006 to 2011 (30.86% to 35.03%), and a corresponding decrease in forested and agricultural (crops, pasture land etc.) land uses (from 2006 to 2011, 54.48% to 50.54%). Barren land has slightly decreased (0.44% to 0.38%), shrub/scrub land has increased (0.79% to 1.63%), and wetlands have remained about the same (5.20% to 5.22%). All of which further demonstrates the continued development in watershed. It should also be noted that the level of change in developed land from 2006 to 2011 was likely slowed by the economic recession that began in December of 2007 and continued into 2010. As the impact of the recession wanes, increased development in the SCW can be expected.



N
Cary
Raleigh
Apex
Garner
Archer Lodge
Clayton
Holly Springs
WAKE
Fuquay-Varina
Wilson's M
JOHNSTON
Smithfiel
Swift Watershed 2011 Land Use
Open Water (1.63%)
Developed, Open Space (21.86%)
Developed, Low Intensity (8.52%)
Developed, Medium Intensity (3.72%)
Developed, High Intensity (0.63%)
Barren Land (0.38%)
Deciduous Forest (16.94%)
Evergreen Forest (11.03%)
Mixed Forest (4.25%)
Shrub/Scrub (1.63%)
Herbaceous (5.54%)
Hay/Pasture (11.97%)
Cultivated Crops (4.35%)
Woody Wetlands (5.08%)
Emergent Herbaceuous Wetlands (0.14%)
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Swift Creek Watershed
County Boundary
The Catena Group
Client:
Dwarf Wedgemussel Viability Study: Phase 2
Swift Creek Watershed Land Use - 2011
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 1 2 Miles
Job No.:
1175
Figure
3

Of the various water bodies within the watershed, Lake Wheeler makes up about 0.875 square mile, and Lake Benson about 0.521 square mile. Other ponded areas constitute the other 1.173 square miles of open water in the watershed.

3.1.1. *Natural Heritage Areas, Parks and Green Space*

There are several natural heritage areas, parks, and green spaces within the Upper SCW (Table 4; Figure 4). The Hemlock Bluffs Nature Preserve near Cary, upstream of Kildaire Farm Road, is approximately 122 acres in size and has a rating of Moderate (See Section 1.0). The Triangle Land Conservancy (TLC) maintains the Swift Creek Bluffs Nature Preserve, which is upstream of Holly Springs Road; it has a rating of Moderate, and is nearly 50 acres in size. TLC also maintains conservation easements on two farms, Theys and MacNair Farms (also referred to as Steep Hill Creek Bottomlands), totaling 130 acres. An area of approximately 160 acres around and including Yates Mill Pond has been rated as Exceptional.

In the Lower SCW (Figure 4), there is a 240-acre Natural Heritage Program natural area (NHNA) (Swift Creek Aquatic Habitat) along the main stem of Swift Creek from Lake Benson to Smithfield, as well as lower portions of White Oak and Little Creeks, which is rated as “High” (NCNHP 2015). A major portion of this NHNA is subject to protective measures that go above and beyond protective requirements that apply to the entire Neuse River (see section 4.2.7). However, in 2013, the NC legislature signed into law Session Law 2013-413, which prohibits local governments from enacting environmental ordinances in areas that are already regulated by an environmental agency. This potentially could dissolve some of the more protective requirements within the SCW. The Environmental Review Commission discussed repealing this law in March of 2014, but it remains in place as of the writing of this report. NCNHP recommends a High Quality Water designation for this stretch of Swift Creek, which would not allow any additional discharges into the stream (NCNHP 2003). Adjacent to a portion of the Swift Creek Aquatic Habitat NHNA is the Swift Creek Magnolia Slopes, which has a rating of General and is almost 20 acres. Along Reedy Branch stream is the 14.7 acre Reedy Branch Floodplain NHNA with a rating of High.

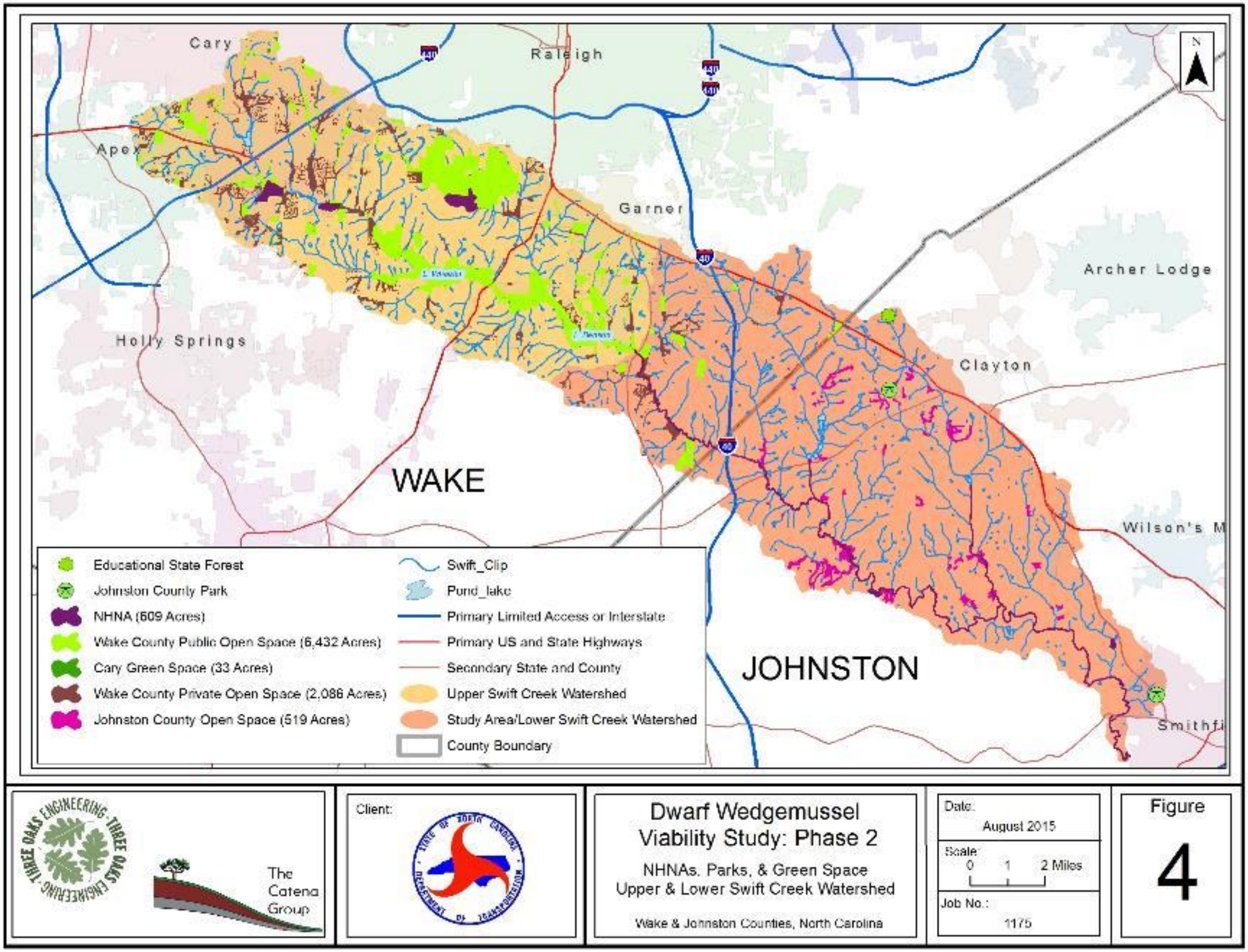

Cary
Raleigh
Apex
Garner
Archer Lodge
Holly Springs
Clayton
WAKE
Wilson's M
JOHNSTON
Smithfi
Educational State Forest
Johnston County Park
NHNA (609 Acres)
Wake County Public Open Space (6,432 Acres)
Cary Green Space (33 Acres)
Wake County Private Open Space (2,086 Acres)
Johnston County Open Space (519 Acres)
Swift_Clip
Pond_lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Upper Swift Creek Watershed
Study Area/Lower Swift Creek Watershed
County Boundary
The Catena Group
Client:
Dwarf Wedgemussel
Viability Study: Phase 2
NHNAs, Parks, & Green Space
Upper & Lower Swift Creek Watershed
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 1 2 Miles
Job No.:
1175
Figure
4

Table 4. Upper SCW and Study Area Total Acreage of Open Space (compared to total area).

Upper SCW	Acres
NHNAs	332
Wake County Public	5,886
Wake County Private	1,638
Cary Green Space	32
TLC	130
Total Open Space	*8,018*
Total Area	*42,279*

Study Area (Lower SCW)	Acres
NHNAs	276
Wake County Public	416
Wake County Private	449
Johnston County Open Space	519
Parks	84
Total Open Space	*1,744*
Total Area	*56,673*

Also of significance are public parks and open or green spaces designated by municipalities. There are a number of such areas in both the Upper and Lower SCW (Table 4).

3.2.Surface Water Classification and Use Support Ratings in SCW

The State of North Carolina assigns a best usage classification to all waters of North Carolina. These classifications provide a level of water quality protection to ensure that the designated usage of that water body is maintained. The minimum designation of Class C waters are defined as waters that are suitable for aquatic life propagation and survival, fishing, wildlife, secondary recreation and agriculture. Class C imposes a minimum standard of protection for all waters of North Carolina. Swift Creek is classified as a Water Supply-III (WS-III), Nutrient Sensitive Waters (NSW) from the headwaters to the dam at Lake Benson (NCDENR 2015). WS-III classification indicates a water body used as a source for drinking water where a more strict classification is not feasible, and also protected for Class C uses. WS-III waters are generally in low to moderately developed watersheds. NSW is a supplemental classification intended for waters needing additional nutrient management due to being subject to excessive growth of microscopic or macroscopic vegetation. Swift Creek from the dam at Lake Benson to the Neuse River is a Class C, NSW stream, including Mahler's Creek, White Oak Creek, Little Creek and Reedy Branch.

There is also a Critical Area (CA) classification on the waters of Swift Creek from about one mile above Lake Benson to the dam at Lake Benson and along an unnamed tributary of Swift Creek flowing into Lake Benson. A CA classification is defined as land within a half-mile upstream and draining to an intake area or draining to the water supply reservoir (NCDWR 2014a). These are areas where the risks associated with pollution to drinking water supplies are greater than in other areas in the watershed.

The entire Neuse River Basin is classified as NSW. Based on the use of surface water within the watershed as a drinking water source, in addition to the desire to protect the many natural resources present, the entire SCW is identified as a high priority for protection in Wake County (CH2M Hill 2003).

Both point source and non-point source discharges contribute to water quality degradation by introducing various pollutants into the water body. Federal and state legislation exists that is intended to help maintain or restore the environmental quality of North Carolina waters.

3.3. Water Quality Conditions in SCW

As discussed in Section 2.3, degradation of water quality is a major threat to aquatic species including DWM. Section (§) 304(a)(1) of the Clean Water Act (CWA) requires the EPA to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are used as guidance to States and authorized Tribes, which under § 303(c)(2)(B) of the CWA are required to adopt numeric standards for § 307(a) priority toxic pollutants, if the discharge or presence of the pollutant can reasonably be expected to interfere with designated uses, such as aquatic life. The § 307(a) list contains 65 compounds and families of compounds, which the EPA has interpreted to include 126 priority toxic pollutants. In addition to narrative and numeric (chemical-specific) criteria, other types of water quality criteria include:

- Biological Criteria (description of the desired aquatic community)
- Nutrient Criteria (protection against nutrient over-enrichment and eutrophication)
- Sediment Criteria (protection from adverse effects of contaminated and uncontaminated sediments)

The CWA also requires states to "hold public hearings for the purpose of reviewing applicable water quality standards and, as appropriate, modifying and adopting standards" at least once every three years, referred to as Triennial Reviews-33 U.S.C. § 1313(c)(1). The most recent Triennial Review hearing was held on November 19, 2013, with a comment period that ended on January 03, 2014. The NC Conservation Network (NCCN) provided numerous comments, pointing out that the Triennial Review hearing was "four years overdue" as the previous public hearing was held in 2006 (NCCN 2014). NCCN also stated that North Carolina "lags behind neighboring states in adopting standards" that meet EPA water quality criteria recommendations. They noted that NC currently does not have water quality standards for ammonia and various heavy metals including copper, and recommend the EPA criteria be used to develop these standards (NCCN 2014). Since then, new rules have been developed that provide water quality standards for heavy metals including copper, which became effective January 1, 2015 (NC Register 2014). Numerous other recommendations were also made with regard to establishing standards, and revising existing standards of various other toxicants. Dissolved metal water quality standards were proposed for arsenic, beryllium, cadmium, chromium III, chromium VI, copper, lead, nickel, silver and zinc. Iron and manganese standards were proposed for removal (NC Register 2014).

3.3.1. *Water Quality Monitoring*

Physical, chemical, and biological parameters are routinely monitored to assess water quality of a particular water body to determine if the established uses of the water body are being maintained. Water quality monitoring programs have been implemented by the NCDWR to assess water quality trends throughout the State. As discussed in Section 3.3, numeric standards of chemical and physical parameters have been established to determine if designated uses are met.

Biological criteria can be monitored in a variety of ways, including benthic macroinvertebrates and fish community composition. Benthic macroinvertebrates, or benthos, are monitored to assess water quality by sampling for selected organisms. The species richness and overall biomass, as well as the presence of various groups intolerant of water quality degradation, are reflections of water quality. A biodiversity rating is given to a sampled water body based on the taxa richness of the stream and a qualitative sampling for intolerant forms such as mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera), collectively referred to as EPT. Stream biodiversity can be rated as Excellent, Good, Good-Fair, Fair and Poor. Excellent and Good ratings indicate that the best usage classification for that stream is being Supported (S); Good-Fair rating indicates that the usage is Supported, but is also Threatened (ST); Fair rating indicates Partial Support (PS) of the best usage; and a Poor rating indicates that the best usage classification is Not Supported (NS).

There are 12 monitoring sites at which water quality and/or discharge rates are measured within SCW, operated by the US Geologic Survey (USGS), the City of Raleigh, or the Lower Neuse Basin Association (LNBA) (Table 5; Figure 5). For stations that monitor discharge, there are maximum, minimum, and mean of daily discharge values calculated in cfs for each day of the recording period. Discharge data is analyzed in Section 6.0. USGS monitoring stations were located via the USGS National Water Information System mapper (USGS 2015).

Water quality is determined based on a set of parameters that indicate the health and function of a water body. The NCDWQ's "Redbook" of Surface Waters and Wetlands Standards (NCDWQ 2003b) provides standard levels at which parameters should be measured to indicate good water quality. Additionally, USEPA has published guidelines on specific parameters, ammonia and copper in particular, that provide more detailed information for aquatic species sensitivity to these parameters (USEPA 2007 and 2013). In this analysis, the EPA's 2013 criteria for ammonia are used, which are dependent on pH and temperature to determine appropriate ammonia ecological thresholds. The EPA's criteria for copper, however, are not used, as this determination requires the measurement of an additional eight parameters, which were not always available. For simplicity, the NCDWQ copper standard (7 ug/L) is used instead. Other parameters of importance to aquatic life, particularly freshwater mussels, examined here are

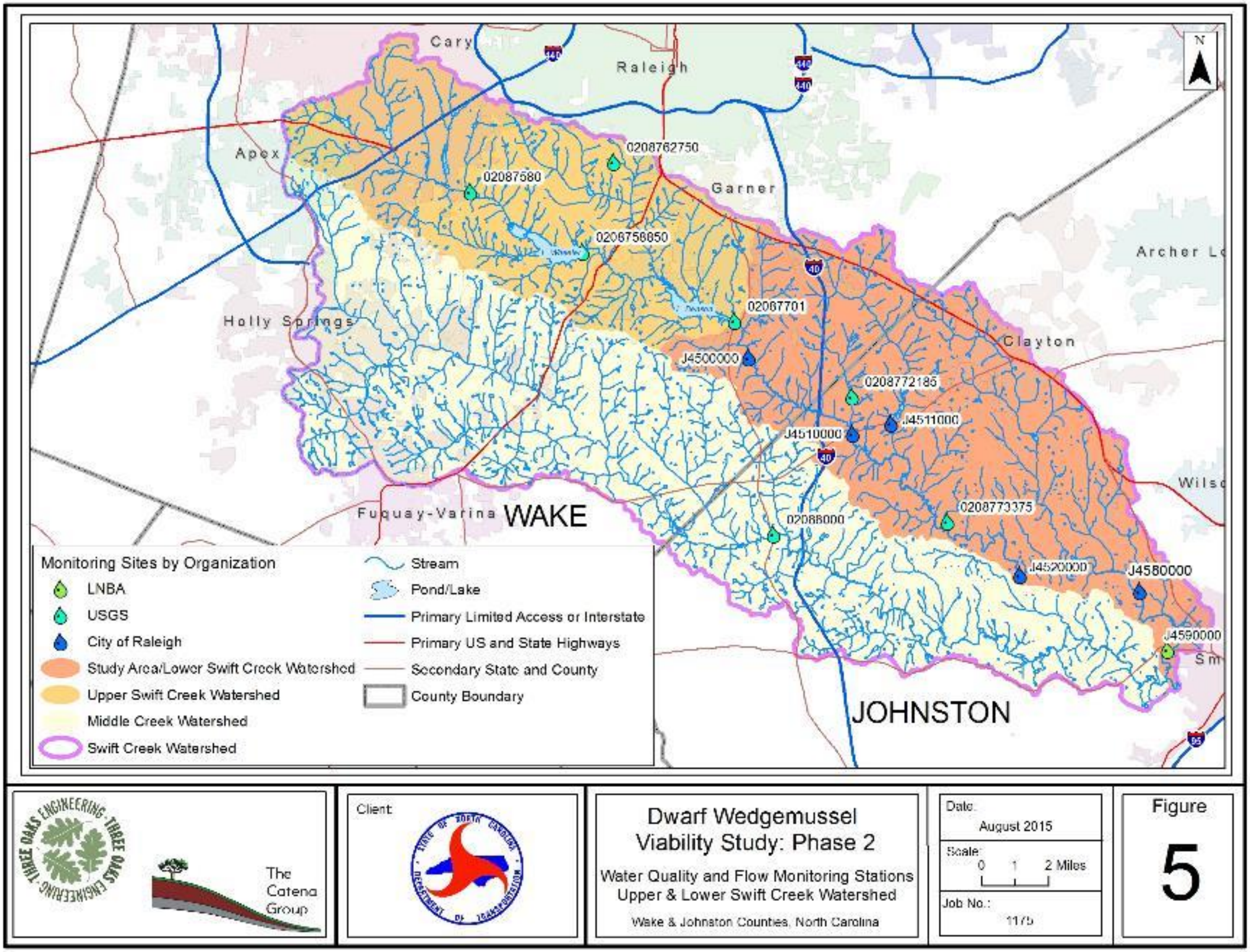

Cary
Raleigh
Apex
Garner
Holly Springs
Archer Lo
Clayton
Wilso
Fuquay-Varina
WAKE
JOHNSTON
Sm
N
0208762750
02087580
0208758850
02087701
J4500000
0208772185
J4511000
J4510000
0208773375
02088000
J4520000
J4580000
J4590000
Monitoring Sites by Organization
LNBA
USGS
City of Raleigh
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Middle Creek Watershed
Swift Creek Watershed
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
The Catena Group
Client
Dwarf Wedgemussel
Viability Study: Phase 2
Water Quality and Flow Monitoring Stations
Upper & Lower Swift Creek Watershed
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 1 2 Miles
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Figure
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(with respective standard levels): DO (>5.0 mg/L), pH (6.0-9.0), turbidity (<50 Nephelometric Turbidity Units (NTU)), and temperature.

Table 5 Surface Water Monitoring Sites in Swift Creek Watershed

Upper/ Lower	Site No.	Location	Operator	Parameters measured*
Upper	02087580	Swift Crk near Apex	USGS	WQ, Discharge
Upper	0208762750	UT to Swift Crk near Yates Mill Pond	USGS	WQ, Discharge
Upper	0208758850	Swift Crk at McCullars Crossroads	USGS	Discharge
Upper	02087701	Lake Benson at Dam near Garner, NC	USGS	WQ
Lower	J4500000 (52)	Swift Crk near Garner (Indian Creek)	City of Raleigh	WQ
Lower	J4510000 (54)	Swift Crk at NC 42 near Clayton	City of Raleigh	WQ
Lower	J4520000 (56)	Swift Crk at SR 1562 near Smithfield	City of Raleigh	WQ
Lower	J4511000 (55)	White Oak Crk at NC 42 near Clayton	City of Raleigh	WQ
Lower	J4580000	Swift Creek at SR 1501 near Smithfield	LNBA	WQ
Lower	0208772185	Swift Crk at NC 42 near Clayton, NC	USGS	Discharge
Lower	0208773375	Swift Crk at SR1555 near Clayton	USGS	Discharge
Lower	J4590000	Swift Crk at NC 210 near Smithfield	LNBA	WQ

*WQ – Water quality

3.3.1.1. Upper SCW

The USGS station near Apex (Site No. 02087580) collected water quality data from 1989 to 1995, again from 2000 to September 2011, and from October 2012 to present. Monthly temperature measurements were taken and ranged between 1°C and 28.2°C. Ammonia, which was measured on a monthly basis, did not exceed either the acute or chronic levels (USEPA 2013) except on one occasion in March, 2011 (measured at 0.26 mg/L). Of the more than 200 DO measurements, approximately 24 dipped below the 5.0 mg/L standard, the lowest of which was 1.7 mg/L in August 2007. Monthly pH measurements indicated the pH levels fell outside the NCDWR recommended range (6.0 to 9.0, NCDWQ 2003b) five times. Copper measurements were taken 25 times between 1989 and 1995, none of which exceed the NCDWR water quality standard.

The LNBA also monitors water quality at USGS station 02087580, but refer to it as “Station SR 1152 Holly Springs Road near Macedonia” (J4414000). Water quality measurements taken included DO, pH, temperature, turbidity, and ammonia, among others. For the result statistics done by LNBA for years 2006 to 2014, see Appendix C.

The USGS station near Yates Mill Pond (0208762750) collected data from 2002 to 2011. Water quality measurements were less frequent than at other stations. Water temperature measurements were taken 19 times and ranged between 6.6°C and 21.2°C. Ammonia levels never exceeded acute or chronic levels, though some measurements did not have corresponding pH and temperature measurements. Ammonia chronic and acute standards are dependent on pH and temperature, but because the pH measurements were generally low (6.0 or below), and ammonia becomes less toxic with lower pH levels, there is less of a chance these ammonia levels posed a risk to aquatic life. Measurements of 19 samples for DO levels indicated just one sample below the standard level of 5.0 mg/L. Twelve of the 22 samples measuring pH were below 6.0, the level the NCDWR recommends for healthy water bodies. Two copper measurements were above the standard for that parameter (USGS 2015). The Yates Mill Pond station also has daily flow rate statistics for 2003 to 2004.

The USGS station in Lake Benson (02087701) collected data in 1970 and then from 1989 to 2011. Samples were taken from April to November. Approximately 100 temperature readings were taken ranging from 10°C to 33°C. Ammonia measurements exceeded the chronic levels in two out of 101 samples (August 30, 2006 and August 8, 2009), but did not exceed acute levels. DO readings on 100 samples noted 38 which were below 5 mg/L. Measurements of pH were taken in both the field and the lab; however, the latter of which not after 1995. The pH level at this station dropped below 6.0 on three occasions (July 5, 2006 and twice on April 26, 2007). Copper measurements were taken fairly regularly, and exceeded 7 ug/L on one occasion (April 15, 2010).

The USGS station at McCullars Crossroads collected discharge data starting in 1988, and continues collecting this data through the present (USGS 2015).

3.3.1.2. Lower SCW

Water quality data collected by the City of Raleigh from 2009 to 2015 includes collection of samples on 93 dates. These were obtained from Edward Buchan, Environmental Coordinator with the City of Raleigh on July 17, 2012, April 21, 2015, and June 23, 2015.

Temperatures at Indian Creek discharge (station number J4500000) near Garner ranged between 2.7°C and 29.4°C. Ammonia levels exceeded the chronic level on five occasions (September 2009, November 2010, January 2011, July 2011, and October 2012), and exceeded the acute level one time (January 2011). DO fell below 5.0 mg/L on 14 occasions. The pH levels remained between 6.0 and 9.0 on days when samples were collected. Turbidity levels did not exceed 50 NTU, except on two days of sampling (290 NTU in July 2012 and 200 NTU in January 2015) (Buchan 2015).

Temperatures at NC 42 (station number J4510000) near Clayton ranged between 2.1°C and 28.8°C. Ammonia levels exceeded the chronic level on three occasions (January 2010, January 2011, and July 2011), but did not exceed the acute level. DO did not dip below 5.0 mg/L. The pH levels remained between 6.0 and 9.0 on days when sampling was conducted. Turbidity exceeded the 50 NTU level on four occasions (January 2010, May 2013, July 2013, and January 2015) (Buchan 2015).

Temperatures at White Oak Creek at NC 42 near Clayton (J4511000) ranged from 2.2°C to 29.3°C. Ammonia levels exceeded the chronic levels on seven occasions, but did not exceed the acute standard level. DO measurements were below 5.0 mg/L on 13 days when samples were taken; pH levels remained between 6.0 and 9.0 on days when samples were taken during the sampling period. Turbidity exceeded the 50 NTU level on three occasions (March 2010, January 2014, and October 2014) (Buchan 2015).

Temperatures at SR 1562 (station number J4520000) near Smithfield ranged between 1.9°C and 27.4°C. Ammonia levels exceeded the chronic level on one occasion (January 2011), but did not exceed the acute level. DO and pH levels remained within the appropriate range on days when sampling at this station was conducted. Turbidity exceeded the 50 NTU level on four occasions (January 2010, May 2013, October 2014, and January 2015) (Buchan 2015).

The USGS station on Swift Creek at NC 42 near Clayton (0208772185) measured flow rates from 1988 to 1997 on 28 occasions, with an average flow of 73 cfs. The greatest flow occurred on May 1, 1996 (796 cfs) and the lowest flow occurred on August 8, 1990 (5.9 cfs). The USGS station on Swift Creek at SR 1555 near Clayton (0208773375) has been taking measurements of flow rates since 2008. For a more detailed discussion of this monitoring station, see Section 6.0.

The LNBA station at SR 1501 (Swift Creek Road) near Smithfield (J4580000) has been monitored since 2012 to present. Temperatures range between 1.7°C and 27.4°C. Ammonia measurements did not exceed chronic or acute standard levels. DO and pH levels remained within the appropriate range on days when sampling at this station was conducted. Turbidity exceeded the 50 NTU level on three occasions (June 2013, July 2013, and January 2015) (Buchan 2015)

The LNBA station at NC 210 near Smithfield (J4590000) was monitored from 2006 to 2012. Temperatures ranged between 3.9°C and 29.9°C in 85 samples. Ammonia measurements were taken a total of 65 times during sampling, with values ranging between 0.01 and 0.44 mg/L. Sample levels of DO were never below 4.0 mg/L from a total of 101 samples, and below 5.0 mg/L in one sample. The pH levels were not recorded outside of the 6.0 and 9.0 range during sampling. Turbidity measurements exceeded 50 NTU in four out of 65 samples. Detailed statistics for data recorded at this station are in Appendix C.

In addition to water quality data collected from USGS, the City of Raleigh, and LNBA, a study was done by the USFWS from June 2003 to July 2004 (Ward et al. 2007). Water quality samples were taken from three streams within North Carolina in which federally endangered freshwater mussel populations are known to exist. One of the watersheds studied was Swift Creek, including two monitoring locations on White Oak Creek, and the use of station J4510000 near Clayton was colocated with a sampling point in the study area. Ammonia, copper, and chlorine levels were analyzed. As discussed in Section 2.3.3, the study concluded that copper levels were elevated in Swift Creek. A more thorough assessment of this study can be found in the Water Quality Report (Three Oaks Engineering/ The Catena Group 2015a-Appendix B).

3.3.2. *303(d) Impaired Streams*

As mandated in Section 303(d) of the CWA, states, territories, and authorized tribes are required to develop lists of impaired waters, which are defined as water bodies that do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. These water quality standards include designated uses, numeric and narrative criteria, and anti-degradation requirements as defined in 40 CFR 131. Failures to meet standards may be due to an individual pollutant, multiple pollutants, or unknown causes of impairment, originating from point and non-point sources and/or atmospheric deposition. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Load limits (TMDLs) of identified pollutants for these waters. All waters in NC are rated Category 5 on the 2012 303(d) list for Mercury; Category 5 impaired waters require development of a TMDL for the parameter of concern (NCDWQ 2012). Once a TMDL is established for a stream segment, the segment is removed from the 303(d) list.

There are a number of streams that are impaired in the SCW (NCDWR 2014b, Figure 6). Based on the most recent report by the NCDWR (NCDWR 2014b), much of the Upper SCW has recently been removed from the 303(d) list upon adoption of a TMDL. Several streams remain on the 303(d) list or have been recently added. A large portion of the Lower SCW is impaired, from Lake Benson to the confluence with Little Creek north east of Smithfield.

3.3.2.1. Upper SCW

There are three stream segments in the Upper SCW listed as impaired (NCDWR 2014b, Table 6). The headwaters of Swift Creek to the confluence with Williams Creek (Assessment Unit # 27-43-(1)a), a distance of 2.6 miles, was added to the 303(d) list in 1998 for Fair Bioclassification. This segment of Swift Creek now has an approved TMDL for ecological/biological integrity, and has therefore been removed from the 303(d) list of impaired streams.

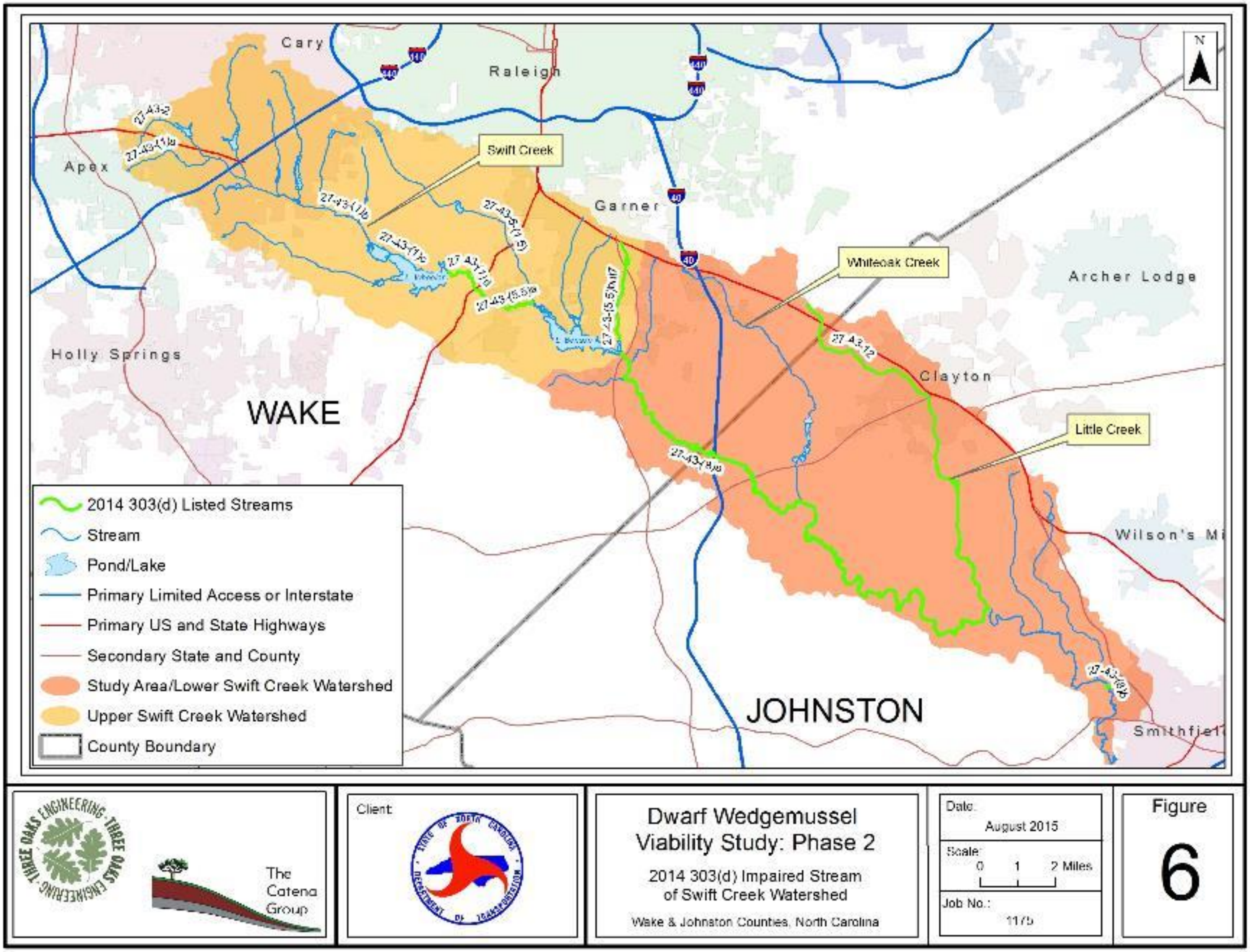

Cary
Raleigh
Apex
Garner
Archer Lodge
Holly Springs
Clayton
Wilson's Mi
Smithfiel
WAKE
JOHNSTON
Swift Creek
Whiteoak Creek
Little Creek
2014 303(d) Listed Streams
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
County Boundary
The Catena Group
Client
Dwarf Wedgemussel Viability Study: Phase 2
2014 303(d) Impaired Stream of Swift Creek Watershed
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 1 2 Miles
Job No.: 1175
Figure 6

Table 6. Upper SCW Impaired (Category 5) Streams 2014. Use of streams is for "Aquatic Life".

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Swift Creek	27-43-(1)d	2.4 FW Miles	Poor Bioclassification	Ecological/Bio Int, Benthos (2008)
Swift Creek (Lake Benson)	27-43-(5.5)a	0.87 FW Miles	Poor Bioclassification	Ecological/Bio Int. Benthos (2008)
UT to Swift Creek (Lake Benson)	27-43-(5.5)but	2.7 FW Miles	Fair Bioclassification	Ecological/Bio Int. Benthos (2014)

FW: Freshwater

From the confluence with Williams Creek to the backwaters of Lake Wheeler (assessment unit number (AU#) 27-43-(1)b), a distance of 5.5 miles, Swift Creek was listed as impaired in 1998 for Poor Bioclassification. This segment of Swift Creek also has an approved TMDL for this parameter (NCDWQ 2012). As determined in the 2009 Basinwide Water Quality Plan, this stretch of stream had Fair benthic ratings at two monitoring sites (JB52 – Holly Springs Road and JB53 – Hemlock Bluffs). The land cover along this stretch is predominantly residential, with severely eroding stream banks and little vegetation. Ambient water monitoring data within this stretch (JA24) has shown low DO levels, elevated fecal coliform levels, elevated turbidity levels and elevated conductivity levels, which are indicative of nonpoint source pollution. The Town of Cary had a wastewater spill in this stretch of the stream in June 2006 totaling 7.9 million gallons. This is, therefore, a stressed segment of Swift Creek and has been highly impacted by growth and an accidental sewage spill (NCDWQ 2009), though it now has a TMDL and has been removed from the 303(d) list (NCDWQ 2012).

Williams Creek (AU# 27-43-2) was also listed as impaired in 1998 for Poor Bioclassification. This segment is 2.6 miles and has an approved TMDL for Ecological/biological Integrity Benthos (NCDWQ 2012). Lake Wheeler (AU# 27-43-(1)c) was not rated on the 2012 303(d) list of impaired streams (NCDWQ 2012), though Chloraphyll a and pH were assessed and determined to have insufficient or inconclusive data. Primary recreational activities in the lake, including swimming and water skiing, were suspended in the summer of 2006 due to elevated bacteria levels which may partially be attributed to the wastewater spill mentioned above (NCDWQ 2009). Such closings of Lake Wheeler have been common in recent years due to high levels of bacteria (Raleigh Public Records 2009).

Swift Creek from Lake Wheeler Dam to the backwaters of Lake Benson (AU# 27-43-(1)d) and AU# 27-43-(5.5)a), a total of 3.3 miles, is impaired due to Poor Bioclassification at sampling site JB56 (NCDWR 2014b, Table 6). Erosion, habitat degradation and urban influences are all problems associated with this stretch of stream (NCDWQ 2009).

An unnamed tributary of Swift Creek (AU# 27-43-(5.5)but) is impaired for Poor Bioclassification as of 2014. This segment is 2.7 miles in length and ends in Lake Benson.

Lake Benson (AU# 27-43-(5.5)b) was not rated on the 2014 303(d) list (NCDWR 2014b). The City of Raleigh, as a condition of building the Dempsey E. Benton Water Treatment Plant in May 2010, has worked to ensure DO levels remain at optimum levels in the lake. An aeration system has been installed, and DO levels have been monitored at the raw water intake of the Dempsey Benton WWTP (below the aerator). This data indicates that during three years of monitoring (2012 to 2014), DO levels were lower than the 5 mg/L critical level recommended by the NCDWR on 338 days, most of which were during summer months (Buchan 2015). These low DO levels indicate the aeration system is not working effectively.

3.3.2.2. Lower SCW

Two stream segments are currently considered impaired in the Lower SCW (Table 6). In 2009, Swift Creek (AU# 27-43-(8), 32.7 miles) below Lake Benson was considered to have good water quality and stream conditions and was rated as Supporting for aquatic life and recreational uses based on Good and Good-Fair benthic ratings at JB54 and JB55 (NCDWQ 2009). Additionally, there were no exceedances at ambient monitoring sites JA25 and JA26. However, sedimentation and erosion were identified as moderately impacting parts of this segment of the stream. Good and Good-Fair benthic ratings were assigned to these segments in 1995 and 2000 as well. In 2012, the upper portion of this stretch of Swift Creek (AU# 27-43-(8)a, 20.6 miles from the dam at Lake Benson to Little Creek) was placed on 303(d) list for aquatic life because of a Fair Bioclassification rating, and this section was listed as impaired again in 2014 (Table 7). The current status of impairment and the previous data indicating good benthos classifications indicates a declining trend in water quality since the mid 1990's in the Study Area, which coincides with the changes in land use within the watershed during this time frame (See Section 3.1).

Little Creek (AU# 27-43-12) has been listed as impaired for ecological/biological integrity since 1998 (NCDWR 2014b), having consistently received a Fair benthic rating since 1991 when it was first sampled. The benthic ratings remained Fair in 2000 and 2005 despite the rerouting of the Clayton WWTP to the Neuse River prior to 2000, which suggests that non-point urban runoff may be a problem (NCDWQ 2009). The length of this segment, from the headwaters of Little Creek to the confluence with Swift Creek, is 11.4 miles.

Table 7. Study Area Impaired (Category 5) Streams 2014. Use of streams is for "Aquatic Life".

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Swift Creek	27-43-(8)a	20.6 FW Miles	Fair Bioclassification	Ecological/Bio Int, Benthos (2012)
Little Creek	27-43-12	11.4 FW Miles	Fair Bioclassification	Ecological/Bio Int. Benthos (1998)

3.3.3. *Point Source Pollution*

Point source discharge is defined as discharge that enters surface waters through a pipe, ditch, or other well-defined point of discharge. This includes municipal (city and county) and industrial wastewater treatment facilities, small domestic discharging treatment systems (schools, commercial offices, subdivisions and individual residents), and stormwater systems from large urban areas and industrial sites. The primary substances and compounds associated with point source discharge include nutrients, oxygen demanding wastes, and toxic substances such as chlorine, ammonia, and metals.

Under Section 301 of the CWA, discharge of pollutants into surface waters is prohibited without a permit by the Environmental Protection Agency (EPA). Section 402 of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) permitting program, which delegates permitting authority to qualifying states. In North Carolina, NCDWR is responsible for permitting and enforcement of the NPDES program. Point source dischargers located throughout North Carolina are permitted through the NPDES program. All dischargers are required to register for a permit. NPDES dischargers are divided into two classes: major and minor. Major discharges are permitted to discharge one million gallons per day (MGD) or greater. Minor discharges are permitted to discharge less than 1 MGD. In the SCW, there are two major discharges (Dempsey E. Benton WTP and Little Creek WWTP) and three minor discharges (Figure 7; Table 8).

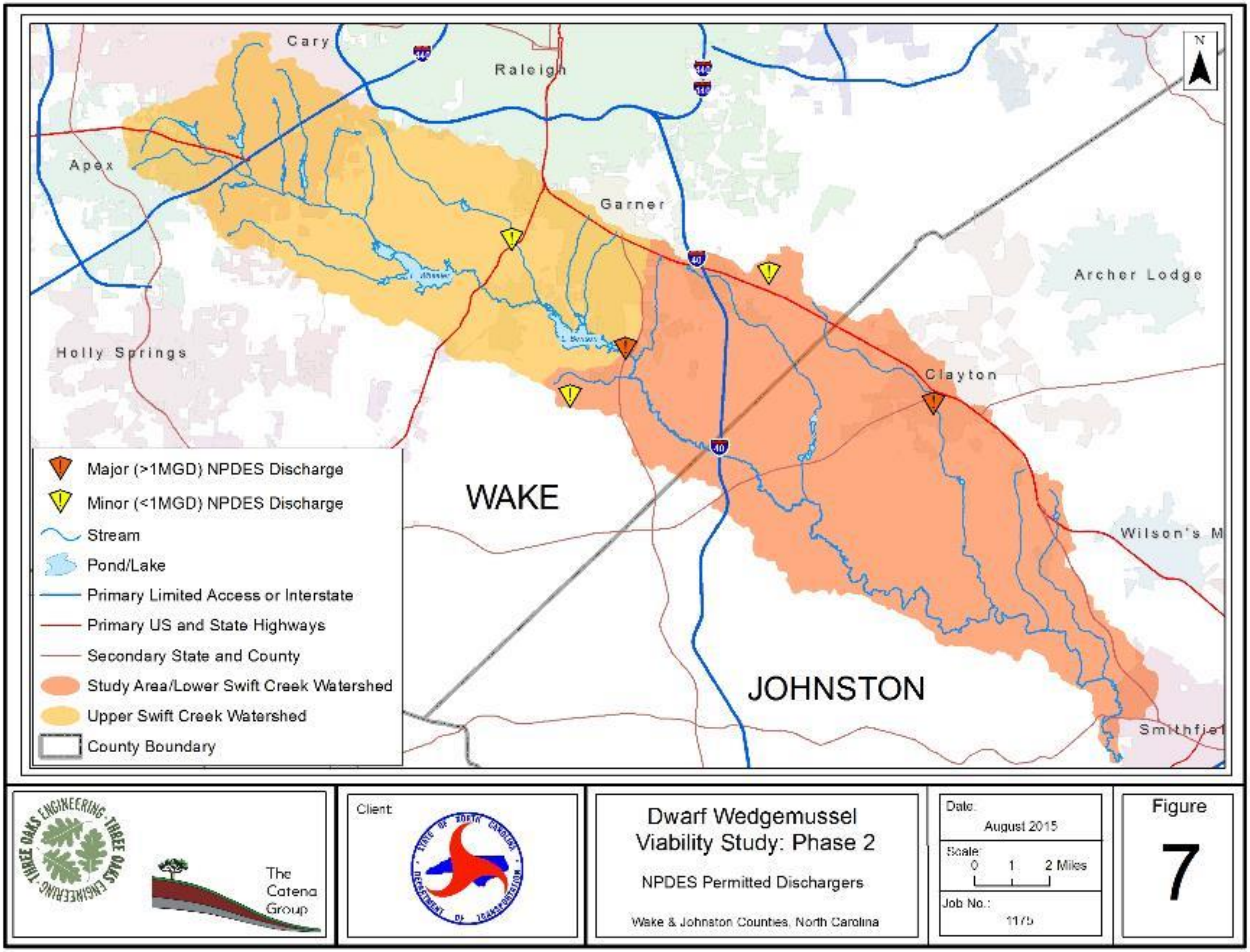
In SCW there are several types of permitted discharges (Figure 7, Table 8). The Dempsey E. Benton Water Treatment Plant (WTP), a municipal discharger, was opened May 12, 2010, and discharges into Lake Benson. The Indian Creek Overlook WWTP, a domestic source, was taken off line as part of the Dempsey E. Benton project in order to reduce the amount of pollutants being discharged into SCW (Buchan 2012).

Table 8. NPDES permitted dischargers in Swift Creek Watershed

Permit	Facility	Class	Type	Flow (Gal/day)
NC0088285	Dempsey E. Benton WTP	Major	Water Treatment Plant	Not limited
NC0025453	Little Creek WWTP	Major	Municipal, Large	2,500,000
NC0060526	Pope Industrial Park WWTP	Minor	100% Domestic < 1MGD	8,000
NC0055701	Nottingham WTP	Minor	Water Treatment Plant	Not limited
NC0049034	Mount Auburn Training Ctr WWTP	Minor	100% Domestic < 1MGD	2,400

3.3.4. *Non-point Source Pollution*

Non-point source (NPS) pollution refers to runoff that enters surface waters through stormwater or snowmelt. There are many types of land use activities that contribute to non-point source pollution, including land development, construction activity, animal waste disposal, mining, agriculture, and forestry operations, as well as impervious surfaces such as roadways and parking lots. Various NPS management programs have been developed by a number of agencies to control specific types of NPS pollution (e.g. pesticide, urban, and construction related pollution, etc.). Each of these management plans develops BMPs to control for a specific type of NPS pollution. For example, financial incentives to reduce agricultural NPS pollution are provided through North Carolina's Agriculture Cost Share Program, administered by NCDENR's Division of Soil and Water Conservation to protect water quality by installing BMPs on agricultural lands.



Cary
Raleigh
Apex
Garner
Holly Springs
Archer Lodge
Clayton
Wilson's M
Smithfiel
WAKE
JOHNSTON
Major (>1MGD) NPDES Discharge
Minor (<1MGD) NPDES Discharge
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
County Boundary
The Catena Group
Client
Dwarf Wedgemussel Viability Study: Phase 2
NPDES Permitted Dischargers
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 1 2 Miles
Job No.: 1175
Figure 7

The effects of non-point pollution on aquatic species associated with impervious surface area are discussed in section 2.3.4.

3.4. NCDWQ 2003 Assessment Report on the Upper SCW

An assessment of the biological impairment in the Upper SCW above Holly Springs Road was conducted by the NCDWQ (NCDWQ 2003a). The goal of the report was to identify the sources and activities leading to impairments in the stream. Additionally, the report recommended a watershed plan for improving biological conditions in the stream. According to the report, the main sources of impairment appear to be toxicity from stormwater runoff, removal of organisms during storm events (stormwater scour), and hydromodificiation from impoundments along the stream (NCDWQ 2003a).

3.4.1. *Toxicity*

Toxicity levels in stormwater samples indicate it as a major contributor to biological impairment. Analysis of water collected after a storm event resulted in mortality of 50 percent of test organisms when a sample was diluted to approximately 60 percent of the ambient concentration. Tolerant species were the dominant organisms found at most of the benthos sampling stations in the Upper SCW (NCDWQ 2009). As such, two of the three streams sampled in the upper SCW received bioclassification scores of Poor, with the other receiving a Fair classification (Table 6).

In comparison, the two stations sampled in the Lower SCW received scores of Fair (Table 7). While streams with a score of Fair are still considered impaired, they are less impaired than streams with Poor scores like those in the Upper SCW. The headwaters of the Little Creek site in the Lower SCW occur in a highly urbanized portion of the City of Clayton, and non-point urban runoff was identified as a potential cause for the stream's impairment (NCDWQ 2002). The site on Swift Creek also received a Fair classification, and as discussed in Section 3.3.2.2, there has been a declining trend with regard to benthos since the mid 1990's. Sedimentation and erosion were identified as stressors in 2009 (NCDWQ 2009), which are often indicative of urbanizing streams. It is also possible that toxicity of the stormwater has contributed to this decline. Toxicants often occurring within stormwater were measured at various locations in Swift Creek as part of Phase 2 of this study (Section 3.5, Three Oaks Engineering 2015a).

3.4.2. *Stormflow Scour*

Scour as a result of high stormflow, and the resulting loss of organisms and microhabitat, is a likely cause of impairment in the stream. Though difficult to distinguish from other stressors, data from the Upper SCW suggest there is frequent loss of substrate due to storm events (NCDWQ 2009). Stormflow scour within the study area as it pertains to habitat viability will be discussed in further detail in Section 6.3.

3.4.3. *Hydromodification*

Hydromodification is the alteration of a stream by the construction of an impoundment or dam. There are 58 identified impoundments in the Upper SCW and the Study Area (Figure 8, NCDENR 2013), which obstruct movement of aquatic organisms such as fish. NCDENR regulates a structure that is 25 feet high or more and impounds 50 acre-feet or more. Of the 58 impoundments, 31 do not meet either of the two requirements, so are not regulated by the state. Most of these impoundments are not required to have a minimum release volume, meaning there could be zero flow downstream of the impoundment during drought conditions. This reduction in flow negatively impacts water quality in the stream by altering temperature, reducing DO, and reducing habitat (NCDWQ 2009). There are numerous other small impoundments in the SCW that have not been identified, that cumulatively also effect conditions in the watershed.

3.4.4. *Recommendations for Improvement*

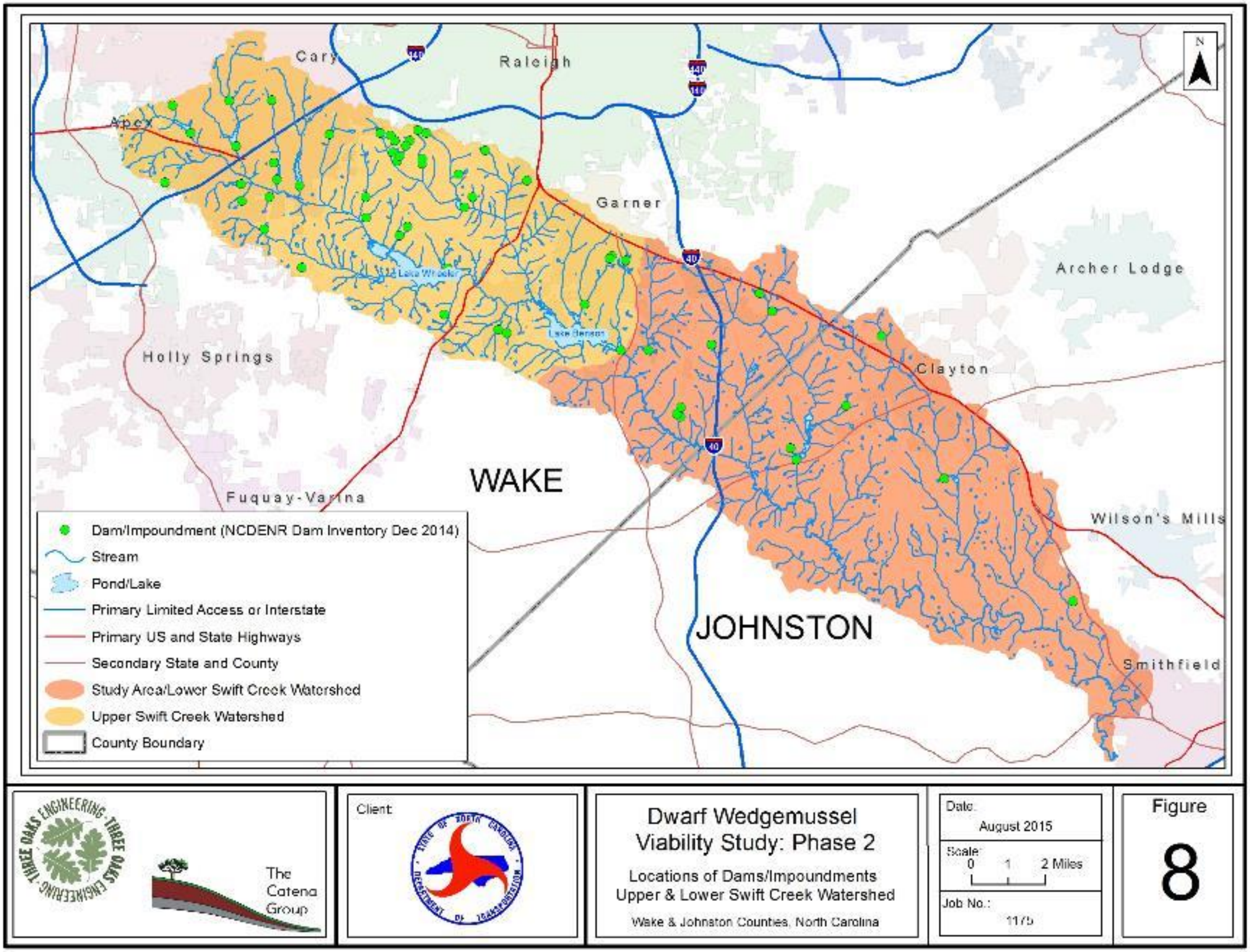
The 2003 Assessment Report (NCDWQ 2003a) provided the following action recommendations in order to curb impairment in the Upper SCW:

1. Implement cost effective stormwater retrofit projects
2. Identify and address toxic inputs
3. Minimum releases from impoundments should be investigated
4. Targeted stream channel restoration in conjunction with stormwater retrofits
5. Reduce nutrient and organic loading (through implementation of the above four)
6. Require effective post-construction stormwater management for any new development
7. Enforcement of sediment and erosion control (particularly Apex, Cary & Wake County)
8. Enhanced watershed education programs

Many of these recommendations could also be applied by the various entities within the Lower SCW as this portion of the watershed continues to develop.

3.5. Neuse 01 Regional Watershed Plan

A Regional Watershed Plan (RWP) is under development for the NC Department of Mitigation Services (DMS, formerly Ecosystem Enhancement Program) for the Neuse 01 watershed, which includes 18 subwatersheds. In the RWP the Upper SCW is divided into two subwatersheds (LakeWheeler-Swift Creek and Lake Benson-Swift Creek), and the Lower SCW is divided into three (Mahlers Creek-Swift Creek, Piney Grove Cemetery-Swift Creek and Reed Branch-Swift Creek). As part of the development of a watershed plan, existing water quality data is often supplemented with data collected specifically for the watershed plan. Coordination with the parties involved in the development of the Neuse 01 RWP should take place to enhance the knowledge of water quality conditions in the SCW.


Cary
Raleigh
Apex
Garner
Lake Wheeler
Lake Benson
Archer Lodge
Holly Springs
Clayton
WAKE
Fuquay-Varina
Wilson's Mills
JOHNSTON
Smithfield
Dam/Impoundment (NCDENR Dam Inventory Dec 2014)
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
County Boundary
The Catena Group
Client
Dwarf Wedgemussel
Viability Study: Phase 2
Locations of Dams/Impoundments
Upper & Lower Swift Creek Watershed
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 1 2 Miles
Job No.:
1175
Figure
8

3.5.1. *Preliminary Findings Report*

The Preliminary Findings Report submitted for the first phase of the RWP (Wildlands Engineering-Catena Group 2014a) developed a functional assessment on a variety of criteria that were evaluated through GIS and other desk-top approaches for each of the 18 subwatersheds. These functional criteria were used to assess subwatershed functions in terms of levels of degradation and identification of stressors and assets. Criteria were selected to provide a mostly quantitative analysis of functional conditions for each subwatershed based on particular, widely-used, and agreed-upon GIS variables and enabling comparisons between subwatersheds to prioritize them for project implementation. Four sets of criteria referred to as "functional conditions categories" were used to evaluate the 18 subwatersheds. These included:

- Stream corridor condition,
- Wetland condition,
- Water quality, and
- Presence of important habitats.

Based on these analyses, five priority subwatersheds were identified for each of the functional conditions categories. The prioritization of the subwatersheds was done to serve as a tool for directing mitigation projects in areas where they would provide maximum benefit. However, it does not imply that projects in non-priority subwatersheds should be excluded from consideration. Some of the subwatersheds were identified as priorities in more than one category, which lends itself to developing a more holistic approach to mitigation than traditional methods allow.

Prioritization of subwatersheds for important aquatic habitats was somewhat different from the other three functional conditions categories as the others assessed priorities based on problems (i.e. water quality issues, lack of stream buffers, etc.) as opposed to assets. The important aquatic habitat category also included a subjective component based on experience in monitoring of aquatic species populations. The 18 Neuse 01 RWP subwatersheds were evaluated through GIS analysis to identify priorities with regards to the highest quality aquatic habitats. The prioritization incorporated various measures of aquatic community importance (presence of rare species, significant natural area designations, etc.), various attributes that impact the quality of aquatic habitats (amount of developed lands, amount of forested lands, etc.), and point sources of water quality impairment (wastewater discharges). Various GIS data layers along with knowledge of the subwatersheds were used in the prioritization process. Using a combination of land use, Natural Heritage Natural Areas, Element Occurrences (EOs), core areas (Landscape/Habitat Indicator Guilds), anadromous fish spawning habitats, NPDES dischargers, and the subjective component described above. The five high priority watersheds from 1-5 include:

- Cattail Creek-Little River,
- Long Branch-Little River,
- Piney Grove Cemetery-Swift Creek,
- Mahlers Creek-Swift Creek, and
- Mill Creek-Neuse River.

The entire occupied range of DWM within Swift Creek is encompassed within the Mahlers Creek-Swift Creek and Piney Grove Cemetery-Swift Creek subwatersheds.

3.5.2. *Project Atlas*

Another component of the first phase of the Neuse 01 RWP was to develop a Project Atlas, which identified the most highly rated watershed improvement projects based on the Preliminary Findings Report. These projects focused only within the identified priority subwatersheds, and were considered “preliminary” as more details would need to be developed in the second phase of the RWP (Wildlands Engineering/Catena 2014b). However, the projects identified were presented as potential mitigation sites for DMS or other mitigation providers, as well as other entities seeking watershed improvement projects.

Two potential projects occurring within the Lower SCW were identified in the Project Atlas, the Swift Creek Ford Tract (Preservation and Buffer Enhancement), and Swift Creek in-stream Habitat Improvements.

3.5.2.1. Swift Creek Ford Tract

This 74 acre potential habitat preservation site is located near the I-40/NC 42 interchange, includes up to 0.72 mile of the mainstem of Swift Creek, and includes properties on both sides of the creek. This portion of Swift Creek is near the upper limits of the currently occupied range of DWM in the creek and occurs in an area that is rapidly being developed for commercial and residential uses. Until 2013, the tract had been used as pastureland, but currently consists largely of open fields and limited riparian buffers. The landowner is interested in selling the property and has been approached by developers (Wildlands Engineering-Catena 2014b). In addition to preservation, the project would also involve riparian buffer enhancement and an in-stream barrier removal caused by a perched utility easement ford crossing. A photograph of this crossing is included in Section 6.2.

3.5.2.2. Swift Creek in-stream Habitat Improvements

As mentioned in Section 2.3.7, ATV use has been identified as a threat to the DWM population in Swift Creek. In addition to ATV use, large log jams are also having localized adverse effect on habitat stability in Swift Creek. While woody debris generally contributes to habitat quality in aquatic environments, excessive amounts that block the channel flow can cause significant bank erosion, transform habitats from lotic to lentic, and create barriers to aquatic passage during some flows. This project would include developing measures to restrict/eliminate ATV use in the stream, and identifying and dislodging excessive log jams (Wildlands Engineering-Catena 2014b.

3.5.3. *Targeted Resource Area Project Sites Identified in Phase 2*

In addition to the Project Atlas Sites identified in the first phase of the Neuse 01 RWP, three additional Targeted Resource Area sites have been identified within the Lower SCW in Phase II of the RWP (Wildlands Engineering 2015).

3.5.3.1. Mahlers Creek Stream Restoration, Preservation and BMP Retrofit

Mahlers Creek is the first major tributary of Swift Creek below Lake Benson. The headwaters occur in a rapidly urbanizing area in the City of Garner near US 70, which has resulted in increased sediment loads being transported into Swift Creek. This potential project would involve traditional stream restoration of degraded reaches south of US 70, buffer preservation of old growth forest, and a BMP retrofit within an industrial development south of US 70.

3.5.3.2. Swift Creek Cattle Pasture Buffer Restoration/Preservation and Stream Restoration

This potential project involves a 97 acre cattle pasture that borders Swift Creek within the current occupied range of DWM. Cattle have direct access to three tributaries to Swift Creek, and the riparian buffer along Swift Creek is fragmented. The project would involve cattle exclusion, and stream and buffer restoration along the three tributaries, as well as buffer preservation and restoration along Swift Creek.

3.5.3.3. Trailer Park Development Buffer Preservation/Enhancement and Stream Restoration

This potential project includes buffer preservation, buffer enhancement and stream restoration on two large tracts of land along Swift Creek and an unnamed tributary to Swift Creek in Wake County below Lake Benson. The 124 acre trailer park development is partially completed and has been platted for additional development 400 feet east of Swift Creek. Between the platted parcels and Swift Creek is a large piece of land owned by the development company that has been severely disturbed by ATV use. Downstream of the trailer park development is a 116 acre agricultural parcel that contains limited amounts of riparian buffer along Swift Creek, and also includes two unnamed tributaries.

3.6. Water Quality Data Collection For DWM Viability Study

As discussed in Section 2.3.3, freshwater mussels have been shown to be highly sensitive to copper and ammonia. The Lower SCW has not been studied as extensively as the Upper SCW, particularly in regards to water quality analysis. One of the recommendations identified in the Phase 1 report was to sample Swift Creek within the occupied range of DWM to determine if these pollutants were of concern with regards to habitat viability. This recommendation has been implemented and the results follow.

3.6.1. *Approach/Methodology*

This component of the viability study involved collecting water quality samples below Lake Benson to identify potential water quality issues that could impact DWM habitat viability. Samples were collected from November 2014 through July 2015 at three locations; the Swift Creek crossings of NC 50 (Benson Road, near former USGS gauge 02087701), SR 1555 (Barber Mill Road, near USGS gauge 0208773375), and NC 210 (near LNBA monitoring site J4590000, Figure 5). Water quality parameters that were measured are listed in Table 9.

Table 9. Water quality parameters measured in Lower SCW.

Field Parameters	Laboratory Parameters
Dissolved Oxygen Temperature Conductivity pH	Calcium Magnesium Sodium Potassium Sulfate as SO4 Chloride Total Alkalinity (as CaCO3) Total Organic Carbon Copper (Total and dissolved) Lead Nickel Zinc Cadmium

These parameters were measured in order to determine basic water quality conditions within the reach of Swift Creek where DWM is known to occur. Of particular importance are ammonia, chlorine, and copper. The most advanced method of determining copper toxicity for freshwater aquatic species is the biotic ligand model (BLM). The BLM uses 12 water quality parameters to evaluate copper toxicity. Therefore, several of these parameters were measured in order to use the BLM for toxicity analysis.

Water samples from each site were collected a total of eight times over the course of the sampling period: once during each season, twice during a high-flow event (when flow at USGS gauge 0208773375 was >50% above the median daily statistic), and twice during a low-flow event (when flow at the same gauge was <50% below the median daily statistic).

Field parameters were measured at the time of sampling by use of a multi-parameter meter (YSI Professional Plus, Yellow Spring, OH, USA). For all parameters, samples were collected from visibly flowing portions of the stream (not in stagnant pools), approximately one meter away from the bank toward mid-channel. Samples that were analyzed in a lab were stored on ice (at ~4°C) in the field and taken the same day to ENCO Laboratory (Cary, NC) for analysis.

3.6.2. *Results*

Total copper was detected in half of the samples, while dissolved copper was detected in about a third of the samples. Four of these samples exceeded the chronic event-specific North Carolina water quality standard for copper (derived from hardness levels measured at each sampling event). Additionally, three of these samples exceeded the acute event-specific water quality standard for copper (USEPA 2007, NC Register 2014). The elevated concentrations of copper appear to occur during lower flow rates, which is typically contrary to what would be expected; that copper levels spike during significant rain events when sediment loads into streams increases.

Ammonia was detected in 11 of 24 samples collected. None of these samples exceeded the event-specific chronic or the acute criteria (USEPA 2013). There were no exceedances of any other toxicants analyzed in this study. The results of the water quality analysis are presented in further detail in the Lower Swift Creek Water Quality Report (Three Oaks Engineering/ The Catena Group 20015a), which is included in Appendix B.

3.6.3. *Discussion*

Both ammonia and copper were detected in Swift Creek during the sampling period from November 2014 to July 2015. These parameters have been identified as the most significant toxicants to freshwater mussels (USEPA 2008), and the detection of them is cause for concern if detected at concentrations in excess of those thought to be safe for mussels. Whether or not the levels of ammonia and copper are high enough to be detrimental to mussels is still in question. To fully answer the question of whether water quality conditions in Swift Creek are harmful to DWM, long-term toxicity analysis on DWM analyzing growth, survival, and reproduction is needed. In the absence of that data, similar analysis on other species of the same genus and/or associate species could be done instead. Such analysis is outside the scope of this report.

Copper toxicity in Swift Creek appears to be mostly dependent on the organic content and pH of the water column, and appears to be elevated during low flow events, which by itself can be a stressor to freshwater mussels (See Section 2.3.4.3). Since toxicity can be determined by measuring only a few additional water quality parameters, monitoring could continue at less cost into the future to see how mussel populations respond to changing water quality conditions. The water quality parameters measured in this study were monitored for less than a year, thus a complete understanding of the water quality conditions in the Lower SCW as they pertain to habitat viability for freshwater mussel populations cannot be reached. Long-term monitoring would be needed to get a clearer picture of this relationship; however, the results identify copper as a potential threat to the habitat viability in Swift Creek.

Ammonia toxicity does not appear to be of concern in the majority of the study area, with the exception of some indication of potential toxicity limited to the section of the creek directly below Lake Benson. The long-term monitoring of Swift Creek by the USGS has demonstrated that event-specific criteria for ammonia are rarely exceeded. Monitoring efforts, however, could be improved to fill in gaps and better understand how to best reduce ammonia contamination.

Other pollutants that were measured, including some heavy metals, did not appear to be at toxic levels to aquatic organisms. As has been discussed, metal toxicity is more complex than just a simple measurement of water conditions at a single sampling. Future analysis may be possible, particularly with the use of the BLM, to determine toxicity to freshwater mussels and other aquatic organisms.

3.7. Watershed Conditions: Summary and Management Recommendations

In the later part of the 20th century, much of the land use in the SCW transformed from being relatively rural to largely urban, with the expansion of the greater Raleigh metropolitan area. This is particularly true in the Upper SCW. While the Lower SCW is less developed, it is trending towards urbanization as well.

There is a fairly comprehensive amount of water quality data in the Upper SCW. Periodic exceedances of various water quality parameters have occurred throughout the Upper SCW, and some stream segments in the watershed are listed as impaired (Section 3.3.2). Comparatively, less data are available for the Lower SCW, and what is available rarely extends beyond the past ten years. While there is a paucity of data, recent trends indicate water quality concerns in the Lower SCW as well, particularly in the section of Swift Creek from Lake Benson to the Little Creek confluence, as it recently was placed on the 303(d) list of impaired streams in 2012 (NCDWQ 2012).

Additionally, as mentioned above, continued monitoring of copper and ammonia at the three sampling locations selected for this study (Section 3.6.1) would help to gain a better understanding of the long term water quality component of habitat viability as it pertains to DWM. Efforts should also be made to identify the sources of these toxicants in the Lower SCW and to develop methods to reduce these inputs. This should be done in coordination with various stakeholders that have a vested interest in the protection and improvement of water quality conditions in the Lower SCW. A stakeholder group was formed for the Neuse 01 RWP, which consists of local municipalities, various regulatory and conservation groups, and local citizens, who collectively provide input in the data collection and analysis as well as decision making process. Additionally, several local government entities were interviewed for this study, including Johnston County, City of Raleigh and Town of Cary. Representatives from USFWS, DMS and NCNHP were also interviewed. A subset of the stakeholder group for the Neuse 01 RWP should be assembled to provide input on long term management of the Lower SCW, and Swift Creek DWM population.

Other potential stakeholders to be considered include:

- Wake/Johnston Soil and Water Conservation Districts
- Neuse Riverkeeper Foundation
- Triangle Land Conservancy
- Triangle J Council of Governments (TJCOG)
- Public and Private Schools (particularly science clubs) in the SCW

4.0 ACCOUNTING OF CONSERVATION MEASURES IN SCW

Several conservation measures have been implemented that are intended to protect water quality and habitat within the SCW. Some of these measures also apply to areas outside of the SCW, while others were developed and implemented specifically to protect SCW. The information discussed below was gathered by reviewing applicable rules and regulations that apply to water quality protection, as well as gathering information from various entities that have a specific stake in protection of SCW.

4.1. General Conservation Measures

There are a number of protective measures that have been adopted that apply to the entire Neuse River Basin, which go beyond what is required in many other river basins in North Carolina.

4.1.1. *Neuse River Riparian Buffer Rules*

The State of North Carolina requires 30-foot vegetated riparian buffers in its water supply watershed protection rules, while requirements for Neuse River basin are set at a 50-foot minimum buffer on each side of perennial and intermittent water bodies. New buffers are not required on existing land uses, unless that land use changes (NCDWQ 2003a). These buffers are not required on ephemeral channels. **Note:** The Regulatory Reform Act of 2015, along with Session Law 2015-246, have brought riparian buffer protections into question. Session Law 2015-246 required the Environmental Management Commission to review riparian buffer rules and whether these rules put undue burdens on property owners. The Commission found riparian buffers to be an effective means for protecting water quality, and are less expensive than placing more restrictions (point source discharge requirements, BMP's etc.) on other entities (such as farmers and local governments). Therefore, riparian buffer rules may be changing, as the Commission is currently in the process of reviewing and updating the rules. Proposed changes will be made public later in 2016.

4.1.2. *Neuse River Basin Stormwater Rules*

As of 1998, all waters of the Neuse River Basin have been under the Neuse Nutrient Sensitive Waters rules, a result of the NSW classification. In addition to the 50-foot minimum riparian buffer rule, new development within the Neuse River Basin cannot exceed nitrogen loads of 3.6 lbs/acre/yr. Only Jordan Lake and Falls Lake have more restrictive nitrogen loading rates (NCDWR 2013b). Also, post-development peak flow rates cannot be any greater than flows from pre-development sites for the 1-year 24-hour storm. The stormwater rules also required government entities to implement a public education program, remove illicit discharges, and install stormwater retrofits where feasible. The Town of Apex is not subject to these rules; development existing before 1998 is also not subject to these rules (NCDWQ 2003a).

4.1.3. *Phase II stormwater (NPDES Permits)*

Developed by the EPA, Phase II stormwater rules require small communities not previously under federal stormwater requirements to obtain permits for discharging stormwater. These rules apply to Cary and Apex. The rules include six minimum requirements: public education and outreach, public participation, illicit discharge detection and elimination, construction runoff control, post-construction management to new and redevelopment, and pollution prevention (NCDWQ 2003a).

4.2. Specific Conservation Measures for the SCW

A number of entities have developed various conservation measures specifically to conserve and protect SCW. However, as noted in Section 4.1.1, some of these rules may no longer be allowed under the Regulatory Reform Act of 2015.

4.2.1. *Swift Creek Land Management Plan*

Wake County and local governments (Apex, Cary, Raleigh, and Garner) adopted the Swift Creek Land Management Plan (SCLMP) on April 19, 1990, to allow for further development of SCW without jeopardizing the health of the stream as a water supply source for Lakes Benson and Wheeler (Wake County 2013). The plan requires vegetative buffers and places limits on impervious surfaces (Memorandum 1988, NCDWQ 2003a). The plan also calls for the control of point source discharges. Areas of critical importance for protection (called critical areas) were identified as: Lake Benson, Swift Creek between Lake Benson and Lake Wheeler, Lake Wheeler and Swift Creek above Lake Wheeler, Little Swift Creek, and Yates Mill Creek (Figure 9). The plan establishes imperviousness limitations for areas without stormwater control measures; 6%

in critical areas and 12% in non-critical areas (Figure 9) (AMEC 2004). Critical areas are those of the watershed closest to the water supply source where it is most important to minimize the discharge and maximize the filtration of potential pollutants (Wake County 2013).

4.2.2. *Apex*

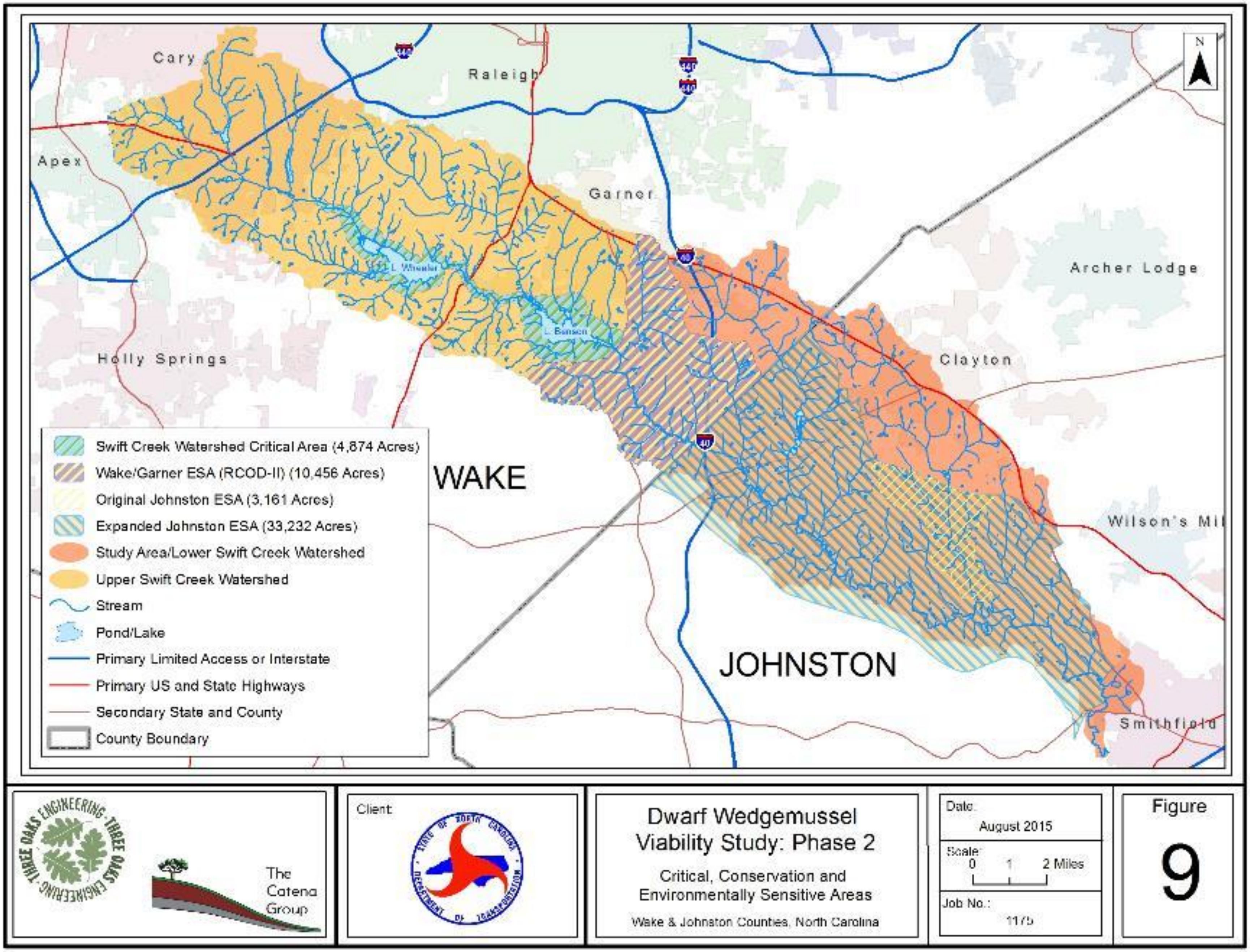
The Town of Apex adopted a Land Use Plan in 2010 that requires 40% of new developments in the resource conservation area be set aside for open space, a 100 foot riparian buffer on perennial streams, a 50 foot buffer on intermittent streams, and no residential development in the 100-yr floodplain. Additionally, the town must capture runoff from 1-inch of rainfall on areas in excess of 12% impervious cover while also removing 85% of TSS. A joint study with the Towns of Cary and Holly Springs of Secondary Cumulative Impact Mitigation Program (SCIMP) was also a requirement of the Plan (AMEC 2004).

4.2.3. *Cary*

The Town of Cary has an estimated 950 acres of land under strict impervious surface limitations. Cary joined Apex and Holly Springs in signing the SCIMP, as described in Section 4.2.2. Cary has a Growth Management Plan (Town of Cary 2000), in which riparian buffer rules are more restrictive than state requirements and 50 foot Neuse River Riparian Buffer requirements. These rules require a 100 foot buffer on perennial and intermittent streams, and a 50 foot buffer on all other streams that appear on the latest soil survey maps. Cary refers to these as Urban Transition Buffers. The Town has also investigated ways to implement a mitigation banking program (AMEC 2004), or a mitigation credit union, but the Final Stormwater Master Plan (Town of Cary 2013) does not indicate a specific mitigation mechanism is in place. The Stormwater Master Plan, however, details ways in which the Town is meeting or exceeding stormwater requirements.

4.2.4. *Garner*

Wake County implements the Town of Garner's Sediment and Erosion Control program. Garner maintains a Swift Creek Overlay District (or Resource Conservation Area), an area in which development is restricted in order to protect Swift Creek. Garner was a signatory of the SCLMP, and therefore has committed to protecting that resource. Garner also developed a Regional Retention Pond BMP Retrofit Plan to install BMPs in the SCW (Garner 2001, AMEC 2004).


Cary
Raleigh
Apex
Garner
Archer Lodge
Holly Springs
Clayton
Wilson's Mill
Smithfield
WAKE
JOHNSTON
L. Wheeler
L. Benson
Swift Creek Watershed Critical Area (4,874 Acres)
Wake/Garner ESA (RCOD-II) (10,456 Acres)
Original Johnston ESA (3,161 Acres)
Expanded Johnston ESA (33,232 Acres)
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
N
Client:
Dwarf Wedgemussel Viability Study: Phase 2
Critical, Conservation and Environmentally Sensitive Areas
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 1 2 Miles
Job No.: 1175
Figure 9
The Catena Group

As a conservation measure associated with the Clayton Bypass project, a 10.7-mile highway connecting I-40 in Wake County and US-70 in Johnston County that opened in 2008, Garner also entered into a Memorandum of Understanding (MOU) with NCDOT and USFWS (2006). Garner continues the use of its current buffer standards, defining an undisturbed buffer to include the 100 year floodplain plus 50 feet on streams (listed in Section 7.2.D of Garner's Unified Development Ordinance). The MOU also affirms Garner's Development Standards for Stormwater Management, which limits nitrogen export load to 3.6 lbs/acre/yr; otherwise, developers can make a one-time payment to the DMS. Residential development exceeding 6 lbs/acre/yr of nitrogen and other development that exceeds 10 lbs/acre/yr of nitrogen must implement stormwater control measures to achieve loads below those thresholds to be eligible for mitigation payments. Garner adheres to the rules set out in the SCLMP, with limits set at 6% and 12% for critical and non-critical areas, respectively. Garner has considered adopting stormwater controls equivalent to Wake County's Stormwater Control, Management, and Watercourse Buffer Regulations (Section 2-10-40). When Garner expands into Wake County's Resource Conservation Overlay District-II (RCOD-II, which is the Swift Creek watershed below Lake Benson), these controls will be amended to treat impervious surfaces on a project basis, rather than on an individual lot basis.

4.2.5. *Raleigh*

The City of Raleigh implements its own Sediment and Erosion Control (S&EC) program and requires standards that are more stringent than the state minimum (AMEC 2004). In particular, an S&EC plan must be submitted prior to any land-disturbing activity greater than 12,000 square feet. Land-disturbing activities resulting in uncovered areas are limited at any time to a maximum total area of 20 acres within High Quality Water Zones. Raleigh operates the Dempsey E. Benton WTP, which opened May 12, 2010. Raleigh coordinated with the USFWS on terms and conditions for mitigation of impacts from the WTP to the DWM. These measures are:

- Tiered minimum flow release schedule from the WTP, which would decrease the amount of water from Lake Benson/Swift Creek when outflows are reduced. Raleigh is required to notify the USFWS when Tier 3 flows (0.8 cubic feet per second) last for more than seven consecutive days
- Limit the maximum base withdrawal rate and the frequency of the maximum withdrawal rate
- Manage Lake Benson Dam to prevent rapid reductions in downstream flows
- Suitable intake-outlet structure designs
- Water quality and quantity monitoring programs
- Decommissioning two small wastewater treatment facilities on Swift Creek (Indian Creek Overlook and Mill Run Mobile Home Park WWTPs)

- Purchase of greenway corridors in the SCW: Steep Hill Creek Corridor and Lake Wheeler/Lake Benson Corridor (Arcadis 2005, USFWS 2006)

City of Raleigh Public Utilities representatives have confirmed that these measures have been implemented. There were no Tier 3 flows recorded (2012 to 2014), with measurements being taken on a daily basis. Water quality monitoring has been conducted (see Section 3.3.1), with temperature, DO, pH, conductivity, fecal coliform, suspended solids, turbidity, and ammonia being measured monthly. Mussel surveys, which the city of Raleigh is funding, will be conducted once every five years following construction for 20 years. The two WWTPs have been decommissioned. Steep Hill Creek Corridor has been purchased, and portions of the Lake Wheeler/Lake Benson Corridor are in preservation. A 27-acre property in Garner adjacent to Lake Benson was purchased for preservation with funding acquired through the Upper Neuse Clean Water initiative. Another project pursued by the City of Raleigh involving property between Lake Benson and Lake Wheeler was already in a conservation easement, so could not be claimed by the city (Buchan 2015).

The City of Raleigh constructed a new backwash facility at the Dempsey Benton WTP. The construction site, on-site control measures, stormwater outfalls, and general site conditions were inspected once per week. The City of Raleigh provided inspection forms from July 2013 to December 2014. During that period, there were ten instances when a control measure was not operating properly and corrective actions were taken. There were three instances of visible sediment from the construction site in the stream or on adjacent property. There were three instances of erosion near the stormwater outfall. Amount of rainfall and when it occurred were also noted on the inspection forms (Buchan 2015). The magnitude of the sedimentation and the time frame for the corrective measures to have been implemented are unknown.

4.2.6. *Wake County*

Wake County implements the S&EC Program for all unincorporated county lands and the following municipalities: Town of Garner, Fuquay Varina, Holly Springs, Morrisville, Knightdale, Wendell, and Zebulon. Buffer rules for Wake County exceed the Neuse River Riparian Buffer Rules and NSW nitrogen regulations, with buffer standards of 100 feet, instead of the 50 foot Neuse riparian buffer. Wake County also has a current land use plan, a Growth Management Plan, and a Consolidated Open Space Plan. Minimum lot sizes are required to be 40,000 sq ft in non-critical areas, and 80,000 sq ft in critical areas (AMEC 2004). In 2000, the Wake County Board of Commissioners established the Watershed Management Task Force, which was made up of officials from local governments. The Task Force was in charge of overseeing the development of the County Watershed Plan. As a result, CH2M Hill completed a Comprehensive Watershed Management Plan, a report in which recommendations were made to the commissioners and local governments in order to protect and enhance water quality (NCDWQ 2003a).

As part of the Section 7 Consultation process of the Endangered Species Act of 1973 as Amended for the Clayton Bypass project, Wake County signed a MOU with USFWS and NCDOT (NCDOT 2005). In this document, Wake County agreed to prohibit fill and new development in floodways or floodway fringes on lots created after May 19, 2003. The MOU also limits nitrogen export loads to 3.6 lbs/acre/yr. Developers can otherwise make a one-time payment to DMS; residential development exceeding 6 lbs/acre/yr and other development that exceeds 10 lbs/acre/yr must implement stormwater control measures to achieve loads below those thresholds to be eligible for mitigation payments. Peak stormwater runoff from new development can be no greater for post development for the one year, 24-hour storm event, except for the following: when increase in runoff is 10% or less; maximum impervious surface of a lot is 15% or less (30% or less for residential development); and pervious surfaces are used to control runoff to the maximum extent. An RCOD-II (Figure 9) was created in which perennial streams have a 100 foot buffer. The ordinance amendment will list the impervious surface limits that apply in the County's underlying zoning districts and that are required by its Storwmater Control, Management and Water Course Buffer Regulations (NCDOT 2005).

Wake County, in coordination with the USFWS, also agreed to several measures in preparation for the Dempsey E. Benton WTP. The USFWS issued a Biological Opinion (BO), requiring Wake County to implement the following measures: put further restrictions on the RCOD-II; restrict the allowed activities within stream buffers in the RCOD-II; recodify existing county stormwater regulations in the RCOD-II Ordinance; limit impervious surfaces to no more than 15% in residential areas and no more than 30% in residential areas with stormwater controls in place (USFWS 2006).

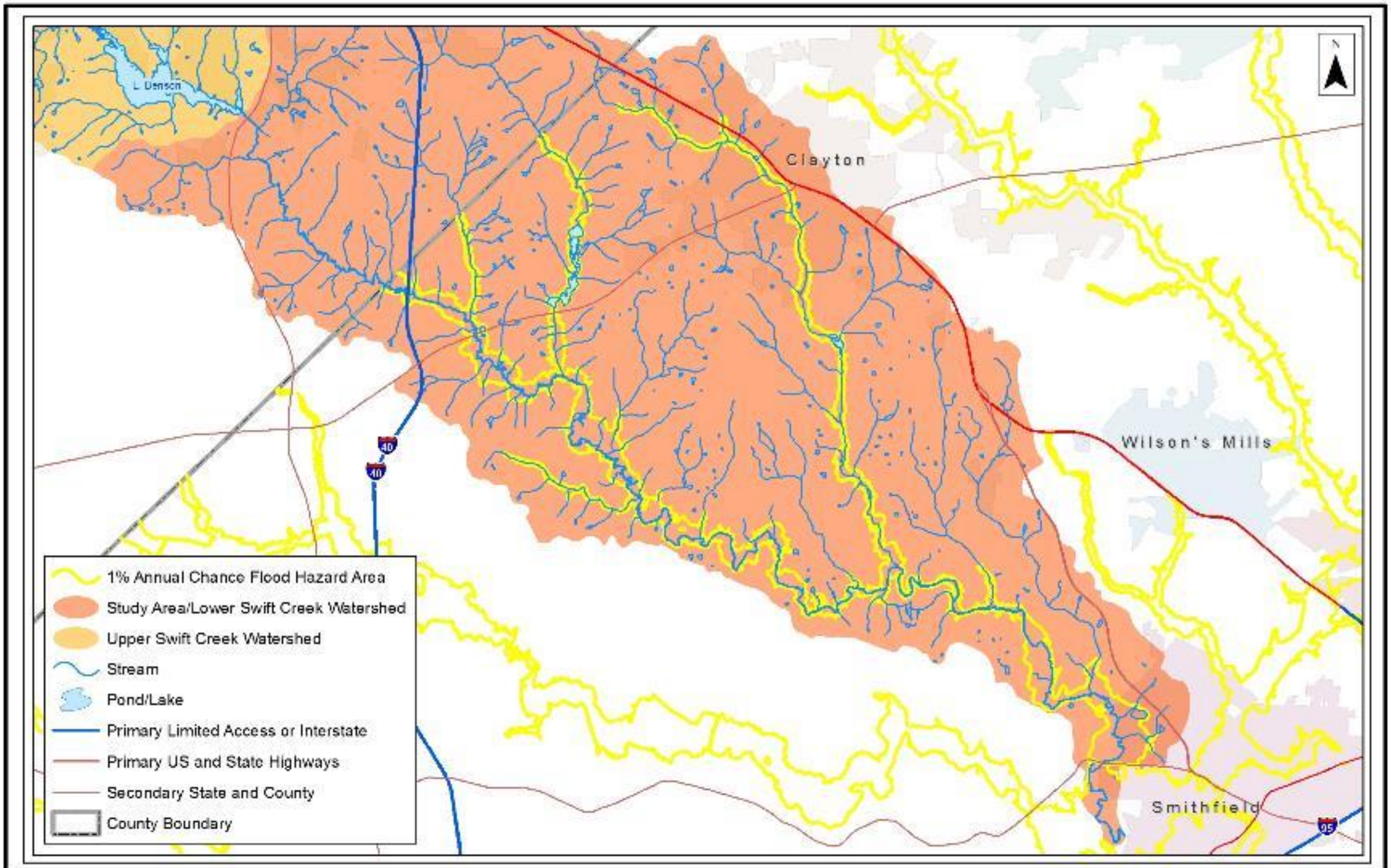
4.2.7. *Johnston County*

NCDOT provided funding to Johnston County for a Watershed Administrator position to implement watershed ordinances as part of development of the Clayton Bypass. The funds were initially received in 1999 and NCDOT supplied funding for five years ($25,000 per year, for a total of $125,000). At that time, the County's stormwater department had just been formed, and a stormwater administrator position was created for the entire county (not just SCW). The passing of the Neuse River Buffer Rules in 1998 was also a driver for creating both the department and the position. When the administrator position was created, Johnston County also developed an Environmentally Sensitive Area (ESA) designation that set limits on impervious surfaces and nitrogen loading rates within the ESA. The ESA was first established around Little Creek from US 70 Bypass to Swift Creek (Figure 9).

Johnston County also entered into an MOU with USFWS and NCDOT to protect SCW for the Clayton Bypass project. In this MOU, the county agreed to expand the boundaries of its ESA (Figure 9). There are stormwater restrictions within the ESA that limit impervious surfaces to 12% in residential areas and 50% in non-residential (versus 15% and 60%, respectively, outside of an ESA). The percent of impervious cover can be increased if BMPs are utilized, payments are made to Land Dedication Fund, or there is a direct dedication of land to preservation. No development is allowed within flood hazard areas (Figure 10), including residential and non-residential structures and improvements to existing structures (NCDOT 2005). Johnston County implemented modification to the Stormwater Management Ordinance limiting total nitrogen from new development to 3.6 lbs/acre/year. Commercial development may make an offset payment to DMS, but shall not exceed nitrogen loads of 8 lb/acre/yr. Residential development does not have the DMS offset payment option (NCDOT 2005). Additionally, the MOU states that Johnston County would consider requiring a 100-foot undisturbed riparian buffer along perennial streams in the ESA, which Johnston County has limited to the main stem channels of Swift Creek, White Oak Creek, Little Creek (from US 70 to Swift Creek) and Little River (from county line to NC 39). All other streams in the ESA do not require the increased 100-foot buffer, but do fall under Neuse River buffer requirements.

There are several areas that are exempt from the current ESA, such as some properties in the I-40/NC-42 interchange area, which drain to Swift Creek. For example, the Golden Corral property was exempt as it was approved prior to the adoption of the ESA regulations. However, the Wal-Mart property was not exempt, and various stormwater BMPs were incorporated into site development.

Under the BMP management program, developers must submit a stormwater management plan, get certification from an engineer in the final stages, and follow-up with an annual inspection approved by the county through a private company. If the inspections indicate non-compliance, they are then required to bring the project into compliance within a year or receive a Notice of Violation.

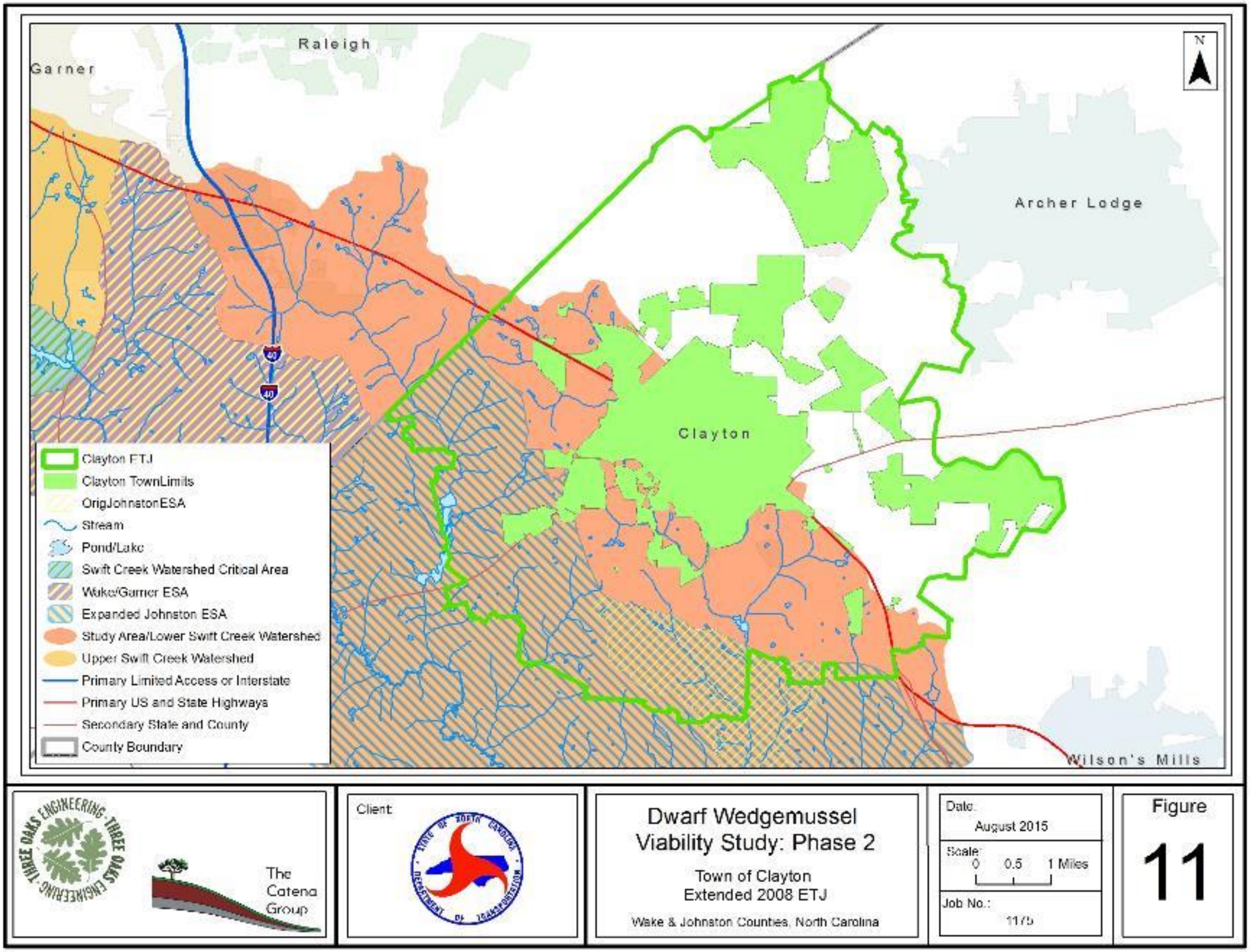


Three Oaks Engineering The Catena Group	Client:	Dwarf Wedgemussel Viability Study: Phase 1 Johnston County Flood Hazard Areas Johnston County, North Carolina	Date: August 2015 Scale: 0 0.5 1 Miles Job No.: 1175	Figure 10

Johnston County teamed with the Triangle Land Conservancy (TLC) to develop criteria to consider which lands warrant being purchased through the Land Dedication Fund. However, finding conservation areas within SCW has been very challenging (Guerrero, personal communication). While there is still a fair amount of land that has not been developed, many of the landowners in the watershed believe their land is highly sought after for developers and the County alike. So far, no lands have been dedicated within the Swift Creek watershed. Since the signing of the MOU in 2005 for the Clayton Bypass, which expanded the ESA to include Swift, White Oak, and Little Creeks, the Town of Clayton has expanded the Extraterritorial Jurisdiction (ETJ) from one mile to two miles around its boundary (Figure 11). This effectively made the ESA regulations no longer applicable within the ETJ. Therefore, Johnston County and Clayton signed another MOU to ensure that areas previously designated as ESA remained subject to the ESA regulations. Clayton is now part of the NPDES Phase II Stormwater Rule, indicating they must adopt a stormwater management plan, among other requirements. Johnston County noted that there are several other areas in SCW that may be in need of stormwater improvements or retrofits in order to improve water quality in the watershed:

- Summerwind (northwest of I-40/NC-42 interchange): A residential and multi-use development. As the site was in the early stages of development, off-site erosion was an issue. NCDWR took the developer to court for sediment loss into the stream and exceeding permitted limits. However, the original developer has since gone bankrupt, but the property is now under new ownership and development has reinitiated.
- Tetra (northwest of I-40/NC-42 interchange): A commercial and multi-use area.
- Pump Station (east of I-40/NC-42 interchange on Swift Creek): A sewer lift station located near Lowe's at I-40/NC-42, next to Swift Creek, which has been degraded.

Johnston County passed an S&EC ordinance in June 2013, which the Public Utilities Department is responsible for overseeing. This ordinance regulates land-disturbing activities to control sediment and erosion and establishes procedures by which to accomplish these goals. Additionally, changes were made to the riparian buffer protection ordinance in January 2014, which abide by the Neuse River Buffer rules. Clayton's buffer and S&EC also falls under Johnston County.


Raleigh
Garner
Archer Lodge
Clayton
Wilson's Mills
N
40
Clayton ETJ
Clayton TownLimits
OrigJohnstonESA
Stream
Pond/Lake
Swift Creek Watershed Critical Area
Wake/Garner ESA
Expanded Johnston ESA
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
The Catena Group
Client
Dwarf Wedgemussel
Viability Study: Phase 2
Town of Clayton
Extended 2008 ETJ
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 0.5 1 Miles
Job No.:
1175
Figure
11

4.2.8. *NCDOT Measures*

As part of the roadway design of the Clayton Bypass, and in coordination with USFWS, NCWRC, and other environmental agencies, NCDOT implemented the following measures:

- Added hazardous spill catch basins, extended controlled access to project sites
- Removed curbs and gutters, installed basin designed to meet runoff for 25-year storms
- Utilized faircloth skimmer with jute baffles and polyacrylamide
- Installed erosion control matting in exposed areas near critical habitat and in ditch lines.

Additionally, NCDOT implemented a water quality monitoring program, seeding and mulching, and erosion and sedimentation control measures. DWM propagation efforts by Dr. Richard Neves at Virginia Tech were funded by NCDOT in which 500 juveniles were propagated for release (Beck and Neves 2001); however, the juveniles were not released into Swift Creek over concern of contaminating current populations, as the brood stock came from other locations because efforts to find individuals in Swift Creek were not successful. Additionally, the design of the Clayton Bypass shifted the alignment of the I-40 interchange away from Swift Creek and included four bridges and drainage design features, thus reducing the impact on the stream (NCDOT 2005). NCDOT also provided funding to Johnston County for the creation of the aforementioned Watershed Administrator position.

The water quality monitoring program consisted of monitoring eight (8) sites for turbidity levels during construction of the Bypass (from 2006 to 2008). Four streams were monitored, with stations located upstream and downstream of the construction. Data was viewed on a weekly basis in order to detect possible sediment problems in the system. During the monitoring period, there were generally very dry conditions. These conditions were not conducive to very accurate data, as the sensors used were designed for deeper water. This resulted in many artificial spikes in turbidity levels and the need for frequent recalibration of the sensors (David Harris, personal communication). Turbidity levels were generally the same upstream and downstream of the construction, aside from the occasional increase downstream of construction (see Appendix D for Quarterly Reports).

4.2.9. *Stormwater Evaluation Tool*

The Stormwater Evaluation Tool (SET) was developed with the intent to identify areas of concern with respect to improperly managed stormwater devices and areas where stormwater is altogether unmanaged (Three Oaks Engineering/Catena 2015b). SET is used to provide a means of rating “sites” where stormwater retrofit could occur within the SCW. The SET was created specifically to evaluate potential sites for BMP retrofit and provide a priority ranking based on site specific characteristics. Potential retrofit sites will be prioritized on the following criteria:

- Ability to prevent stream erosion, sedimentation and water quality degradation
- Ability to prevent pollutant loading
- Ability to implement the BMP retrofit project

Evaluations are conducted through inspections that include looking for existing BMP devices, active erosion and potential for erosion, sediment accumulation, water discharge method, and impervious surface area, among other characteristics. These characteristics are rated and recorded on a SET form.

Each site is evaluated by examining select site attributes and assigning a numerical score for each. The evaluation form is used to record the score for each attribute and determine the total numerical score for each site. Evaluation sites will be prioritized for BMP retrofit based on their total score, as well as best professional judgement. Sites receiving scores above 35 are deemed high priority for retrofit. A site that already has an operational BMP should receive a lower numeric rating compared to a site with no BMP.

Areas of high intensity development within 500 feet of the mainstem of Swift Creek and its tributaries were deemed within the area of interest. Initial evaluations of sites located within the area of interest included shopping centers, hotels, office parks, industrial areas, and residential developments. The complete SET report (Three Oaks Engineering/Catena 2015b), including the forms, is contained in Appendix E.

4.2.10. *Preservation/Mitigation sites*

There are three DMS mitigation sites in Swift Creek Watershed below Lake Benson and up to the first impoundment along tributaries to Swift Creek:

- Big Bull Creek Restoration Site (DMS ID: 92214) is approximately 37 acres on White Oak Creek and an unnamed tributary to White Oak. The site was previously used as livestock pasture and hay production prior to 2006 when riparian buffer restoration was completed. The entire site was reforested with Piedmont Bottomland Forest community species. A conservation easement on the site provides buffer mitigation in the watershed below Austin Pond.
- The Moore Property site (DMS ID: 725, ONEID: 051-001) was conveyed as a conservation easement in perpetuity to NCDOT in 2003. The site is 84 acres and construction of restored wetlands was completed in July 2011. The site was a mitigation site for the Clayton Bypass project (TIP R-2552) on Swift Creek next to Johnston County Airport.
- Site 092-014 Underhill Property, which is a closed-out 84 acre preservation property that was part of the R-2000 (Northern Wake Expressway) mitigation project. The property is

now owned by Wake County and appears as a mitigation site on the Wake County Public Open Space files (Figure 4).

4.3. Accounting of Conservation Measures: Summary

As described in Section 4.2, there are multiple conservation measures that have been developed and implemented within the SCW. These measures consist largely of establishing minimum buffer requirements, limiting the amount of imperviousness and nutrient inputs, and providing stormwater and erosion control measures. Additionally, measures associated with the Dempsey Benton WTP provide for maintenance of minimum flows in the Lower SCW. Other measures, such as establishing a USGS gauging station in the Lower SCW and developing artificial propagation techniques for the DWM, may aid in management decisions for this species in Swift Creek.

The effectiveness of these measures with regards to providing sufficient protection for the Lower SCW in terms of maintaining a viable DWM population into the future is unclear for a number of reasons. First, many of the conservation measures were enacted as a response to the rapid urbanization of the watershed, and thus some of the degradation of the watershed had already occurred prior to measures being implemented. Second, in most instances there were no specific monitoring components associated with the various conservation measures to determine if the measures are accomplishing their goals (i.e. are limits on impervious surface reducing stormwater effects on Swift Creek, are stormwater and erosion control measures reducing the amount of sedimentation and channel erosion impacts in Swift Creek, etc.). Finally, there is no clear understanding of how long it takes from the time conservation measures are implemented until improvements become apparent. This is especially true in a watershed like SCW, where there are multiple stressors; however, mitigation/conservation efforts are often project specific, or narrowly focused on one area or specific problem, as opposed to a holistic approach.

As will be discussed in Section 5.0, there has been a declining trend in the relative abundance of most mussel species occurring within the project area since the period of 1992-1996, but especially during the period of 1997-2001. Given this decline, it would be easy to draw a conclusion that the conservation and protective measures that are in place in the SCW are not sufficient to maintain a viable DWM population. However, for the reasons just alluded to, this conclusion may not be completely accurate. In the three periods following 1997-2001 (2002-2006, 2007-2011, 2012-2015) the decline seems to have leveled off for most species. An alternate conclusion might then be that the declines occurred prior to the conservation measures being implemented, and that by putting those measures in place, a total collapse of the mussel fauna was avoided, and populations may rebound once the measures have been in place for a long enough period of time.

It is likely that neither of these conclusions are totally accurate and that the level of the effectiveness of the conservation measures, and their adequacy to maintain population viability is somewhere in between. Population and habitat viability will be discussed in further detail in the following three sections.

5.0 DWM POPULATION TRENDS IN SWIFT CREEK

The overall goal of this study is to determine the long term viability of the Swift Creek DWM population. The recovery goal for the DWM (USFWS 1993) is "to restore and maintain viable populations …to a significant portion of its historical range in order to remove the species from the Federal list of endangered and threatened species". As mentioned earlier, the maintenance of a viable population in Swift Creek is listed as a recovery objective (USFWS 1993). The recovery plan defines a viable population as "a population containing a sufficient number of reproducing adults to maintain genetic variability and in which annual recruitment is adequate to sustain a stable population." While the definition of what constitutes a viable population is clear, a quantifiable measure of population viability has been difficult to determine.

5.1. NC Scientific Council Recommendation on Viability Measures

The NC Scientific Council on Freshwater and Terrestrial Mollusks (The Council), which currently consists of 17 scientists recognized for their respective knowledge on the status of mollusk species in North Carolina, was assembled by the North Carolina Nongame Wildlife Advisory Committee, an advisory committee that reports to the NCWRC, to evaluate status listings of the rare, threatened, and endangered mollusks of North Carolina. The Council recognized a need to develop a quantitative ranking system to use as a tool for determining imperiled status of species to lessen the subjective biases of existing ranking systems. One component of developing such a ranking system is determining population viability. As such, the Council's quantifiable criteria to measure population viability of freshwater mussels suggested the species should:

- Occupy between 10-20 miles of continuous habitat if dendritic (occurring in main stem and tributaries), or greater than 20 miles if linear, with no gaps greater than 2 miles of unoccupied habitat.
- Occur at 75% of sites within occupied habitat.
- Have a relative abundance as measured by CPUE of $\geq$ 5 individuals per hour at 50% of sites within occupied habitat.
- Exhibit evidence of reproduction; contain gravid individuals, and/or multiple size classes, including younger individuals.

These criteria have not been tested on mussel populations in the state, but were based in the collective opinions of the Council, and will likely need to be adjusted as these methods are applied and more information becomes available. While these measures of viability have not been officially adopted, this study evaluated these parameters in the analysis.

5.2. Study Approach

The study consists of two components; a desktop evaluation of previous survey data to determine species abundances over time, and in-stream studies to evaluate particular indicators of population viability. The DWM has consistently been rare in Swift Creek since its discovery in 1991. Because of this rarity, the DWM cannot be analyzed singularly in this study. As with many rare species, it is often necessary to evaluate more common associate species to serve as surrogates in the analyses. Therefore, this analysis focuses on trend data specific to the DWM, while also considering the entire mussel fauna in Swift Creek.

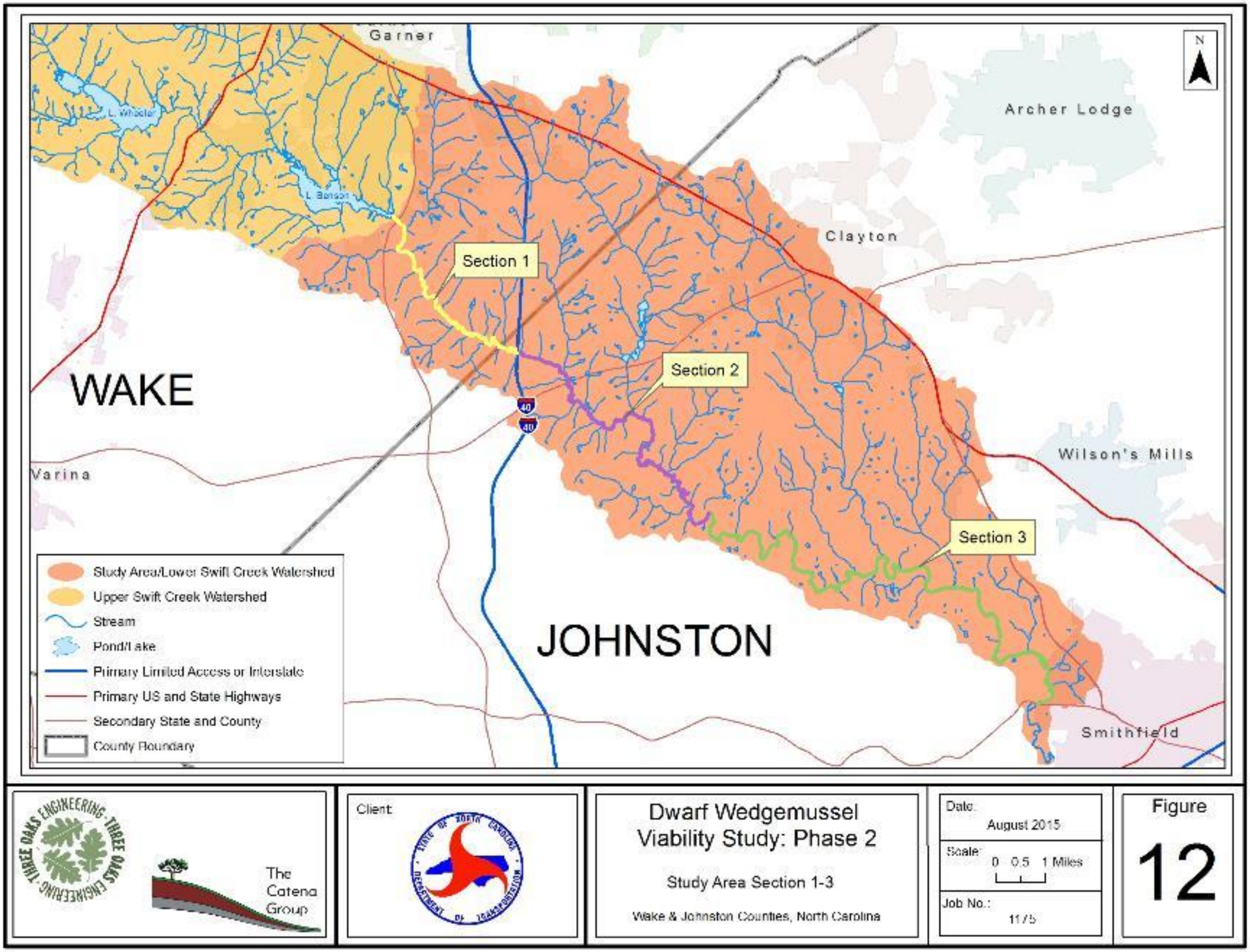
For purposes of data reporting, analysis, and discussion, the general study area of Swift Creek is divided into three sections of unequal length to account for general habitat conditions as follows (Figure 12):

1. Section 1 (Lake Benson to I-40),
2. Section 2 (I-40 to Barber Mill Road)
3. Section 3 (Barber Mill Road to the Neuse River)

With regards to the freshwater mussel fauna, Swift Creek is one of the most species rich and extensively surveyed water-bodies in North Carolina. However, nearly all of the surveys employed an "informal" sampling design using timed qualitative searches for mussels at various locations. The primary objective of this type of sampling is to determine presence/absence of a particular species, and is not recommended for population density studies, or long term monitoring (Strayer and Smith 2003). Thus, conclusions on population trends derived by simply analyzing the existing dataset without accounting for sampling variance would have inherent flaws as the dataset does not account for the level of uncertainty inherent with variables, such as survey effort, seasonality, surveyor experience, and survey conditions (water depth, visibility, flow, etc.). To account for this, a probability-based design that involved a number of repeat surveys at selected sites was incorporated into the field component of this study to develop detection probabilities for the mussel species occurring in Swift Creek. These detection probabilities will assist in making inferences of trends from previous survey data. While this will not totally eliminate the unknown biases of the informally sampled dataset, it will strengthen assumptions made with regard to previous survey data being representative of the overall population.

5.3. History of Mussel Surveys and Mussel Fauna in Swift Creek

Until the 1990s, documented collections of freshwater mussels in the Swift Creek subbasin were very limited. Walter (1956) sampled mollusks at five stations and reported only five mussel


Garner
L. Wheeler
L. Benson
Archer Lodge
Clayton
Section 1
Section 2
Section 3
WAKE
JOHNSTON
Varina
Wilson's Mills
Smithfield
40
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
N
Client
Dwarf Wedgemussel
Viability Study: Phase 2
Study Area Section 1-3
Wake & Johnston Counties, North Carolina
Date:
August 2015
Scale:
0 0.5 1 Miles
Job No.:
1175
Figure
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The Catena Group
THREE OAKS ENGINEERING

species. Alderman (1991) reported 11 species, including the DWM at four stations. Since the discovery of DWM in Swift Creek in 1991, numerous mussel surveys have been conducted throughout the subbasin, including a relict shell survey at 118 stations in 1992 (Flowers and Miller 1993), various status/monitoring surveys by the NCWRC from 1992-2006, comprehensive efforts in 1996 and 2003 undertaken by the NCDOT for the Clayton Bypass roadway project (NCDOT 2005), and baseline and six-month post construction surveys for the Dempsey E. Benton WTP in 2007 and 2010 respectively. Additionally, surveys were conducted for the Complete 540 - Triangle Expressway Southeast Extension in 2010, 2011 and 2012. The results of these surveys were provided to Lochner and NCDOT in three separate reports, which are included in Appendix F.

Historically, at least 18 species of freshwater mussels have been reported to occur in the Swift Creek subbasin. The Green Floater reported as occurring in Swift Creek by Walter (1956) is the only species known from the creek that has not been found in recent years, as it was last collected (one specimen) in 1991 (Alderman 1991). Brief descriptions of each of the mussel species known from Swift Creek are provided in Appendix F.

5.4. DWM Occurrences and Distribution in Swift Creek

In Swift Creek a total of 49 live and 12 relict shells have been found through 21 stream miles from 1992-2016 (Figure 13). The lower 10 miles, however, are represented by only one individual, and the species has not been found in this 10 mile section since 1991. Additionally, two individuals have been recorded in both Little Creek and Middle Creek and one in White Oak Creek, which are tributaries to Swift Creek. A table listing all the DWM records from the SCW, including year and specific locations is included as Appendix G.

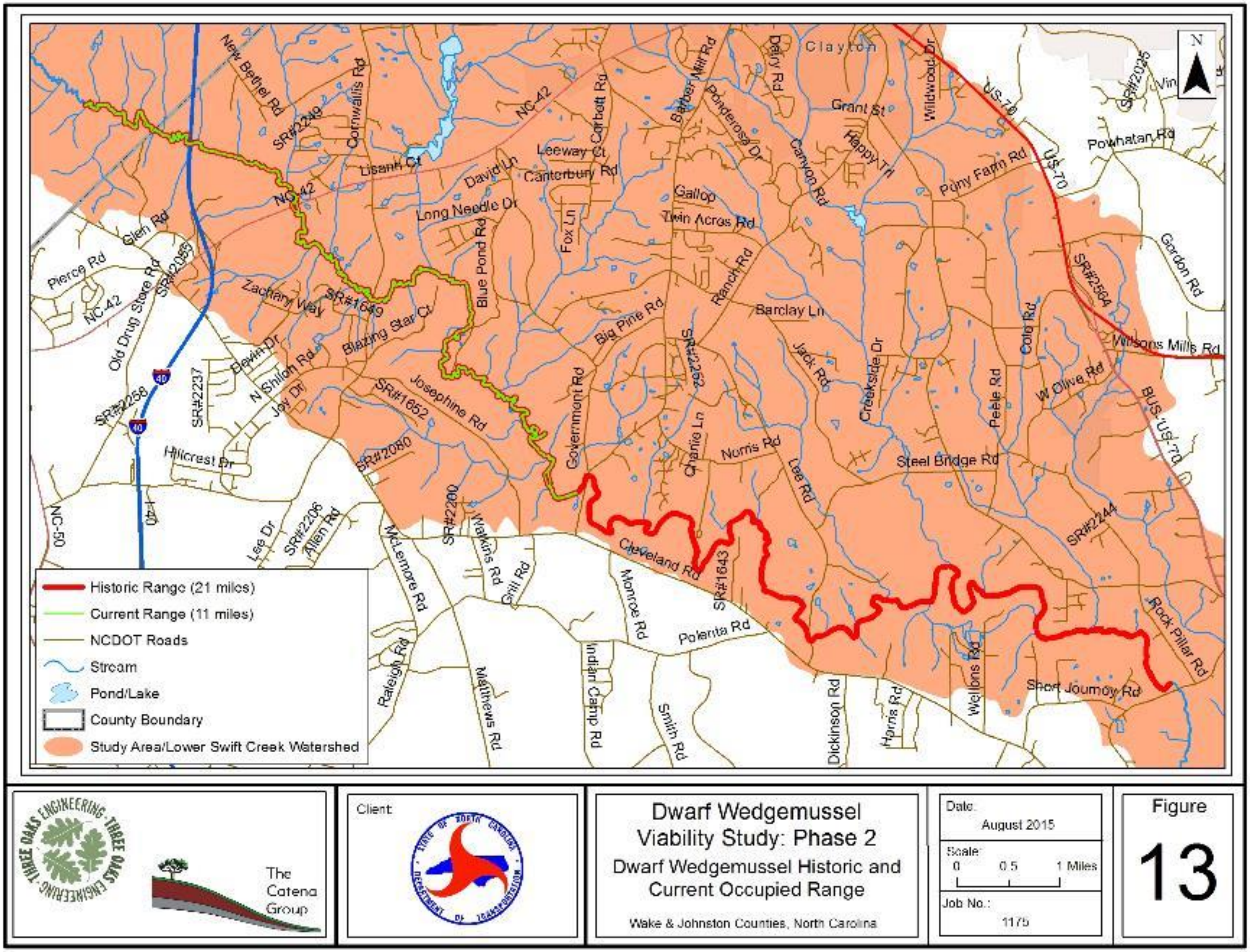
5.5. Mussel Population Trends in Swift Creek

The objective of this component of the study was to analyze population trends of the mussel species in Swift Creek. This analysis focuses on relative abundances, as measured by catch per unit effort (CPUE) of each species over time, and age class distribution (as inferred from size class data) over time for particular species when size class data is available.

5.5.1. *Relative Abundance Trends*

The CPUE, which indicates the number of individuals found in one hour of survey time, for each species occurring in Swift Creek was evaluated over time in the three sections of the study area. Two different measures of CPUE were considered:

1. CPUE for each species only at sites where it was detected within each section (Site Specific)


Historic Range (21 miles)
Current Range (11 miles)
NCDOT Roads
Stream
Pond/Lake
County Boundary
Study Area/Lower Swift Creek Watershed
Clayton
N
New Bethel Rd
Cornwallis Rd
NC-42
Corbett Rd
Barber Mill Rd
Ponderosa Dr
Dairy Rd
Grant St
Wildwood Dr
US-70
Powhatan Rd
Pony Farm Rd
Happy Trl
Canyon Rd
Leeway Ct
Canterbury Rd
Lisann Ct
David Ln
Long Needle Dr
Gallop
Twin Acres Rd
Fox Ln
Blue Pond Rd
Ranch Rd
Barclay Ln
Big Pine Rd
Glen Rd
Pierce Rd
Old Drug Store Rd
Zachary Way
SR#1649
Blazing Star Ct
Bevin Dr
N Shiloh Rd
Joy Dr
SR#2258
SR#2237
SR#1652
Josephine Rd
Government Rd
Charlie Ln
Norris Rd
Jack Rd
Creekside Dr
Peele Rd
Cole Rd
W Olive Rd
SR#2564
Wilsons Mills Rd
Gordon Rd
BUS US-70
Steel Bridge Rd
Lee Rd
SR#2244
Hillcrest Dr
SR#2080
SR#2200
Watkins Rd
NC-50
Lee Dr
SR#2206
Allen Rd
McLemore Rd
Cleveland Rd
SR#1643
Grill Rd
Monroe Rd
Polenta Rd
Rock Pillar Rd
Short Journey Rd
Wellons Rd
Harris Rd
Dickinson Rd
Smith Rd
Indian Camp Rd
Matthews Rd
Raleigh Rd
THREE OAKS ENGINEERING
The Catena Group
Client:
Dwarf Wedgemussel Viability Study: Phase 2
Dwarf Wedgemussel Historic and Current Occupied Range
Wake & Johnston Counties, North Carolina
Date: August 2015
Scale: 0 0.5 1 Miles
Job No.: 1175
Figure
13

2. CPUE for each species at all survey sites combined within each section, whether the species was detected or not (Total Effort).

These data were divided into the following six time periods:

1. ≤1991
2. 1992-1996
3. 1997-2001
4. 2002-2006
5. 2007-2011
6. 2012-2015

It is important to note that each of these periods contains variability in data collection as to methods, level of effort, survey site location, etc. Many of the survey sites, particularly in the first three time periods, focused on the best habitat for rare species, such as the DWM, Atlantic Pigtoe and Yellow Lance, while later surveys were more comprehensive of a variety of habitat conditions within the stream. As such, conclusions based on apparent trends, particularly for habitat specialists like the Atlantic Pigtoe, need to account for variability in survey methodologies. Variability in survey methodologies is less likely to be a factor when evaluating trends with habitat generalists such as the *Elliptio* species. The number of survey hours per section for each time period is shown in Table 10; however, it should be noted that at the time of the writing this report, an intensive survey effort in Swift Creek was underway as part of monitoring requirements, and the results of these on-going surveys are not reflected in the analyses below, but will be incorporated into the Biological Assessment that will be prepared for this project.

Table 10. Number of mussel survey hours by sections

	Study Area Section		
Time Period	**1**	**2**	**3**
≤1991	0	1	7
1992-1996	6	8	9
1997-2001	23	21	3
2002-2006	44	51	53
2007-2011	145.5	306.69	116.16
2012-2015	47.53	287.99	56.87

5.5.1.1. DWM

As mentioned in section 5.4, a total of 49 live DWM have been found in Swift Creek since 1991, with the majority (42) found in Section 2, and only one individual found in Section 3. The above values include one DWM found in 2016 in Section 2 that is not included in the CPUE calculations or charts below. Since the 1992-1996 period, the Site Specific CPUE has declined steadily from a high of 3.5/hr in Section 2 to <0.35/hr in both Section 1 and Section 2 in the

2007-2011 period, and <0.3/hr in Section 2 during the 2012-2015 period (Chart 1). It should be noted that the Site Specific CPUE (1.0/hr) for the 2002-2006 period is represented by only one individual. The Total Effort CPUE (Chart 2) highlights the amount of effort required to detect this species. While it has consistently taken a significant amount of survey effort to detect DWM in Swift Creek, as with the Site Specific CPUE (Chart 1), a declining trend is apparent over the same time periods.

Chart 1. CPUE of Dwarf Wedgemussel only at sites where it was detected within each section

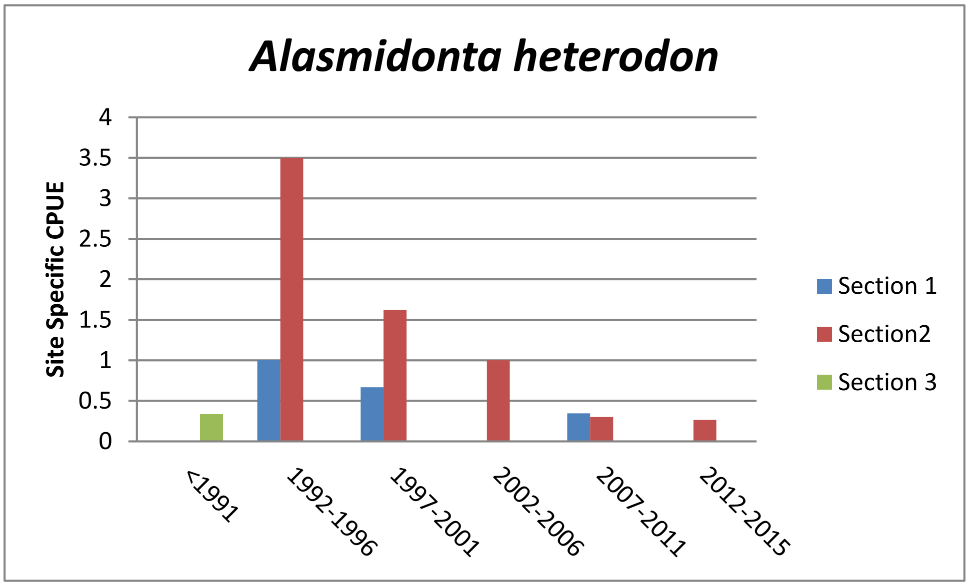
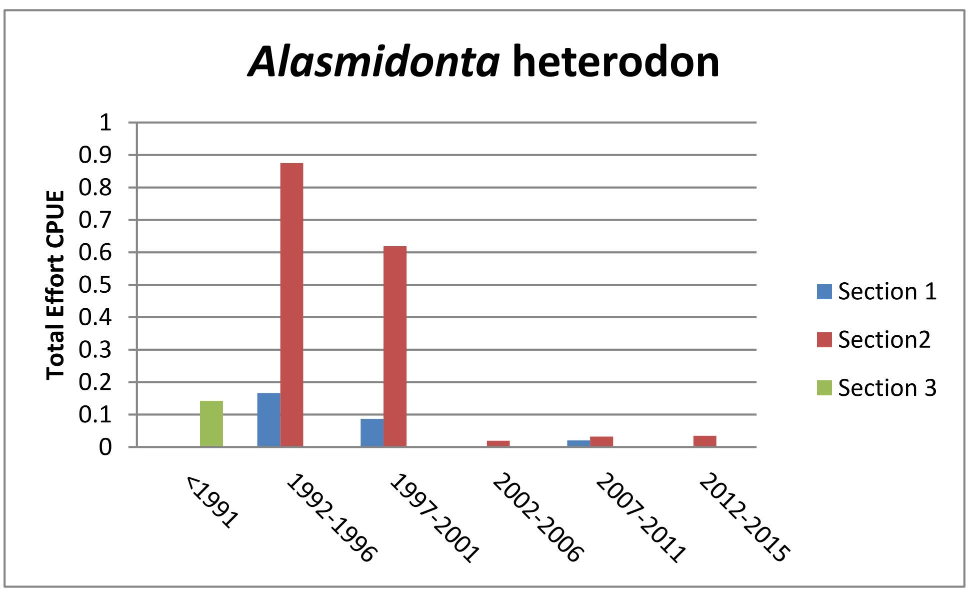


Chart 2. CPUE of Dwarf Wedgemussel at all survey sites combined within each section, whether the species was detected or not



5.5.1.2. Atlantic Pigtoe

The Atlantic Pigtoe has been found in all three sections of Swift Creek in every sampling period, with the exception of <1991, when it was reported only in Section 2. This is likely due to a limited amount of survey effort during that sampling period. Both measures of CPUE (Charts 3 and 4) indicate a declining trend of Atlantic Pigtoe CPUE since the 1992-1996 period, although the decline seems to have leveled off in the last three sampling periods.

Chart 3. CPUE of Atlantic Pigtoe only at sites where it was detected within each section

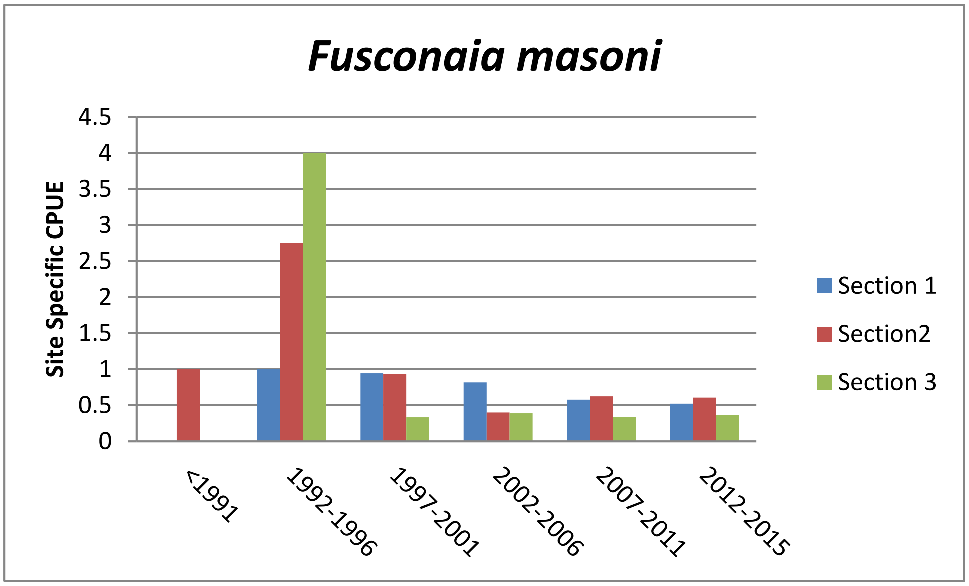
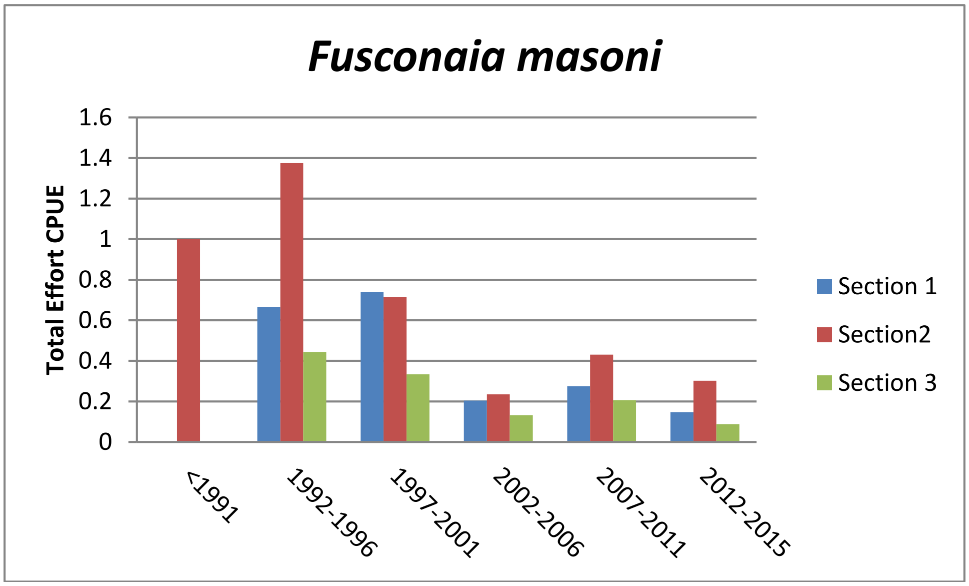


Chart 4. CPUE of Atlantic Pigtoe at all survey sites combined within each section, whether the species was detected or not



5.5.1.3. Elliptio Species

This composite of *Elliptio* species represents at least three species (*E. complanata* complex, *E. icterina* complex and *E. congerea*). Due to plasticity of shell morphologies and taxonomic uncertainties within the genus, discrepancies regarding species identification exist within the dataset. For example, the Box Spike (*E. cistelliformis*) is reported from Swift Creek. This species, which was described from the Neuse River Basin was synomonized with *E. complanata* (Johnson 1970). Thus, some surveyors in Swift Creek may have recognized the *E. cistelliformis* form as separate from *E. complanata*, while others may have grouped them together. To account for this, all *Elliptio* species excluding *E. lanceolata*, *E. roanokensis* and various lanceolate *Elliptio* forms (*E. fisheriana*, *E. producta*, *E.* spp. c.f. lance and *E. viridula*), were grouped together for this analysis. *Elliptio* species generally account for the highest percentage of the freshwater mussel fauna in most Southern Atlantic Slope streams (Johnson 1970), which is the case within Swift Creek.

As with the DWM and Atlantic Pigtoe, both measures of CPUE point to a declining trend in relative abundance of the *Elliptio* species since the 1992-1996 period in all three sections of Swift Creek, though the decline seems to have leveled off in the last two sampling periods (Charts 5 and 6). While *Elliptio* species were found at every site surveyed there are minor discrepancies between the two charts; for a few surveys, no search times were included or information about non-protected species was omitted; thus the CPUE values between the two charts are different during some sampling periods.

Chart 5. CPUE of Elliptio Species only at sites where it was detected within each section

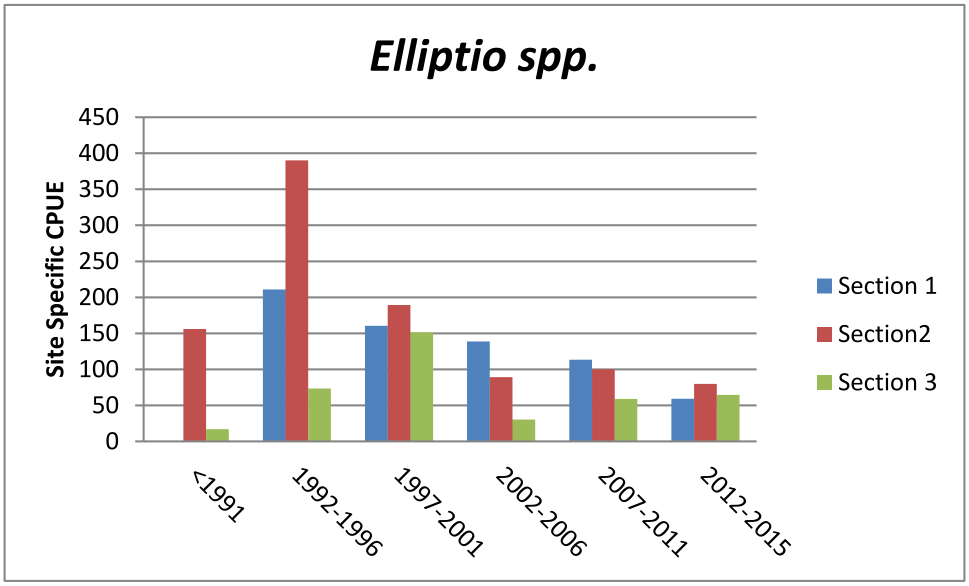
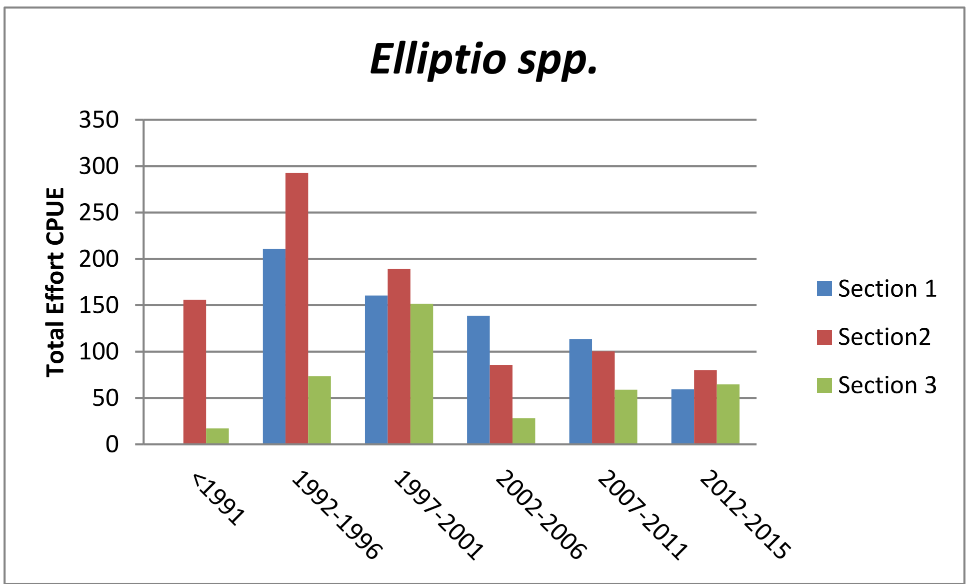


Chart 6. CPUE of Elliptio Species at all survey sites combined within each section, whether the species was detected or not



5.5.1.4. Notched Rainbow

The Notched Rainbow is extremely uncommon in the study area, being found only in Section 2 in very low numbers (≤ 1.5/hr, and ≤ 0.125/hr in Chart 7 and 8, respectively). Live individuals have not been found since 2006; however, two fresh dead shells were found in 2012 as part of this study. Given its rarity, population trends are not able to be determined within the time period of the data set.

Chart 7. CPUE of Notched Rainbow only at sites where it was detected within each section

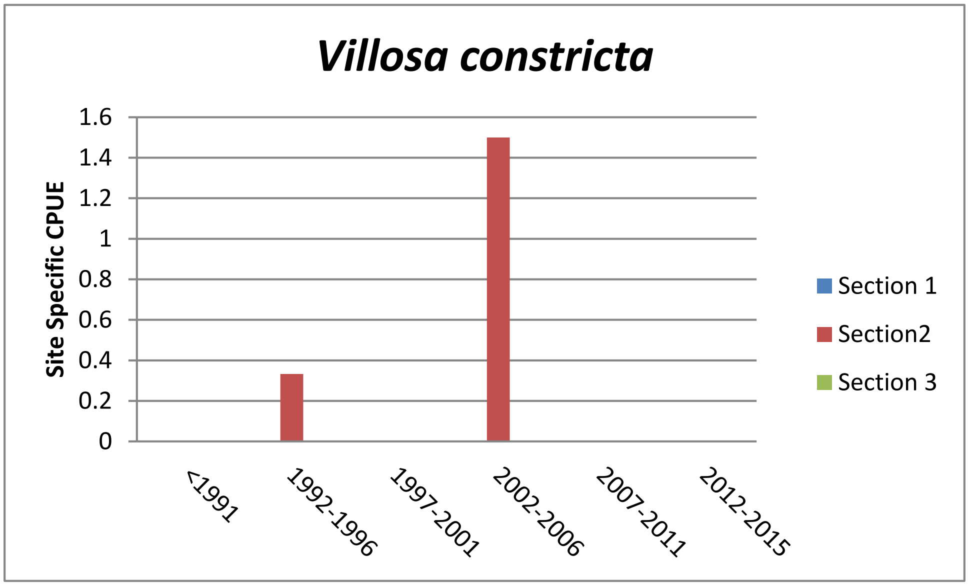
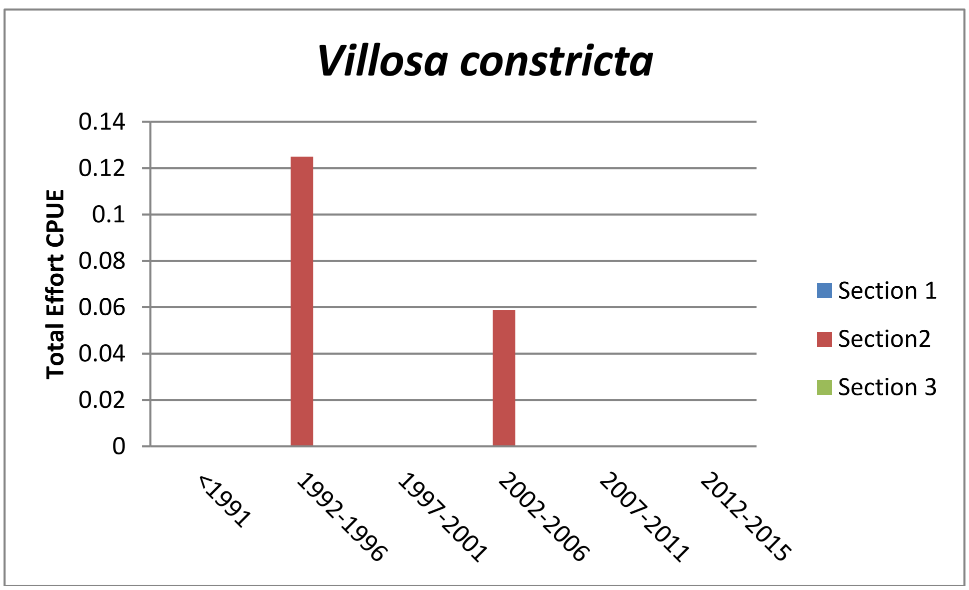


Chart 8. CPUE of Notched Rainbow at all survey sites combined within each section, whether the species was detected or not



5.5.1.5. Triangle Floater

The Triangle Floater has been found in all three sections, with the highest CPUE (Site Specific and Total Effort) occurring in Section 3. The CPUE dropped slightly in all three sections between the 1992-1996 and the 1997-2001 periods, and then declined significantly in the following periods (< 0.72/hr for Total Effort in all three sections). Both measures of CPUE (Charts 9 and 10) show similar declining trends, though the decline seems to have leveled off in the last two sampling periods (Charts 5 and 6)

Chart 9. CPUE of Triangle Floater only at sites where it was detected within each section

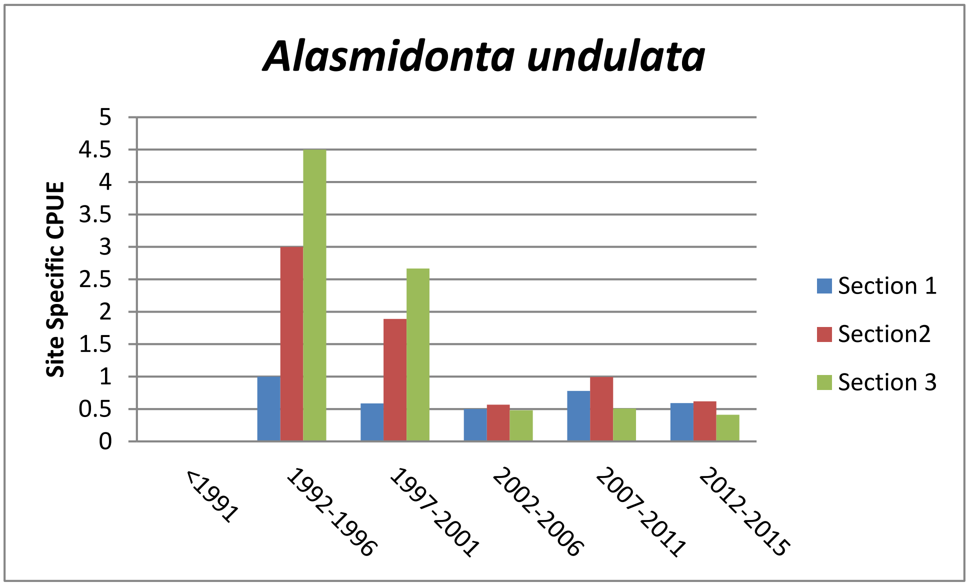
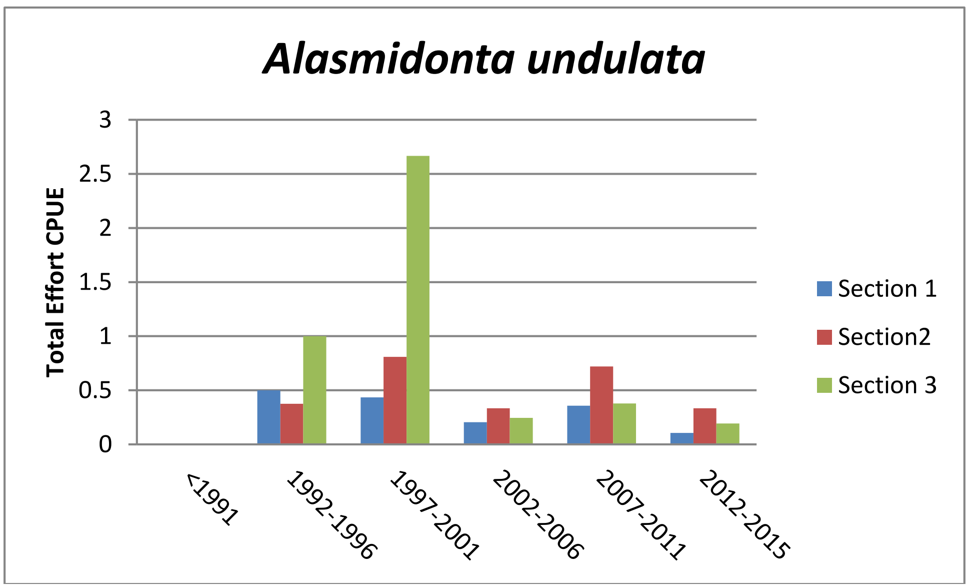


Chart 10. CPUE of Triangle Floater at all survey sites combined within each section, whether the species was detected or not



5.5.1.6. Yellow Lance

The Yellow Lance has been found in all three sections. Both measures of CPUE indicate that at least within Section 2 the Yellow Lance was much more common in the 1992-1996 period than in later years, and that it has become extremely rare since then (Charts 11 and 12).

Chart 11. CPUE of Yellow Lance only at sites where it was detected within each section

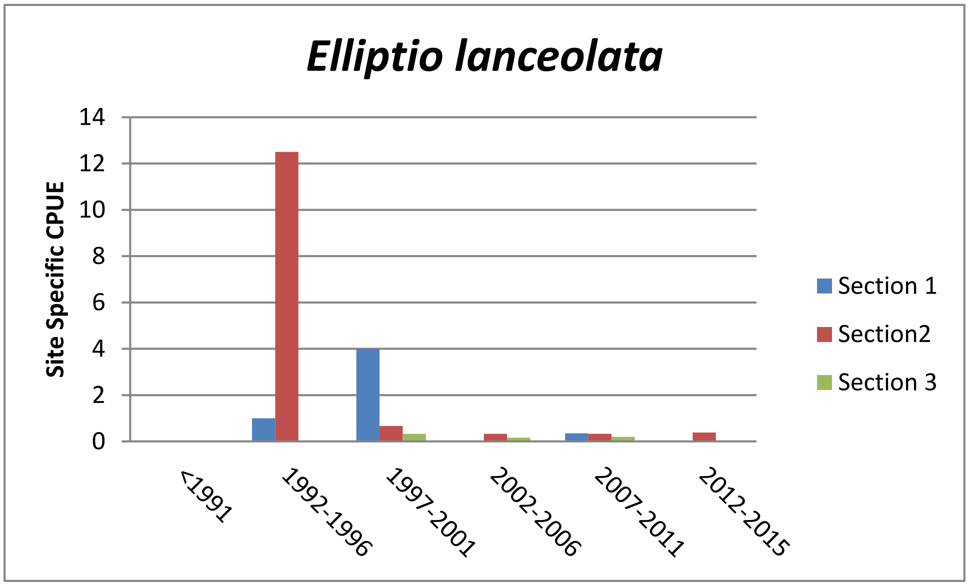
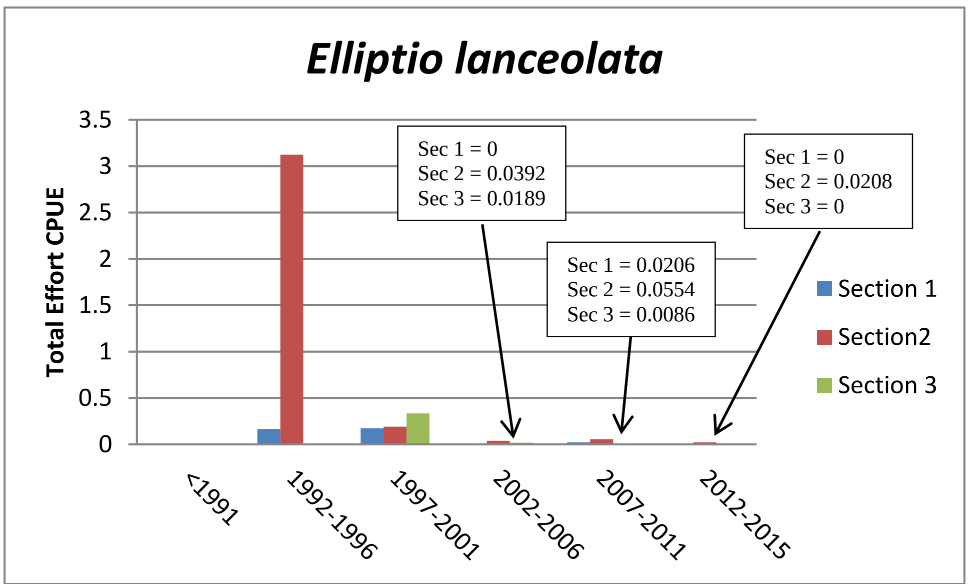


Chart 12. CPUE of Yellow Lance at all survey sites combined within each section, whether the species was detected or not



5.5.1.7. Eastern Lampmussel

The Eastern Lampmussel occurs in all three sections, and the CPUE declined from the 1992-1996 to the 1997-2001 period; however, it has remained fairly consistent since that time (Charts 13 and 14).

Chart 13. CPUE of Eastern Lampmussel only at sites where it was detected within each section

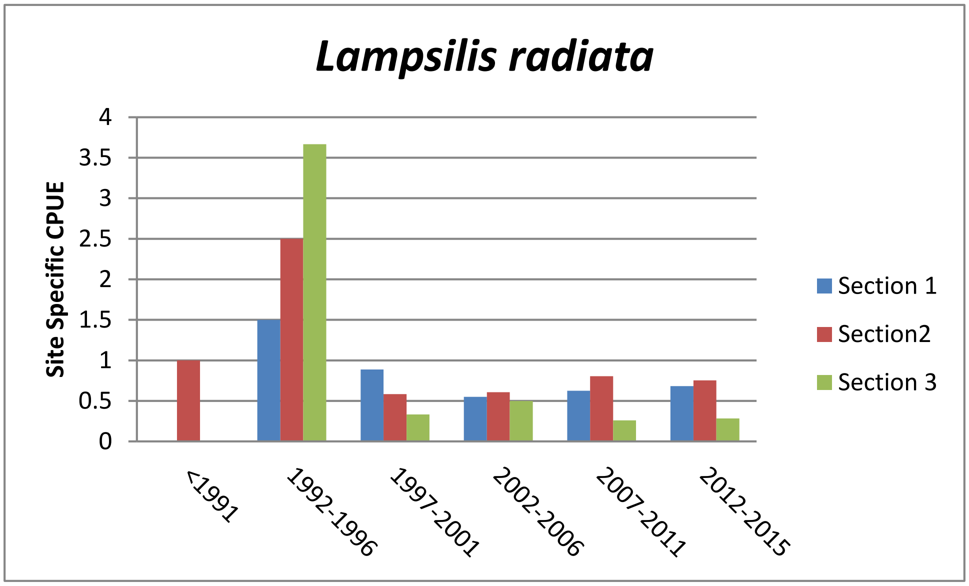
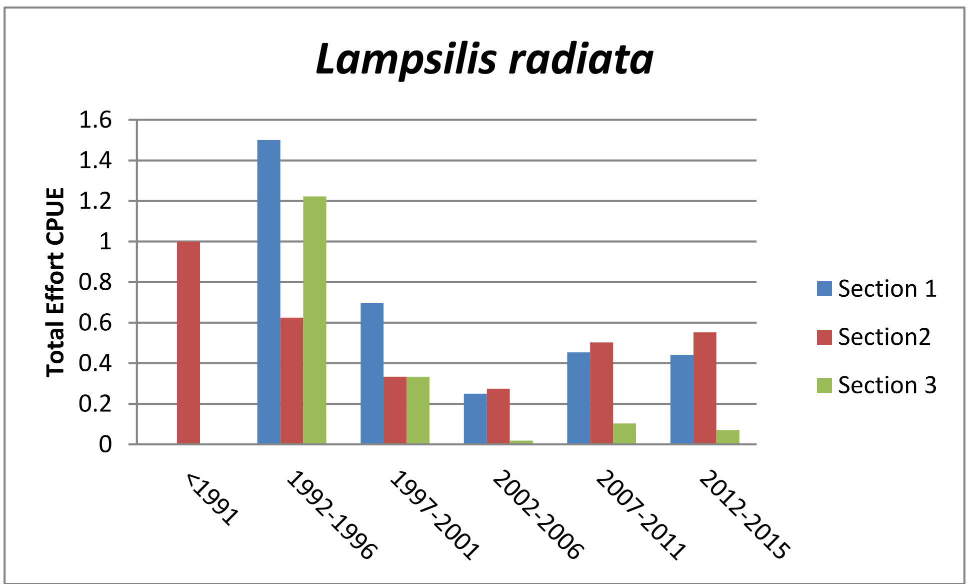


Chart 14. CPUE of Eastern Lampmussel at all survey sites combined within each section, whether the species was detected or not



5.5.1.8. Creeper

The CPUE declined after the 1992-1996 period, and has been consistently low (Site Specific and Total Effort) in all three sections in the last three sampling periods (Charts 15 and 16).

Chart 15. CPUE of Creeper only at sites where it was detected within each section

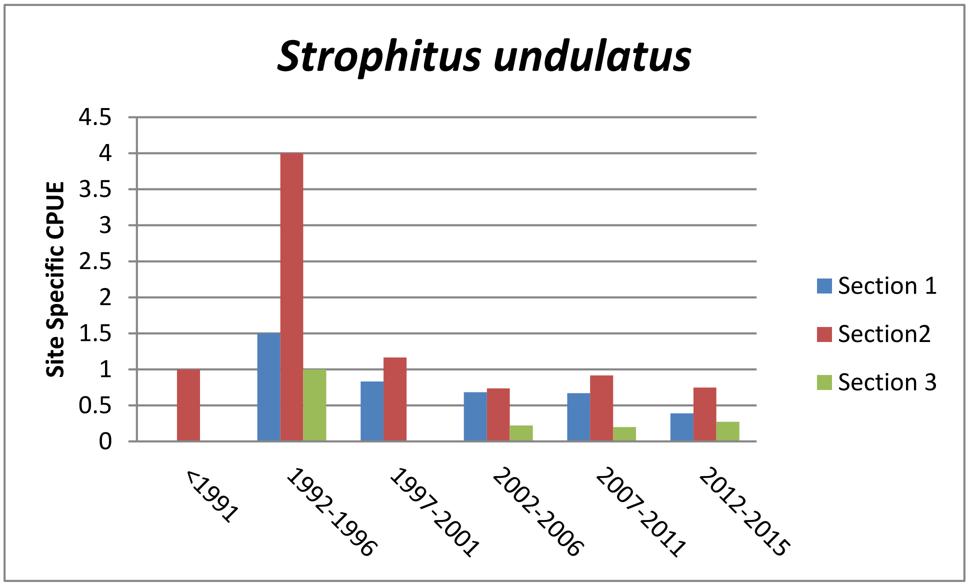
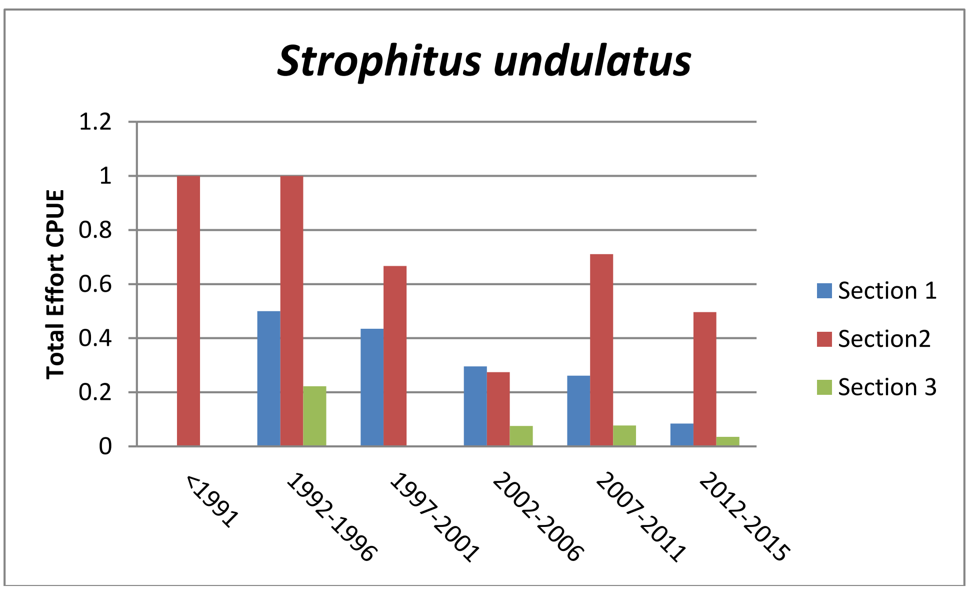


Chart 16. CPUE of Creeper at all survey sites combined within each section, whether the species was detected or not



5.5.1.9. Roanoke Slabshell

The Roanoke Slabshell has been found in all three sections. The highest Site Specific CPUE occurred in the <1991 sampling period; however, trends are very difficult to determine. In 2001, a total of 53 individuals were found at a site in section 3; no search time was recorded for this site resulting in no CPUE being calculated for Chart 17. The CPUE shown in Chart 18 is exaggerated as it does include those 53 mussels but the specific search time was not able to be factored into the Total Effort search time. Despite these flaws within the dataset, a declining trend does seem apparent after the 2002-2006 period. It should be noted however, that the relatively low CPUE for this species compared to other Elliptio species (*Elliptio* spp.), which are all generally easily detected when present (Section 5.7) may somewhat be a reflection of sampling effort, rather than actual rarity as this species typically occurs within the deeper habitats, which are not as easily sampled and are often not targeted.

Chart 17. CPUE of Roanoke Slabshell only at sites where it was detected within each section

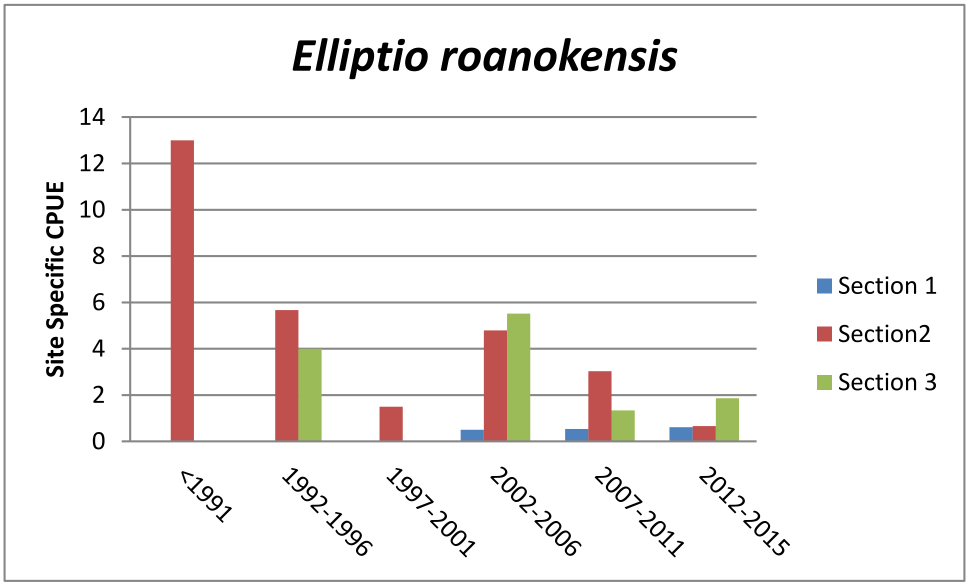
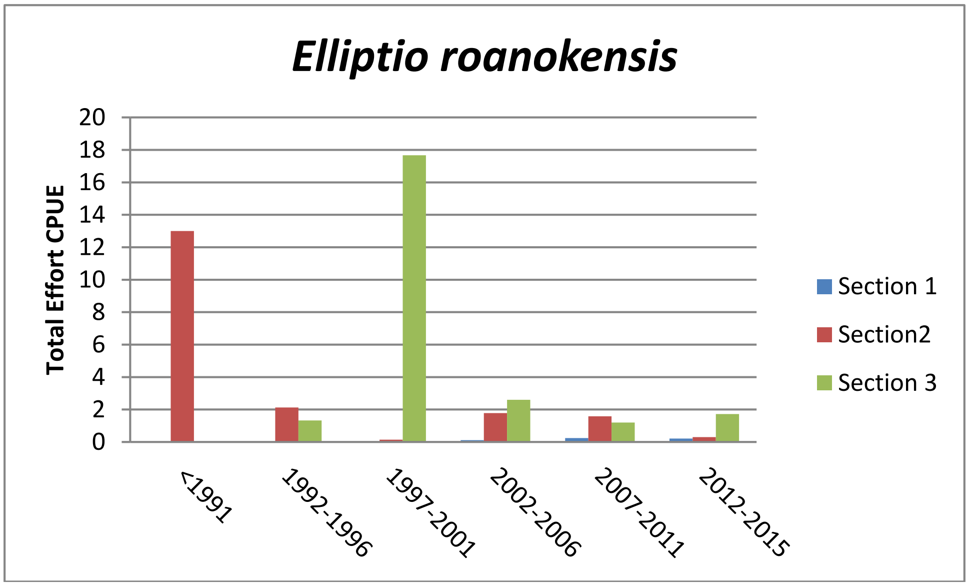


Chart 18. CPUE of Roanoke Slabshell at all survey sites combined within each section, whether the species was detected or not



5.5.1.10. Eastern Floater

The Eastern Floater is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification and many forms of pollution (Connecticut Dept. Environmental Protection 2011). This species was not detected in Section 1 of Swift Creek in surveys prior to the third sampling period (1997-2001), where it was found in low numbers in Section 1 (Charts 19 and 20). Since that time it appears this species is expanding its range in Swift Creek, as it was found more consistently in Section 1 and 2 during the fourth (2002-2006) and fifth sampling periods (2007-2011). This increase in range may be indicative of continuing habitat modification in the stream. Trends in CPUE are difficult to determine, as there were also individuals found with no search time recorded.

Chart 19. CPUE of Eastern Floater only at sites where it was detected within each section

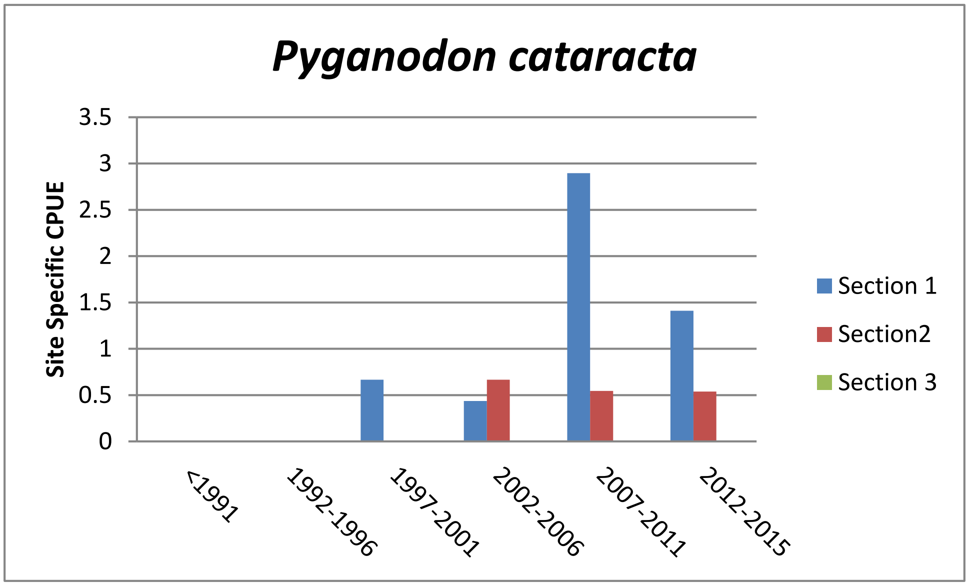
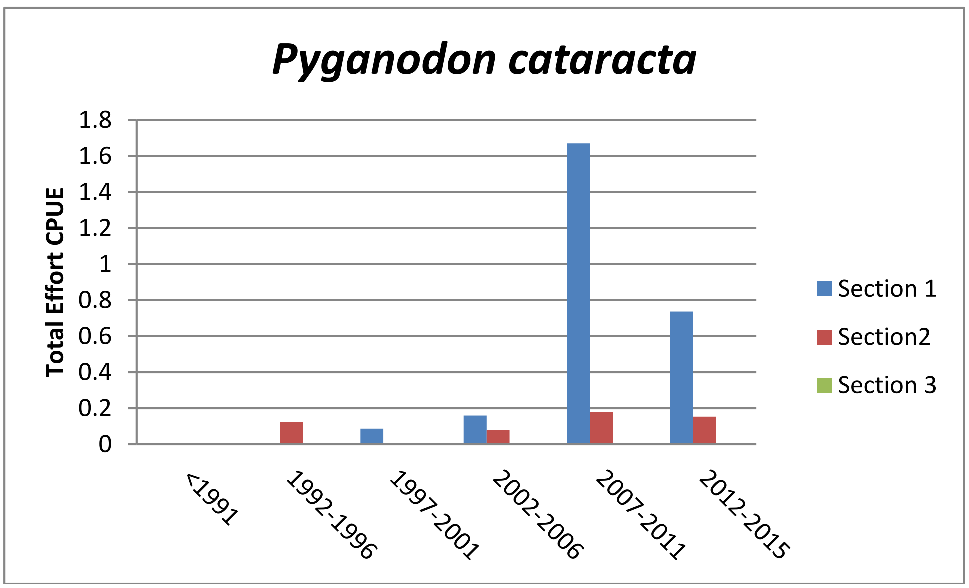


Chart 20. CPUE of Eastern Floater at all survey sites combined within each section, whether the species was detected or not



5.5.1.11. Paper Pondshell

Similar to the Eastern Floater, the Paper Pondshell is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification (Williams *et. al* 2008). This species has only been found in Section 1 and 2 of Swift Creek (Charts 21 and 22). It appears that there has been a slight increasing trend in relative abundance of this species in Swift Creek; however, this could easily be a function of sampling effort/bias rather than a reflection of abundance.

Chart 21. CPUE of Paper Pondshell only at sites where it was detected within each section

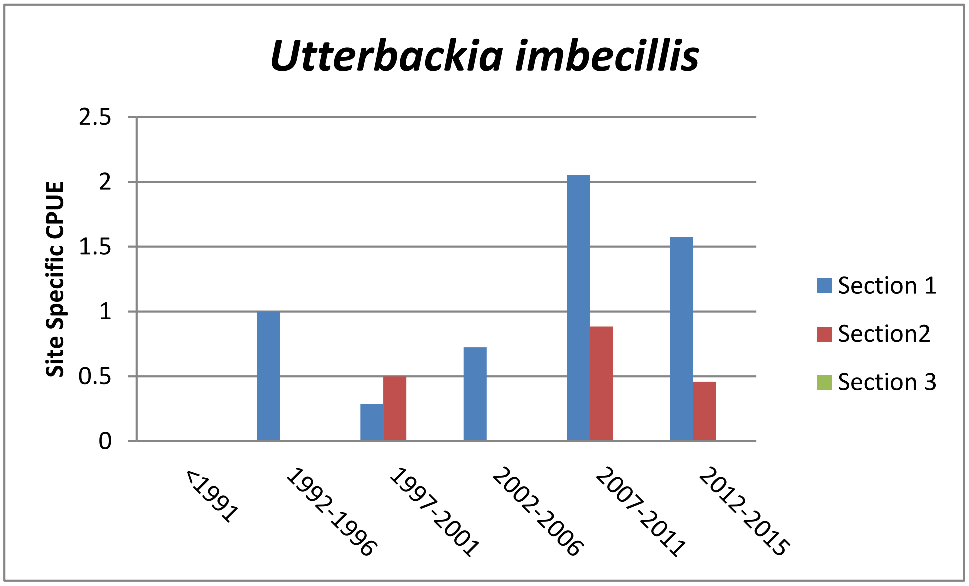
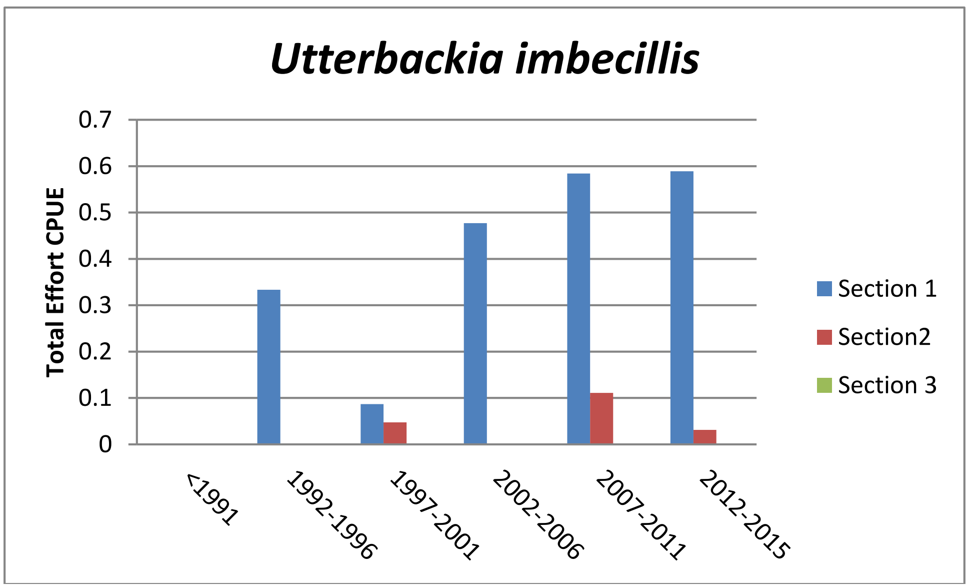


Chart 22. CPUE of Paper Pondshell at all survey sites combined within each section, whether the species was detected or not



5.6.Age Class Distribution Analysis

Healthy mussel populations are usually represented by multiple age classes, as age class diversity is an indicator of reproductive success over time (Grabarkiewicz and Gottgens 2011). Although not a perfect correlation, shell length is often used to estimate age of mussels. Size class data is readily available for sampling periods four, five and six for the following species:

- Dwarf Wedgemussel

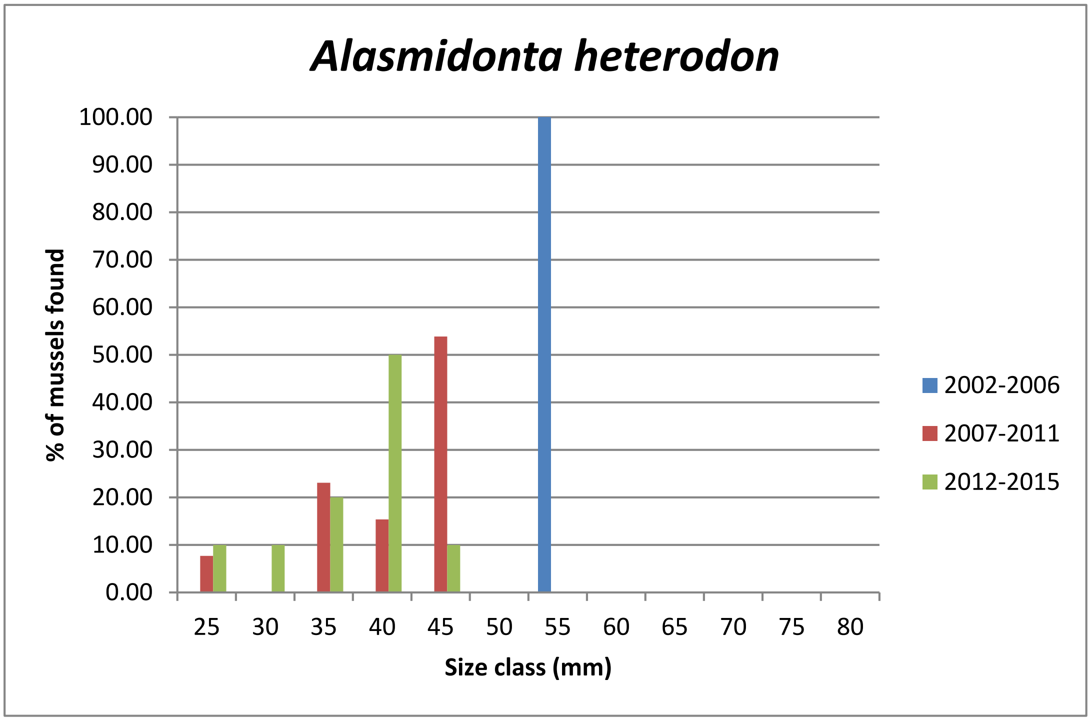
- Triangle Floater
- Yellow Lance
- Atlantic Pigtoe
- Eastern Lampmussel
- Creeper
- Notched Rainbow

This data was compiled and sorted into various size cohorts for each species. Size cohorts for each species were divided by five millimeter increments, with the exception of the Eastern Lampmussel, which was divided into 10 mm increment, as this species attains a large size and grows relatively quickly. While the size cohorts cannot be used to determine exact age of the populations, a population with multiple size cohorts is reflective of a population with multiple age classes. Some size class data also exists for these species for earlier sampling periods, but was not gathered consistently to be used in this analysis. In addition, the DWM, Yellow Lance, and Notched Rainbow were found too infrequently to make any conclusions on age class distribution over time. For example, in the 2002-2006 time period only one individual DWM and one Yellow Lance were found, and thus the population for that time period is represented by only one age class. It should also be noted that smaller individuals are more difficult to detect using the survey methodologies that produced the dataset; thus smaller (younger) size classes are more likely to be underrepresented.

5.6.1. *DWM*

There are three time periods where there is size class data readily available (2002-2006, 2007-2011, 2012-2015); however, only one individual was found during the 2002-2006 survey period, and the other two are represented by 13 and 10 individuals, respectively. Given the small dataset, it is not possible to decipher any trends overtime. Although represented by very few individuals, multiple size classes were observed in the last two sampling periods (Chart 23).

Chart 23. Size Class Distribution of Dwarf Wedgemussel



While determining the exact age of an individual mussel in the field is difficult, age can be estimated by size (total length) and growth rests. Michaelson (1995) determined the age of 43 DWM from the upper Tar River in North Carolina, and then evaluated the range in shell size for each age group (Table 11). For example, 75 % of the individuals in the 13.0-16.9 mm size class were one year old, and 25% were two years old. Aging individuals greater than 37 mm and 6 years old is difficult, as growth rates decline as individuals age (Michaelson 1995).

Table 11. Percent Composition in Age Groups (yr) adapted from Michaelson (1995)

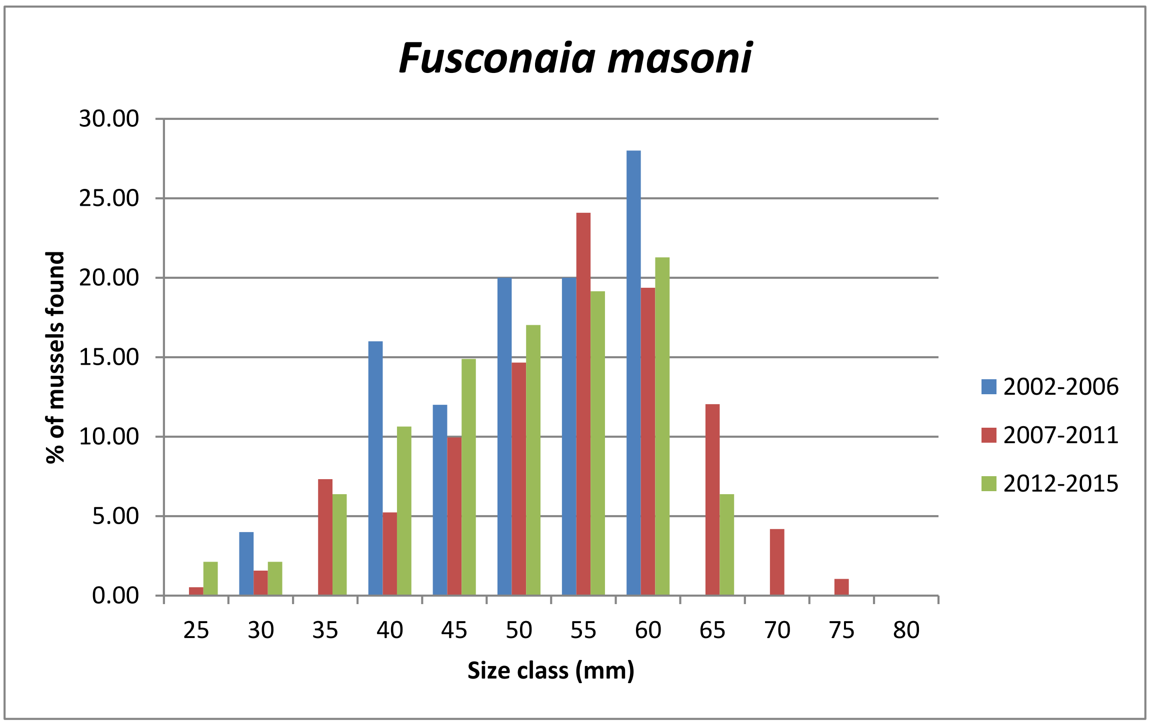
Length (mm)	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	> 6 yr
9.0-12.9	80	20	~	~	~	~	~
13-.0-16.9	75	25	~	~	~	~	~
17.0-20.9	~	100	~	~	~	~	~
21.0-24.9	~	22	78	~	~	~	~
25.0-28.9	~	~	27	64	9	~	~
29.0-32.9	~	~	~	20	60	20	~
33.0-36.9	~	~	~	~	~	100	~
N =	7	12	10	8	4	2	0

Using these age percentages for size classes, the DWM found in Swift Creek during the most recent sampling period (2012-2015) likely represent at least four age classes, including relatively young (3-4 year old) individuals (Table 11).

5.6.2. *Atlantic Pigtoe*

Comparison of size class distribution for Atlantic Pigtoe for the three time periods indicate that smaller size classes represent a higher percentage of the population in the two most recent sampling periods compared to the first one, suggesting multiple age classes with recent recruitment. If in fact the level of recruitment has increased during the last two time periods an increasing trend in relative abundance would be expected. However, the CPUE was fairly similar between these three time periods (Chart 2, Section 5.5.1.2), thus it is unclear if the rise in smaller size class individuals will result in increased population numbers.

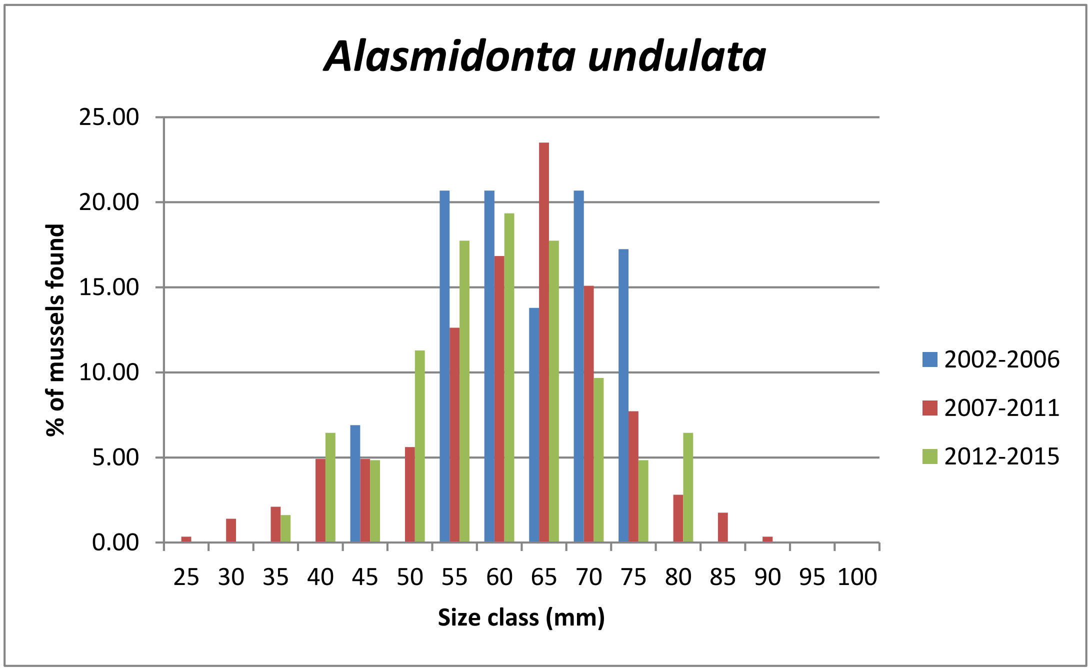
Chart 24. Size Class Distribution of Atlantic Pigtoe



5.6.3. *Triangle Floater*

Like with the Atlantic Pigtoe, similar trends are apparent in that the population is currently represented by multiple size classes and higher percentage of smaller ($\leq$ 50 mm) individuals were found in the second and third sampling period compared to the first (Chart 14), also suggesting multiple age classes with recent recruitment.

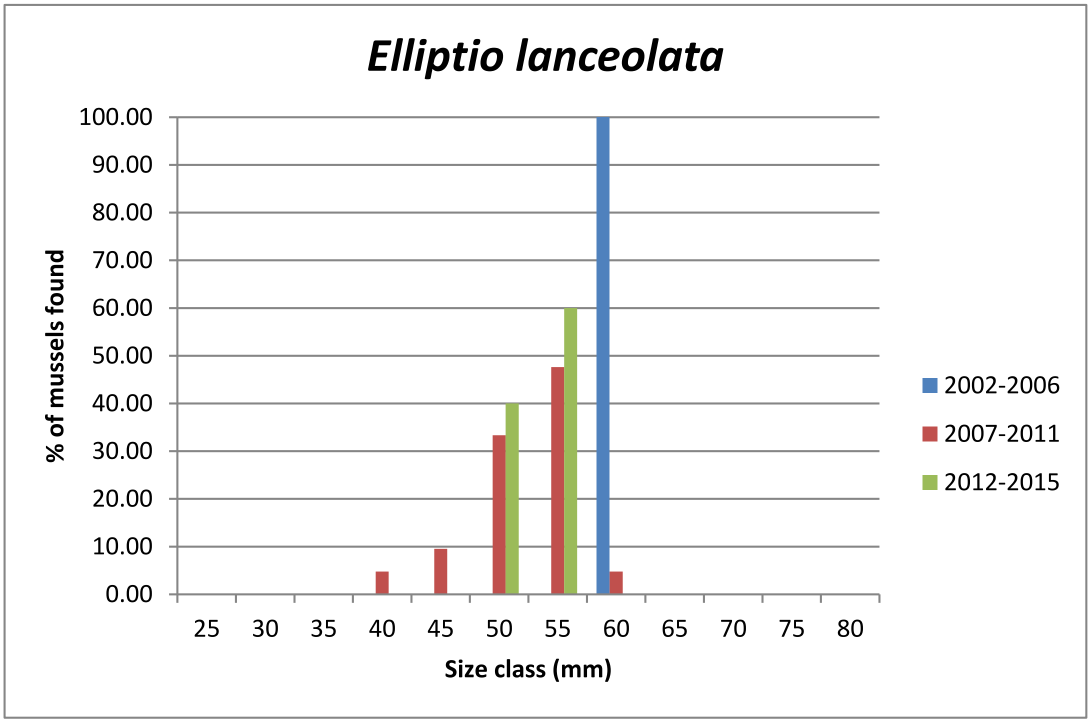
Chart 25. Size Class Distribution of Triangle Floater



5.6.4. *Yellow Lance*

While there are a number of size classes present, the Yellow Lance population is represented by very few individuals (one in the 2002-2006 period), thus it is difficult to make any conclusions regarding age class distribution (Chart 15).

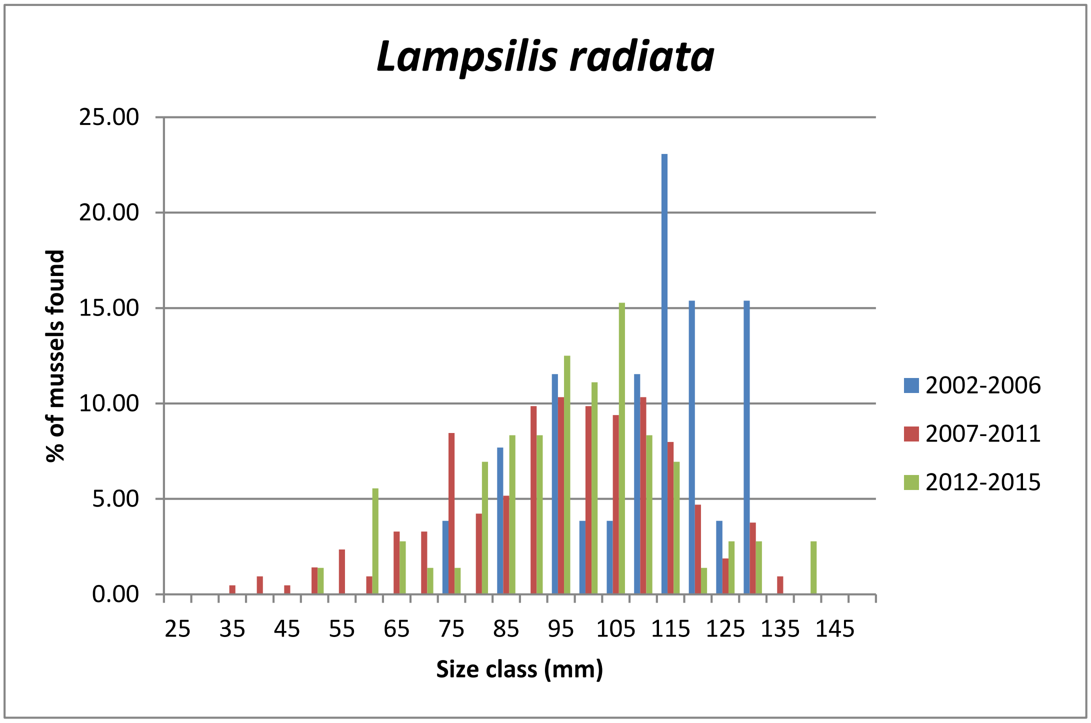
Chart 26. Size Class Distribution of Yellow Lance



5.6.5. *Eastern Lampmussel*

The Eastern Lampmussel population appeared to be represented by a higher number of large (older) individuals in the 2002-2006 period compared with the following two periods (Chart 16), again suggesting a trend towards a population with a more even distribution of age classes with indication of recent recruitment.

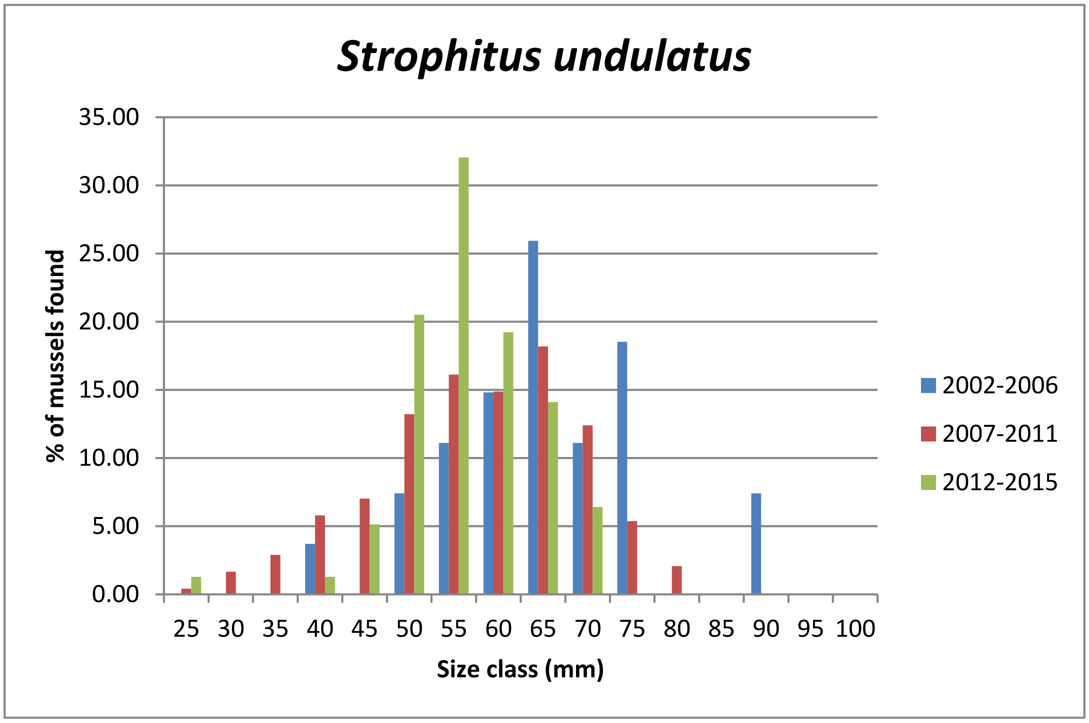
Chart 27. Size Class Distribution of Eastern Lampmussel



5.6.6. *Creeper*

Like the Eastern Lampmussel, the Creeper population appeared to be represented by a higher number of large (older) individuals in the 2002-2006 period compared with the following two periods (Chart 17), again suggesting trend towards a population with a more even distribution of age classes with indication of recent recruitment.

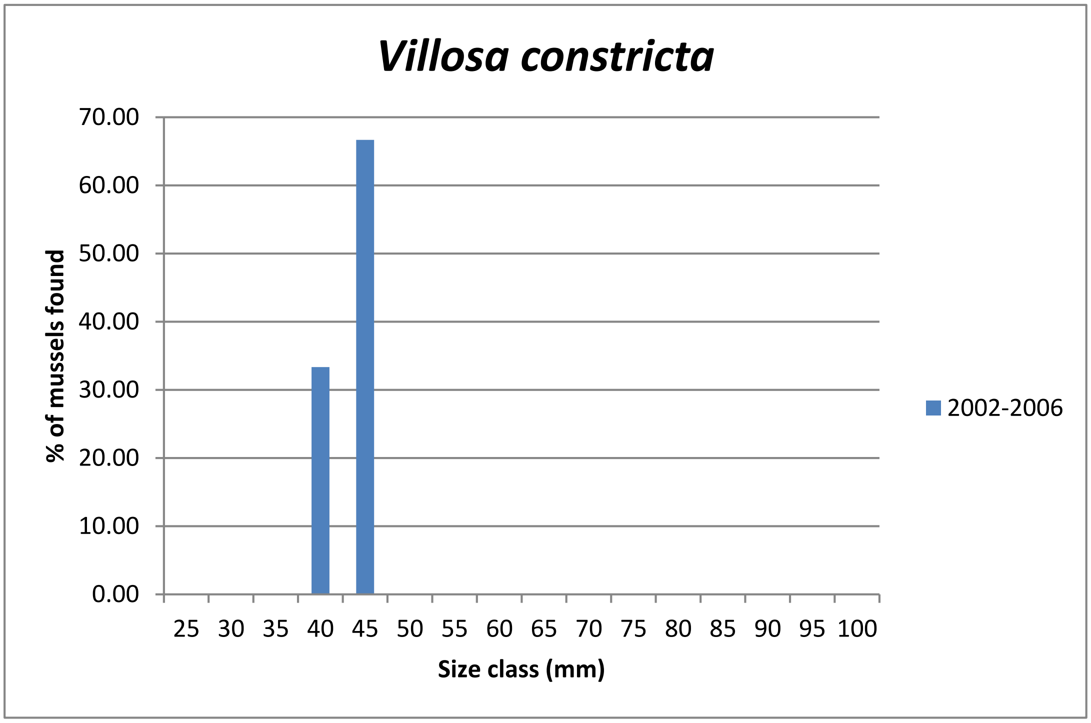
Chart 28. Size Class Distribution of Creeper



5.6.7. *Notched Rainbow*

The Notched Rainbow population is represented by only three individuals, and only within one time period (Chart 18), thus it is difficult to make any conclusions regarding age class distribution.

Chart 29. Size Class Distribution of Notched Rainbow



5.7. Mussel Detection Probability Analysis

One concern with making population trend conclusions for cryptic species like freshwater mussels is their inherent difficulty of being detected. The ability to detect a particular species during a mussel survey is dependent on a variety of factors including surveyor experience, survey conditions, and survey design, as well as particular biological traits of the particular species, including size, habitat preferences, and behavioral attributes such as vertical (burrowing up and down in the substrate), and horizontal (moving across the substrate) movement. Larger sized species such as the Elliptio mussels are typically easier to detect than very small species like the DWM. Detectability is further compounded for the DWM, as Deep Stream Margin Roots, one of the in-stream microhabitats identified as primarily supporting this species in Swift Creek (Entrix 2005), are very difficult to sample. As such, population size estimates for species that are difficult to detect may be underestimated because of this attribute.

Understanding the detection probability for a species is crucial in determining population size and viability. As discussed in Section 5.3, the DWM has consistently been detected in Swift Creek in low numbers since 1991. The fact that the species has persisted in the creek for well over 20 years, despite relatively few individuals ever being recorded, coupled with evidence of reproduction (presence of gravid individuals) and recruitment (small size classes present), there is a potential that the DWM has been under-detected in Swift Creek.

To account for the imperfect detection of the DWM and other mussel species, a sampling design was developed and implemented in 2012 where mussel surveys were conducted at nine sites: three currently occupied sites, three formerly occupied sites and three randomly selected sites. Each site was then re-surveyed in the same season using similar methodologies and under similar conditions. The results of these surveys are provided in Appendix H.

Detection probabilities for each species occurring at the nine sites were then developed using the statistical program PRESENCE version 5.9 (Hines 2006). PRESENCE is software that has been developed primarily to fit occupancy models to detection/non-detection data. Two models were evaluated for 13 different mussel species:

- Group 1: constant P: species at all sites/samples are detected with a single probability, P
- Group 2: survey-specific P: survey-specific detection probability at all sites, P(1)=detection probability for 1st survey, P(2)=detection probability for 2nd survey, etc.

The results of this analysis demonstrate the varying levels of detection between species. For instance, with both models the probability that *Elliptio complanata* and *E. icterina* occur at a site is 100%, with 100% detection probability. The Yellow Lance (*E. lanceolata*) on the other hand has a high detection probability (100% with both models) as well; however, there is a low probability (11% both models) that it is present. Whereas with the DWM, the probability that it occurs at a site is 44% with a 50% detection probability with one model, and a 33% presence probability with a range of detection probability from 33% to 100% with the second model. The occupancy and detection probabilities for each species are shown in Table 12.

Table 12. Detection Probabilities by Species

Species	Group 1: Constant P Psi *	Group 1: P** site 1	Group 1: P** site 2	Group 2: Survey Specific P Psi *	Group 2: P** site 1	Group 2: P** site 2
A. heterodon	0.4444	0.5000	0.5000	0.3333	1.0000	0.3333
A. undulata	0.6944	0.8000	0.8000	0.6667	1.0000	0.6667
E. complanata	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
E. congarea	0.9389	0.7692	0.7692	0.8889	1.0000	0.6250
E. icterina	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
E. lanceolata	0.1111	1.0000	1.0000	0.1111	1.0000	1.0000
E. roanokensis	1.0000	0.5000	0.5000	1.0000	0.5556	0.4444
E. sp cf mediocris	0.9259	0.6000	0.6000	0.9259	0.6000	0.6000
E. sp cf producta	1.0000	0.1111	0.1111	1.0000	0.1111	0.1111
F. masoni	0.8000	0.8333	0.8333	0.8000	0.8333	0.8333
L. radiate	0.9074	0.8571	0.8571	0.9074	0.8571	0.8571
P. cataracta	0.4444	0.5000	0.5000	0.3333	1.0000	0.3333
S. undulatus	0.9074	0.8571	0.8571	0.8889	0.75000	1.0000

* Psi = probability that species is present, ** P = probability that species will be detected

A larger number of sampling locations, with surveys conducted over multiple seasons would likely result in more precise detection probabilities for each species; however, this component of the study was not continued into the Phase 2 portion of the study, as the objective was met to demonstrate that the DWM has a relatively low detection rate and may often go undetected during a one-time survey.

5.8. Population Trends Summary

With the exception of the Eastern Floater and Paper Pondshell, which are considered tolerant of habitat degradation, the relative abundance (CPUE) of all other mussel species in Swift Creek has declined since the mid 1990's. As discussed in Section 5.1, there are imperfections with the Swift Creek mussel survey dataset in that it does not account for variables such as surveyor experience, survey design, survey effort, survey conditions and seasonal variations, all of which factor into the effectiveness of a survey. Additionally, as shown in Table 10 in Section 5.5.1, there has been a disproportionately greater amount of survey time spent in Swift Creek in the last three sampling periods compared with the previous three.

While these inherent flaws undoubtedly contribute to some of the differences in relative abundances over time, it is apparent that population levels have declined to some degree. Variability in survey methodologies may be more important in explaining CPUE differences of small sized species, which in Swift Creek tend to also be rare. The variability is less likely to be a factor when evaluating trends with larger sized species like the Elliptio mussels which, as shown in Table 12 have a high detection probability (100%), and also tend be habitat generalists. While still very common in Swift Creek, the measure of relative abundance (CPUE) of Elliptio mussels declined dramatically since the 1990's. This decline continued into the early 2000's, but seems to have leveled off in recent years.

Another species that is in obvious decline in Swift Creek is the Yellow Lance. While never abundant in Swift Creek, a Site Specific CPUE of greater than 12 /hr was recorded in Section 2 in the 1992-1996 time period. The CPUE has been < 0.5/hr in the last three sampling periods. Given the fact that the species has a high (100%) detection probability (Table 12), the current low CPUE can be attributed to increasing rarity. This is further supported by the low occupancy probability (11%) shown in Table 12. Additionally, it was not found during the 2015 surveys conducted for this study and has yet to be found during the on-going surveys being conducted for the Dempsey Benton project, suggesting the species is very near extirpation from Swift Creek.

The detection probability analysis suggests that DWM may be under detected in Swift Creek. While this may be true, it is still one of the rarest species occurring in the stream, which is reflected in the very low CPUE.

It is apparent that overall mussel populations have declined in Swift Creek over the 24 year period; however, the decline appears to have leveled off. Additionally, there are some indications of positive trends in the most recent years, particularly with some of the "sensitive" species, including Atlantic Pigtoe, Triangle Floater, Eastern Lampmussel, and Creeper. The CPUE for these species were very similar between the last three sampling periods, indicating the decline has subsided. Additionally, based on size class analysis the populations of these species seem to be represented by a greater level of size class distribution in the two most recent sampling periods compared to the previous one. This suggests recent recruitment, which if it continues will likely correlate to increased CPUE, as individuals grow and become more easily detected. A longer dataset with regards to size class is needed to determine if this is an actual trend.

As alluded to in Section 4.3 it is unclear if the various conservation/protection measures that have been implemented in the SCW have been in place for a long enough period of time to determine if they are having a positive effect on the freshwater mussel populations. It has been reported that recovery of mussel populations into areas where they have been eliminated can take many years to occur if it occurs at all (Waters 2000, Sietman et al. 2001). However, in most of these cases it appeared the lack of sufficient mussel refugia to serve as a seed source to allow for re-colonization is what inhibited re-colonization. Given the slow nature of mussel population recovery, it is possible that mussel populations are slow to respond to improving conditions. Fraley and Simmons (2004) reported a slow but steady range expansion of the Appalachian Elktoe (*Alasmidonta raveneliana*) another federally listed mussel species in the Nolichucky River system and suggested it was in response to improving water quality conditions associated with the enactment of the Clean Water Act in 1972.

6.0 IN-STREAM HABITAT VIABILITY IN SWIFT CREEK

The NC DWM Work Group identified "unsuitable physical habitat" as the most important threat to the Swift Creek population (Smith et al. 2014). Thus, the continued persistence of the DWM in Swift Creek will be largely dependent on the suitability of future habitat conditions. To evaluate this, various habitat parameters including water quantity, channel stability, and substrate composition were considered.

6.1. Stream Flow (Hydrograph Analysis)

The effects of extended drought on freshwater mussels were discussed in Section 2.3.4. As part of this component of the study, stream flow data from two USGS gauging stations were analyzed over the entire period of record to assess current and historic water quantity conditions (Figure 5). Only one gauging station currently exists on Swift Creek below Lake Benson that records discharge. It is at SR 1555 near Clayton (208773375) and has been in operation from 2008 to the present. There is a gauge on Middle Creek (02088000) at NC-50 near Clayton that has discharge records from 1939 to present. Though Middle Creek is not within the Lower SCW, the two watersheds are directly adjacent to one another and contribute to the larger Swift Creek watershed. Therefore, the gauge on Middle Creek is used here as a surrogate indicator for long term hydrograph data of the SCW.

Two drought indicator thresholds were evaluated;

1. More than one consecutive day at or below 1 cfs
2. More than one consecutive day at or below 5 cfs

For each gauge, the number of times (periods) either of the above two drought indicator thresholds was met, it was noted in Table 13 (see Appendix G for complete data table). For example in the 1980-1989 time period at the Middle Creek gauge, there were 20 different times (periods) when the flow was at or below 1 cfs for more than one consecutive day, with a total of 224 days below 1 cfs.

The data from the Swift Creek SR 1555 gauge demonstrates that the stream has experienced periodic episodes of low flow throughout the period of record. However, the relatively short period of record does not allow for extensive analysis of flow conditions in the lower portion of Swift Creek. The data from Middle Creek is much more extensive. The Lower SCW and Middle Creek watersheds can be assumed to have similar precipitation levels and land use, as headwaters of both streams are within the jurisdictions of Raleigh suburban towns, such as Apex, Cary and Garner. Middle Creek has also experienced periodic episodes of low flow, and sometimes extremely low flows, the most notable occurring in the summers of 1954 and 1986, which lasted more than 35 days.

Table 13. Periods of Extreme Low Flows: Swift Creek and Middle Creek

	Swift Creek at SR 1555 near Clayton (208773375)		Middle Creek at NC-50 near Clayton (02088000)	
	Number of Periods of Threshold Events (Total Number of Days)		Number of Periods of Threshold Events (Total Number of Days)	
Year Range	**at or Below 1cfs**	**at or Below 5cfs**	**at or Below 1cfs**	**at or Below 5cfs**
1940-1949	~	~	0	16 (93)
1950-1959	~	~	4 (55)	22 (251)
1960-1969	~	~	2 (27)	3 (90)
1970-1979	~	~	2 (26)	28 (222)
1980-1989	~	~	20 (224)	54 (696)
1990-1999	~	~	1 (3)	6 (41)
2000-2009	0	1 (4)	0	1 (1)
2010-2013	0	5 (14)	0	0
2014-2015	0	0	0	0

~ - Gauge was installed in 2009 – no previous data available

While there was also a gauge in the Lower SCW at NC-42 that operated between 1988 and 1997; unlike the other gauges, which collected the average daily flow rates, the NC 42 gauge only collected a single flow measurement during 28 different days during the eight year period. As such, this dataset is too limited to be used in this analysis.

6.1.1. *Stream Flow Summary*

As discussed in Section 2.3.4.3, the geology of the SCW makes it inherently susceptible to extended low flow periods, particularly in the upper portions. The stream flow data confirms the propensity for extended periods of low flow. The fact that the Swift Creek gauge had 14 days of consistently low flows in just the last four years suggests that Swift Creek has not had as consistent flows as Middle Creek, as no drought indicator thresholds were reached at the Middle Creek gauge during the last four years..

The tiered minimum flow releases guaranteed from Lake Benson provide a level of protection against extreme low flows that did not exist previously. Further analysis is needed to understand if these minimum flow guarantees are sufficient to maintain the DWM population.

6.2.Current and Historic Channel Stability

Aerial photos of the Study Area were obtained from NCDOT's Photogrammetry Unit, and analyzed to determine general channel course stability and adjacent land use during the time period available (1969 to 2010). It is important to note that complete aerial coverage of the Study Area is not available for any given year. The same three sections used in the viability component of this study were used here (Figure 12):

- Section 1 – Lake Benson to I-40

- Section 2 – I-40 to Barber Mill
- Section 3 – Barber Mill to Neuse River.

During the time period analyzed, there was no major channel migration observed. However, below the NC 42 crossing, the main channel is braided into two distinct smaller channels (east and west). According to the landowner, prior to the early 1990's the west channel carried the majority of flow, and the east channel had flow only during high flow periods (Henry Ford landowner, personal communication). Since that time, the majority of flow has been concentrated in the east channel, and the west channel consists of stagnant, deep scour pools, and very shallow sand bar dominated areas with very little flow. This is further supported by mussel survey data from that time period. In fact, the DWM was recorded at a site in the west channel in 1994; however, it was not located in 2011 or 2012 and, based on current habitat conditions (stagnant pool), that site is no longer considered to be occupied. There is a buried gas line with a ford crossing made of cinderblocks on the east channel that is significantly perched to a point that is likely a barrier to upstream migration of fish (Photo 3).

Photo 2. Perched Utility Crossing in East Braid of Swift Creek below NC 42

Examination of the aerial photography also provides a visual depiction of the conversion of land use that occurred within the Study Area in recent years. Some of the major land conversion events are noted for each of the sections.

Section 1: Between 1971 and 1986, sections of the I-40 corridor were cleared of vegetation. Between 1971 and 1991, square retention ponds off Wren Road were constructed as were the spray fields near New Bethel Church Road. Between 1986 and 1991 the Indian Creek Overlook neighborhood, which had a small domestic WWTP (recently decommissioned), was built. Between 1997 and 2010 the Southern Trace Neighborhood was built near the NC-50 and Benson Road intersection, southeast of the Ten-Ten Road intersection.

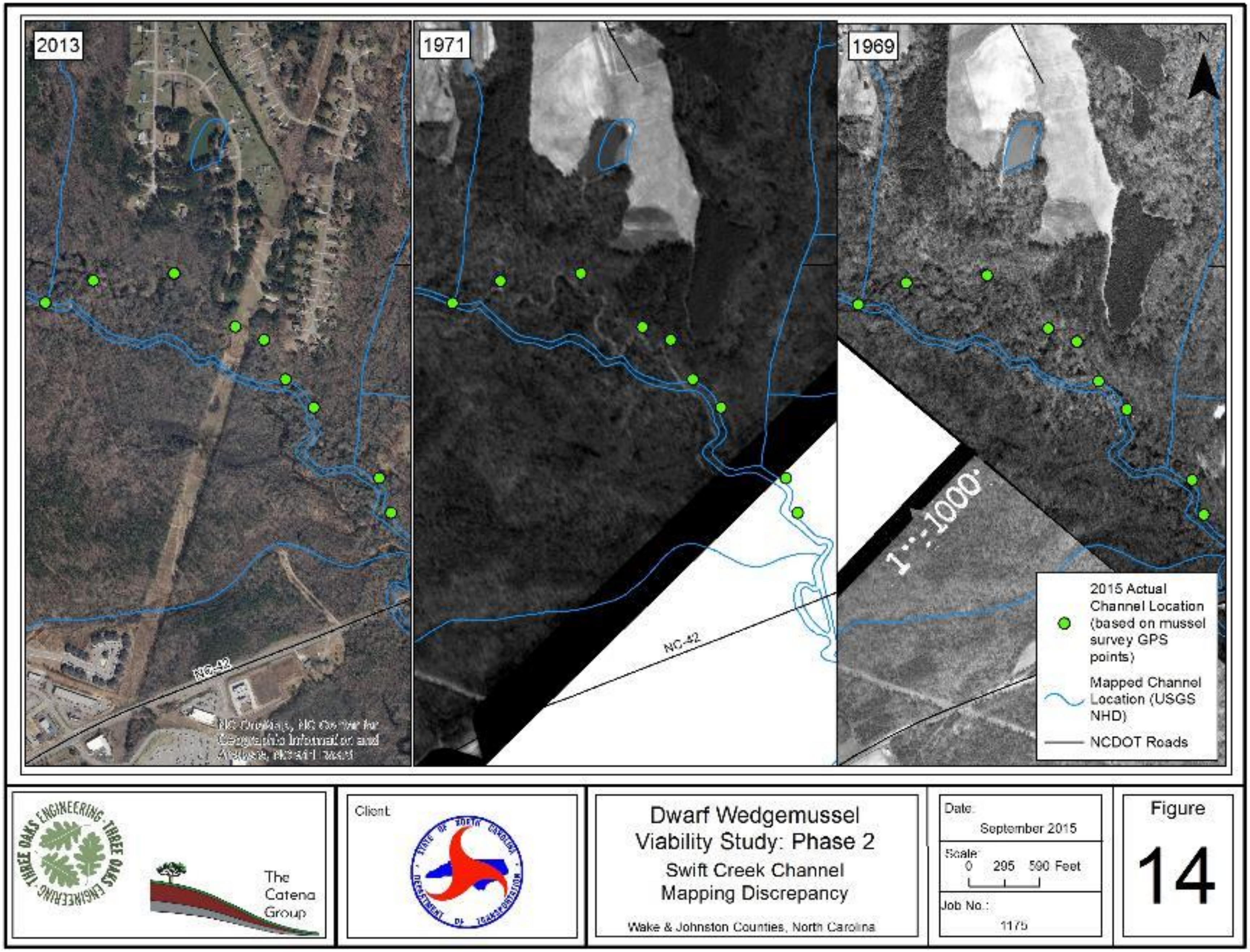
Section 2: In 1985, construction of the I-40/NC-42 intersection had begun and was completed by 1991. Between 1985 and 1997, an increase in development of the I-40/NC-42 interchange was evident (Photo 3). Between 1997 and 2010, a bigger pond was added at the end of Zachary Way (SR 2060), which is west of Cornwallis Road and south of Swift Creek. There was also a new area of houses on Cornwallis Road opposite of this pond site, and south of Swift Creek off Josephine Road (SR 1526).

Photo 3. I-40/NC 42 interchange: 1985 on the left and 2012 on the right.

Section 3: Between 1969 and 1991 the Johnston County Airport was constructed. Also during that time, a new area of houses was constructed at Norris Road and Sterling Drive, which is north of Swift Creek. Between 1991 and 1994, the Johnston County Airport runway was expanded. Between 1994 and 2010, there were several developments in this section. A new area of houses was constructed south of Swift Creek at Cleveland Road (SR 1010) and Wood Creek Lane near Monroe Road (SR 1513). A new pond was constructed at the end of Casey Road northeast of Swift Creek near the intersection of Little Church Road (SR 1563). Lastly, a new area of houses was built at Clayton Pointe Drive (SR 3174) and Rock Pillar Road (SR 1572).

6.2.1. *Channel Stability Summary*

While there is no definitive evidence that large scale channel migration and instability has occurred in the Study Area, an error in the USGS 7.5 minute topographic map depicting the Swift Creek channel was discovered. An approximately 0.5 mile stretch of Swift Creek above NC 42 is incorrectly mapped on the USGS map. At the furthest point the actual channel is close to 600 feet to the north of where it was mapped. A power line crossing that was put in sometime between 1971 and 1986 occurs right in the middle of this section. When this discrepancy was discovered it was speculated that the channel was relocated during the construction of the power line. However, examination of aerial photographs does not support this. Figure 14 clearly shows that in 1969 and 1971 the channel was basically in the location where it currently is. The Johnston County Soils Survey published in 1994 also depicts the channel it its current location (USDA 1994). The USGS map was created in 1973; however, it is unclear when the data used to create the map were generated; thus it is possible that the channel had migrated to the north


2013
1971
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N
NC-42
NC-42
1":1000'
NC Orthoimagery, NC Center for Geographic Information and Analysis, NCSIRI based
2015 Actual Channel Location (based on mussel survey GPS points)
Mapped Channel Location (USGS NHD)
NCDOT Roads
The Catena Group
Client:
Dwarf Wedgemussel Viability Study: Phase 2
Swift Creek Channel Mapping Discrepancy
Wake & Johnston Counties, North Carolina
Date:
September 2015
Scale:
0 295 590 Feet
Job No.:
1175
Figure
14

sometime before 1969. It is very unlikely that the channel was intentionally moved, as channel relocation practices during this time frame generally did not incorporate the level of sinuosity that the existing channel contains. This error was reported to USGS the National Hydrography Dataset (NHD) Partner Support Regional Point of Contact.

There is some indication that smaller scale channel migration may have occurred. These small scale changes would not be evident using aerial photography. However, the aerial photo analysis clearly demonstrates the urbanization of the Lower SCW. The effects of urbanization on in-stream channel stability are described in Section 2.3.4.

6.3.In-stream DWM Habitat Assessment Analysis

Throughout its range, the DWM has been reported from a wide variety of habitats (from small streams to large rivers) and substrates (sand and gravel to muddy sand and clay) (USFWS 1993). Two general in-stream habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). As part of the Phase I Study, a Habitat Assessment within Swift Creek was performed to further understand the habitat requirements of DWM in Swift Creek. The geomorphology analysis component addressed then current habitat conditions in Swift Creek and its ability to continue to support the DWM. The habitat assessment was performed at nine sites within Swift Creek in 2012: three sites previously occupied (PO) by DWM, three sites considered currently occupied (CO) at that time, and three randomly selected (RS) sites (two of which supported DWM). Various habitat attributes were evaluated and quantified in the first phase of this study (Phase 1) and preliminary conclusions were drawn on what physical attributes are important habitat components for DWM in Swift Creek (Catena 2013). The results revealed a correlation in DWM presence and substrate particle size.

This analysis was expanded for the second phase of this study (Phase 2). The nine original sites were resurveyed, and nine additional sites were selected to be considered as potential augmentation (PA) sites based on the habitat attribute results of the Phase 1 habitat analysis. The nine PA sites were established mostly in an approximately 11 mile stretch of Swift Creek from Cornwallis Road to Steel Bridge Road.

Mussel and habitat surveys were conducted in 2015 within a 200 foot section at all 18 sites (PO, CO, RS, and PA). The assessment consisted of timed mussel surveys, stream cross sectional profiles, particle size distribution analyses, bank erosion hazard index (BEHI) analysis, streambed scour analysis, and qualitative analyses accompanied by photo documentation for each site. The report, Complete 540 – Triangle Expressway Dwarf Wedgemussel Habitat Assessment Survey Report – Phase 2 (Three Oaks Engineering/Catena 2015c), is Appended (I).

6.3.1. *Geomorphology Study Results*

Throughout all of the survey sites, Swift Creek is a low gradient, meandering, point-bar, riffle/pool dominated stream type that has alluvial channels within broad well defined floodplains. The CO sites are located between NC 42 and Barber Mill Road (SR 1555) while the PO sites are located from just above the Wake/Johnston County line downstream to approximately 0.3 mile below NC 42. The PA sites were established downstream of the CO and PO sites, with the exception of PA-9, which is located upstream of all of the CO and RS sites except one CO-1 (Figure 1 in Three Oaks Engineering/Catena 2015c (Appendix J)). The drainage area, wetted width, bankfull width, bankfull width/depth ratio, and bankfull cross sectional area are generally greater in the CO sites and PA sites than in the PO sites.

6.3.1.1 CO Sites

As was the case for the CO sites during Phase 1, mussel survey results from Phase 2 yielded some of the higher catch per unit efforts (CPUE) from these sites (53.7-116.0 mussels/hr) as well as species diversity ranging from 6-8 species per site. However, when comparing the results of the Phase 2 mussel surveys with those conducted for Phase 1, CPUE and species diversity were generally lower than mussel survey results from Phase 1 (Table 2 and Table 3 in Three Oaks Engineering/Catena 2015c (Appendix J)).

The habitat conditions at these sites have generally degraded since the Phase 1 surveys were conducted. CO-1 in particular, where mussel abundance and diversity was most notably reduced since Phase 1, is higher in the watershed and close to the development near the intersection of I-40 and NC-42. The major causes of change in habitat conditions at the CO-1 site appear to be associated with bank failure and a large tree that has fallen into the channel. As a result, there has been an increase in ponded areas, increased bank erosion, and the creation of a detritus/woody debris trap over the exact locations where DWM individuals had been found in previous years. DWM was not found at this site during the 2015 surveys. Two different DWM individuals were found at the CO-2 site, one while during surveys associated with this project, and the other while surveying for the Dempsey Benton project.

6.3.1.2 PO Sites

These sites consist of a deeper run/pool complex with a dominant shifting sand substrate. The channel banks are unstable and steep in areas throughout these reaches. Further indicators of an unstable channel, such as excess woody debris and detritus and mid-channel bar formations, were also evident. DWM was previously known from these locations, but has not been observed in several years during subsequent surveys. While habitat attributes were not quantitatively measured during the previous surveys when the DWM was recorded at each of these three sites, in each instance they were described as riffle/run habitats with heterogeneous substrate consisting of sand, pea gravel, gravel and rock, with minor bank erosion (NCWRC 2015). Streambank substrate is dominated by clay with some silt accumulations. Mussel survey results from 2015 yielded a CPUE of 33, 90.4, and 49.8 mussels/hr for Sites PO-1, PO-2, and PO-3 respectively. PO-1 had a low diversity with a total of only three species. PO-2 and PO-3 had a diversity of six and four species, respectively.

Evidence of sedimentation was observed at site PO-2 using a scour chain. One scour chain was established within the thalweg during the initial site visit on November 11, 2014. During the second cross-sectional survey conducted on February 6, 2015, there was approximately 1.5 feet of sand deposited on top of the location of the scour chain. Attempts to recover the scour chain were futile.

6.3.1.3 RS Sites

These 3 sites were randomly selected from 15 sites that were surveyed for the first time in 2012. DWM was found at sites RS-1 and RS-3 in 2012. RS-1 is a sand dominated pool/glide complex with high amounts of large woody debris. Adjacent land use is mainly floodplain with a large wetland system that flows into the RS-1 stream reach. Water levels are deep throughout, and a single DWM was observed there in 2012. During mussel surveys from 2015, RS-1 had a CPUE of 108.2 mussels/hr with a diversity of 9 species. RS-2 is approximately 1,000 feet upstream of RS-1. This site is very similar to RS-1 with a deeper run/ pool complex containing large amounts of woody debris with pockets of detritus dominated substrate. The substrate is mainly dominated by sand with clay banks. RS-2 had a CPUE of 97.8 mussels/hr with a diversity of 6 species. RS-3 is approximately 1.4 mile downstream of RS-1. This stream reach is a run/pool complex dominated by sand with silt accumulations along the base of the clay banks. Woody debris is at low to moderate levels. Adjacent land use consists of a forested riparian buffer with a cutover forest community beyond a 200 foot buffer on both sides of the creek. RS-3 had a CPUE of 130 mussels/hr with a diversity of 6 species, the highest CPUE for any of the sites surveyed to date.

6.3.1.4 PA Sites

These sites were chosen based on the heterogeneous nature of their substrate. Most of these sites have a forested riparian zone, though some are near busy roads or residential areas. Scour chains were established at survey sites PA-2, PA-3, and PA-5. Although efforts were made to recover them, scour chains at survey sites PA-2 and PA-3 were not found. Cross sectional surveys for these sites depicted little change in the channel dimension between site visits. The scour chain installed at survey site PA-5 depicted no evidence of scour or sedimentation, which indicates habitat stability. The PA sites are trending towards a larger substrate particle size, in general. Though no DWM were found at any of the PA sites, mussel abundance and diversity were relatively high and contained some associate species of DWM (Triangle Floater, Creeper, Eastern Lampmussel, Atlantic Pigtoe and Roanoke Slabshell). Efforts were made to find PA sites in the upper portions (between NC 50 and I-40), and lower portions (between Steele Bridge Road and NC 210) of the entire study area, but few areas that were considered "potentially suitable" were found during stream reconnaissance efforts.

6.3.2. *Geomorphology Study Conclusions*

The results of this component of the study reveal a pattern of larger substrate size correlating with higher freshwater mussel CPUE and greater species diversity. Three of the five sites with recent records of DWM contained a gravel component ranging from 25-46% of the substrate within the cross section. Data for the remaining two DWM sites (RS-1 and RS-3) reflected a finer substrate composition of a clay/sand substrate for RS-1 with no gravel, while RS-3 contained 1% gravel with the remaining composed of sand and clay. As observed during the 2012 geomorphology surveys, site RS-3 had a gravel trough within the thalweg of the cross section located left of center in the channel. This gravel component was buried under silt/clay deposits during the Phase 2 surveys. Even though DWM was found in RS-1, this site is still considered an outlier in that it does not contain the same habitat attributes as the other sites that support DWM, as it is largely composed of a sand dominant pool habitat. However, there was small, stable microhabitat of stream bank that supported one young DWM (~2-3 yrs old) during the 2012 surveys. RS-2 has a gravel component of approximately 12-17%, but DWM was not found.

Sites between Barber Mill Road and Steel Bridge Road, or PA-3 through PA-8, are thought to have the best habitat for supporting DWM through augmentation. This area appears to have the most stable banks with heterogeneous substrate, along with existing mussel abundance and diversity. These sites occur within the historic 21 mile range of DWM in Swift Creek; however, DWM has never been recorded in these locales. The lack of DWM occurrences may be a function of level of survey effort, as a greater amount of effort has occurred in the upper portions of the 21 mile range. The three previously occupied sites occur within the upper portion of the DWM range in Swift Creek. A likely reason these areas are no longer occupied is due to an apparent transition to a shifting sand substrate, which is generally indicative of unstable conditions.

7.0 DWM POPULATION VIABILITY IN SWIFT CREEK

Continued analysis and studies are needed before making a definitive conclusion regarding the long term viability of the DWM within Swift Creek. The preliminary indicators of long term viability are mixed; however, the potential for this species to persist into the future in Swift Creek is highly dependent on habitat viability, which was discussed in Section 6.0. Each of the population viability criteria, as set out by the NC Scientific Council on Freshwater and Terrestrial Mollusks (Section 5.1), are discussed below, along with overall mussel population trends. The consensus of the council was that a population is considered viable if each of these criteria should be met.

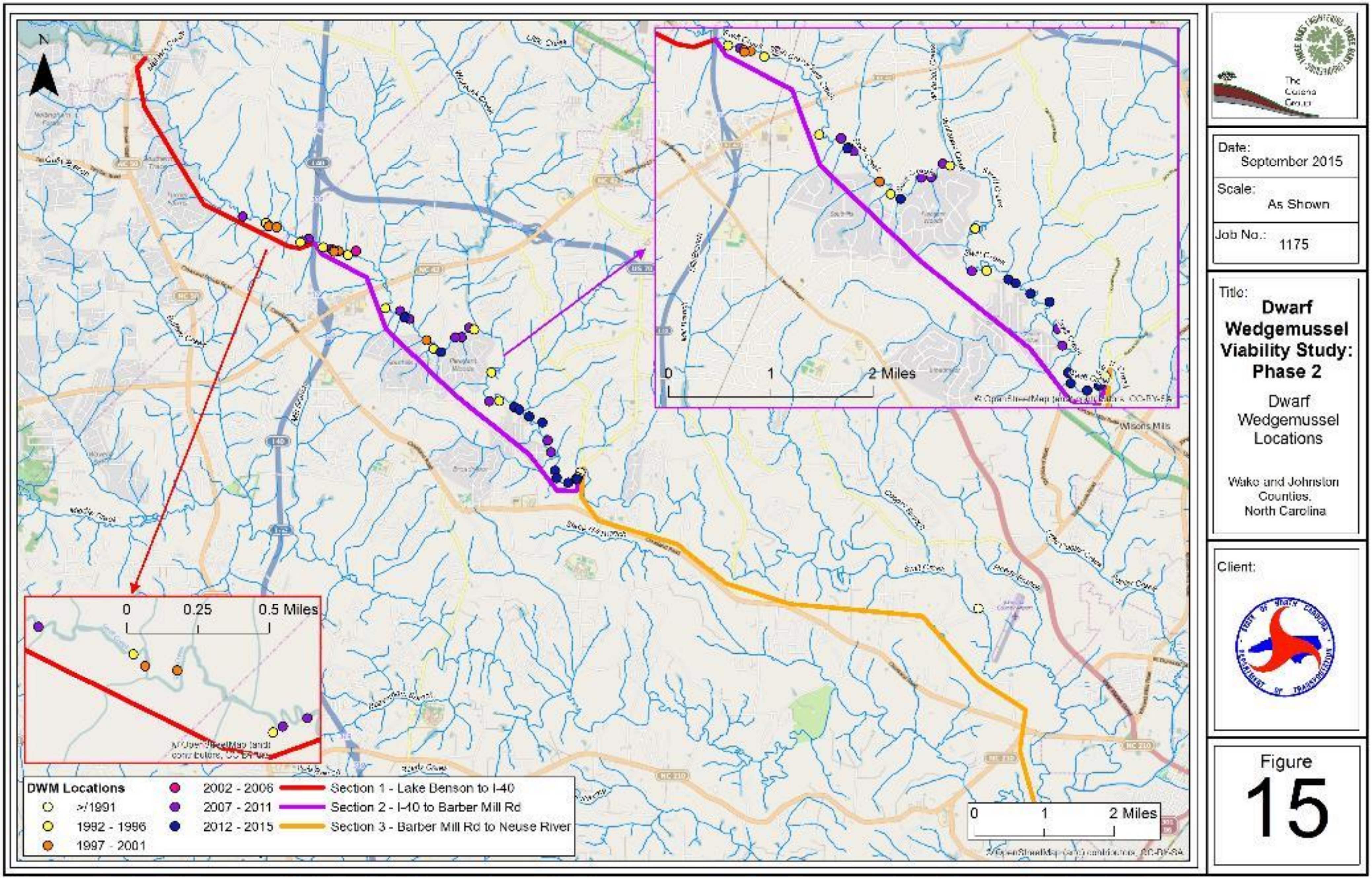
7.1. Length of Occupied Habitat Criterion

The historic range of the DWM population in the mainstem of Swift Creek has been reported to be approximately 21 miles (Figure 13). However, as mentioned in Section 6.3, the lower 10 miles of this range are represented by only one individual found in 1991. Considering the occurrences of DWM in the tributaries White Oak Creek, Little Creek, and Middle Creek, and the fact that there are no known physical barriers that would limit connectivity (thus creating > two miles of unoccupied habitat), the assumed historic occupied habitat would be approximately 53.7 miles. This 53.7 miles was derived by adding the historic 21 mile range in Swift Creek to the combined distances of the most upstream DWM records in the respective tributaries to the respective confluences with Swift Creek (0.2 mile in White Oak Creek, 2.0 miles in Little Creek and 25.0 miles in Middle Creek), plus an additional 5.5 miles of Swift Creek from the most downstream historic occurrence to the confluence of Middle Creek.

There is however, no survey data to support the 53.7 mile range, and using a two mile distance of un-occupied habitat as a distance to separate populations, it is possible that the 53.7 mile range represents a metapopulation, comprised of a number of smaller local populations. If this is the case, the Little Creek, Middle Creek and the lower 10 miles of Swift Creek are three local populations, of which the latter two appear to have been extirpated.

The survey efforts of 2007, 2010, 2011, and 2012 established a then current occupied range of at least 11 miles (Figure 13) in Swift Creek, with no gaps of unoccupied habitat greater than two miles. Whether that indicates a reduction in range of 10 miles of a population, or whether two distinct populations occurred in Swift Creek is unclear; however the 11 mile section has consistently been occupied since 1992. Eleven miles of occupied habitat are at the lower limits of the first population criterion. The DWM has not been found since 2007 in the upper portion of the 11 mile range during subsequent surveys, and habitat degradation (unstable substrate and stream banks) in this general portion of Swift Creek is evident. There also appears to be a tendency for the more recent findings of DWM to be clustered in the lower portion of the range (Figure 15). Though it may be premature to assume that the DWM no longer occurs in this portion of Swift Creek, the evidence suggests a declining range.

While the species was not found in Little Creek during the most recent surveys (2011), habitat conditions appear relatively stable and are similar to those observed when DWM was found in 2003, suggesting that the species may still persist in Little Creek. Based on this assumption, it is unclear if this would constitute a separate population since there are greater than two miles with no recent DWM records between the downstream limits of the current 11 mile occupied range in Swift Creek and the confluence of Little Creek, or if it would represent a dendriditic expansion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Title:
Dwarf Wedgemussel Viability Study: Phase 2
Dwarf Wedgemussel Locations
Wake and Johnston Counties, North Carolina
Client:
Figure
15
DWM Locations
>/1991
1992 - 1996
1997 - 2001
2002 - 2006
2007 - 2011
2012 - 2015
Section 1 - Lake Benson to I-40
Section 2 - I-40 to Barber Mill Rd
Section 3 - Barber Mill Rd to Neuse River
0 1 2 Miles
0 0.25 0.5 Miles

of the 11 miles of occupied habitat (assuming DWM is present in the greater than 2 mile gaps). More intensive surveys at various time intervals are needed in Little Creek as well as within Swift Creek near the confluence with Little Creek to determine DWM occupancy.

7.2. Occur at 75% of Sites within Occupied Habitat Criterion

Since 2007, within the 11 miles of Swift Creek believed to be occupied, the DWM was found at 6 of 62 surveyed sites (9.67%) in 2007, 5 of 83 sites (6.02%) in 2010, 3 of 47 sites (6.38%) in 2011, 8 of 44 (18.18%) in 2012, 1 of 1 (100%) in 2013, and 1 of 18 (5.56%) in 2015. However, when considering the results of the occupancy and detection probability analysis, the predicted occupancy is much higher (44% in one model and 33% in the other model). This rate is still well below the 75% occupancy target.

7.3. CPUE > 5 Individuals per hour at 50% of Occupied Sites Criterion

The CPUE for DWM has consistently been very low since its discovery in Swift Creek, and has declined from a high of 3.5/hr in Section 2 during the 1992-1996 period, to 1.0/hr also in Section 2 during the 1997-2001 (represented though by only one individual), to <0.5/hr in the subsequent two periods in both Section 1 and Section 2. Most of the DWM site occurrences are represented by one individual. The highest number of individuals ever recorded at a site during a single survey was 4 in 1997 (2.0/hr). One of the hypotheses for the low CPUE of DWM at occupied sites was attributed to non-specific survey methods to detect all mussel species rather than specifically targeted DWM. As such, habitat specific surveys targeting DWM were performed beginning in 2011 at all of the known DWM sites in the Swift Creek watershed. The theory was that the CPUE for DWM would be higher in occupied areas applying these targeted methodologies. However, these targeted surveys failed to detect the DWM at any of the previously known sites, although it was found at three previously unknown sites, further demonstrating its rarity in Swift Creek. The reasons for not detecting this species at any of the target sites are unclear, as many of these sites still contained the microhabitats associated with DWM. In addition, numerous mussels of other species that were tagged at some sites in 2007 were recovered in the same locations in 2011, which suggests a relatively stable habitat. In 2012 however, the DWM was detected at three of the previously known sites (CO), as well as at four previously un-sampled sites. In 2015, two individuals were found on two separate occasions at one of the three CO sites (CO-2), and another individual was found on another occasion at one of the three RS (RS-2). All three of these individuals were taken to the NCWRC fish hatchery in Marion to facilitate the propagation effort (See Section 8.2).

As mentioned in Section 5.1, the viability criteria have not been tested on mussel populations in the state, but were based in the collective opinions of the Council, and applied across the board to all mussel species. As demonstrated in this study, different species have differing levels of detection, and a CPUE criterion for one species may not necessarily be applicable to another species. When considering the CPUE measure of 5/hr as an indicator of viability, not only does the DWM population in Swift Creek not meet this criteria, with the exception of the Elliptio spp. none of the other species would currently meet this criteria, and most of them would not have met it in the early sampling periods either. Therefore, the CPUE criteria may need to be adjusted as these methods are applied to various species and populations and more information becomes available.

7.4. Evidence of Recent Reproduction Criterion

Evidence of recent reproduction within a population can be determined by either finding gravid (holding progeny) individuals, and/or finding multiple size classes, including younger individuals. In the southern portion of its range, the period of gravidity reported for DWM is from November through April. However, based on previous survey data in Swift Creek the majority (78%) of DWM were collected between mid-May and October, which may suggest that at least in Swift Creek, the DWM may be more easily detected during periods when it is not gravid. It is unclear if this is a reflection of seasonal variation in detection probability, or due to a smaller number of surveys conducted during periods of gravidity.

In order to evaluate this, surveys conducted in 2011 were initially designed to be performed during the later portion of the gravidity period, more specifically late March to late April. While these months are only a portion of the period of gravidity, survey conditions (amount of daylight, water levels and temperatures etc.) would allow for maximum survey efficiency. However, due to weather patterns, all of the surveys could not be performed during this time frame, and no gravid individuals were observed. In 2012 however, two of six live individuals found were gravid. One of those individuals was observed to be gravid in early March, and then again in late November, which indicates two successful periods of reproduction, as the species releases glochidia in late spring (Michaelson 1993).

Evidence of reproduction can also be determined by the presence of young age classes. While overall numbers of DWM in Swift Creek were very low, survey efforts conducted since 2007 indicate continuing reproduction, as small (young) size-class individuals were found in each of those years. It is unclear whether this reproduction is sufficient to maintain population viability, particularly when considering the indication of declines in relative abundances of the mussel fauna over time.

7.5. Overall Mussel Population Trends

As stated throughout this report, the DWM is very rare within Swift Creek, but it has persisted in the stream for the last 24 years. This rarity, whether inherent in southern populations, or a result of population declines, makes it difficult to project future viability when there is no information on population(s) numbers prior to 1991. As such, inferences on DWM must be made from also evaluating population trends of the other species occurring in the Study Area. As summarized in Section 5.8, the indicators of future viability developed from the population trends analyses are mixed. On one hand there is a declining trend in relative abundances of nearly all species, and on the other, there is some evidence that indicates these declines have leveled off, and there is increased recruitment of younger individuals.

7.6. Viability Conclusions

The results of the various components of this study indicate that the mussel fauna of Lower SCW is subject to multiple stressors which may threaten future viability. The Notched Rainbow, Yellow Lance and DWM appear to be the most vulnerable species. While further analysis of population and habitat trends would allow for a more definitive conclusion, the results of this study point to a population that is vulnerable to extirpation. Changes in the watershed have happened in a relatively short period of time, and the overall mussel fauna appears to have declined in conjunction with these changes.

Various conservation measures and protections have been put in place, in part as a response to the rapid urbanization of the watershed. Given the small dataset for DWM (47 individuals found over a 24 year time period) it is difficult to ascertain much in the way of population trends, other than it has been consistently rare over the time of the dataset. With regards to most other species occurring in Swift Creek that are also considered "sensitive" (Atlantic Pigtoe, Creeper, Eastern Lampmussel and Triangle Floater), it appears that the population declines have leveled off in recent years (Section 5.5), and the populations are represented by multiple age classes with evidence of recent reproduction. However, two of the sensitive species, the Notched Rainbow and the Yellow Lance may have declined to a point that they are below detection level, if they haven't already been extirpated from the creek. Only a few individuals of the Notched Rainbow have ever been found in Swift Creek, thus it is difficult to make any conclusions regarding population trends; however, with regards to the Yellow Lance it is obvious that this population has declined dramatically.

In terms of habitat viability, there are a number of indicators of degradation, particularly in the upper portion of the study. For instance as discussed in Section 3.3.2.2 the bioclassification ratings for the study area portion of Swift Creek has declined to the point where a major portion of the stream (11.4 miles) has been listed as impaired since 2009. Sedimentation and erosion were identified as sources of degradation in this portion of the stream (Section 3.3.2.2). Additionally, in the upper portion of the DWM range in Swift Creek some of the sites where DWM is considered to no longer be present (PO), habitats are dominated by shifting sand, scour pools, and unstable streambanks. These sites were described as riffle/run/pool sites with a heterogeneous substrate in previous years when DWM was found (Section 6.3.1.2).

While it is apparent that habitat has been degraded in some of the study area, relatively stable areas with heterogeneous substrate still exist (6.3.1.4). It is important to point out that the Swift Creek watershed in general is a dynamic stream system where changes in the watershed have occurred. The channel dimensions, and substrate composition in any given area have been adjusting to this change, and will continue to do so until a dynamic equilibrium has been reached. The same can be said about sites near Steele Bridge Road, which are now being considered as augmentation sites. While habitat attributes were not quantified, some surveys conducted in these areas in the early to mid-1990's describe sand as being the dominant substrate as opposed to gravel, which is currently present.

It is thus apparent that habitat conditions in some areas have changed overtime within the study area. As long as areas of suitable habitat continue to be present within the stream, and there are sufficient dispersal mechanisms to facilitate recruitment, the DWM has a chance of persisting in the stream (assuming water quality is sufficient). However, the lack of long-term quantitative habitat monitoring over time makes it difficult to predict long term habitat viability from a physical standpoint. There are recently developed High Definition Stream Survey (HDSS) monitoring methodologies that allow assessment of habitat conditions over long stretches of stream channels using geo-referenced video technology, which could be used to help determine long term habitat viability. These methods will be discussed further in Section 8.0.

The water quality component of habitat viability as it pertains to DWM population viability is also somewhat nebulous. As discussed in Section 3.6, copper may be a source of habitat degradation that could affect long term viability, as four of the 24 water quality samples collected during this study had copper levels that exceeded North Carolina water quality standard. These exceedances occurred during periods of low flow (Section 3.6.2). Ammonia and other heavy metals do not appear to be a major concern in the study area (Section 3.6.3). With the limited dataset (one year of monitoring) and not knowing the source of copper it is unclear if this is a chronic problem in Swift Creek, or an irregular occurrence.

In summary, there are still some high quality habitats present within the study area, there are some existing levels of protection, although not exceptional, there are some water quality concerns, and through the Neuse 01 RWP the Swift Creek watershed is being targeted for conservation/mitigation efforts. Additionally, there appears that there has been a levelling off in the decline of many of the sensitive mussel species and their populations appear to have some level of recruitment. When factoring in all of this information, coupled with evidence of recent reproduction and recruitment of DWM, it can be concluded with some level of uncertainty that there is a chance for this species to persist into the future. This chance of persistence is very tenuous, especially without active management and increased habitat protection.

This level of uncertainty is due to numerous factors, including a lack of historic population data, an insufficient amount of time to evaluate effectiveness of the various conservation measures that have been implemented, not knowing what additional protective measures may be implemented, and not knowing what population management resources will be available. For example, the NC DWM Work Group concluded that population augmentation through captive propagation is an essential component of management strategies to ensure DWM persistence in North Carolina (Smith et al. 2015). This is especially true with populations such as Swift Creek where the Allee effect (high risk of demographic extirpation due to low population abundance and lack of dispersal) is one of the major limiting factors of population viability. As mentioned in Section 4.2.8, the DWM has successfully been propagated (Beck and Neves 2001). Additionally, in North Carolina, a cooperative program between the NCWRC and the College of Veterinary Medicine at North Carolina State University is actively propagating imperiled mussel species. There is an ongoing commitment in developing a Swift Creek DWM population augmentation plan and acquiring the funds needed to implement this plan, which will be discussed further in Section 8.0.

8.0 DWM POPULATION MANAGEMENT RECOMENDATIONS

As discussed throughout this report, there are many uncertainties with regard to the future viability of the DWM population in Swift Creek. The reasons for the uncertainties have been explained, and are mainly related to existing data gaps and lack of historic information. One thing that is certain however, is that there are various active management tools and additional conservation measures that, if implemented, will increase the chances of long term viability. These measures will be discussed below. It is not to be implied that long term viability is dependent on all of these measures being implemented; however, the more that are done, will increase the chance for persistence, and some of them, like population augmentation appear to be critical. **Furthermore it is not being suggested that NCDOT be responsible for implementing, or funding all of these measures, rather it will take a cooperative effort with multiple stakeholders and multiple sources of funding to carry these out.** These measures are not discussed by level of importance, as some of them may have equal value.

8.1.In-stream Habitat Monitoring Using HDSS Approach

As discussed in Section 6.3.2 the Swift Creek channel is in a state of disequilibrium; however, there are still high quality habitats within the stream. The Geomorphology component of this study assessed habitat conditions within 200 foot sections at 18 sites within the portion of Swift Creek. While the methodologies employed for this study are very useful in characterizing and quantifying habitat conditions at specific locations, it is not feasible to apply these methods to the entire 32 miles of Swift Creek that constitutes the study area.

The HDSS approach uses geo-referenced video to develop spatially continuous maps of the existing stream bank and streambed conditions over long stream reaches in a relatively short period of time. A standard HDSS Kayak system consists of a sit-on-top kayak, three GPSenabled video cameras mounted facing forward, left, and right (90°), a hull-mounted down looking video camera, and a flush-mounted depth sensor. The GPS receiver provides sub three meter GPS accuracy and output time and location data (approximately one each second (1Hz)). The GPS data is combined with the depth data within the multiplexer and then is recorded onto a flash drive. The geo-referenced video is then combined with the GPS and depth data such that each data point is associated with Coordinated Universal Time (UTC) and coordinate information.

The data that can be gathered using these methods has a number of potentially useful applications in managing the DWM population:

1) Provide a baseline characterization of stream bank and substrate conditions, that can then be monitored overtime,

2) develop aquatic habitat GIS layers for depth, habitat type (pool, riffle, run), substrate type, percent embeddedness, and left and right bank condition scores, and combine this with recent mussel survey data, to further understand DWM habitat characteristics

3) document areas of high habitat suitability for endangered DWM and other species of concern

4) identify problem areas, which would help guide restoration efforts.

This HDSS was developed by members of Trutta Consulting (http://truttaconsulting.com/) and has been implemented on numerous occasions. The methodologies and utilities are explained in more detail in Connell and Parham (2015).

8.2.DWM Population Augmentation Using Captive Propagation Techniques

Captive propagation of freshwater mussels is becoming an increasingly useful tool in the management and restoration of freshwater mussel populations. The Allee effect (high risk of demographic extirpation due to low population abundance and lack of dispersal) has been recognized as one of the major limiting factors of DWM population viability in Swift Creek. Whether the cause for the Allee effect in Swift Creek is due to past, or ongoing anthropogenic factors is unclear. If the Allee effect is operating in Swift Creek causing unsustainable recruitment for the DWM population, the release of propagated individuals might increase population viability given the leveling off in population declines for some of the other mussel species (Section 5.5). However, if underlying conditions (habitat degradation) are not sufficient to sustain the population, the release of propagated individuals may not enhance viability even if the Allee effect is operating.

As mentioned in various sections of this report, the NC DWM Work Group concluded that population augmentation through captive propagation is an essential component of management strategies to ensure DWM persistence in North Carolina (Smith et al. 2015). The work group evaluated various scenarios to determine the relationship between the number of propagated DWM individuals released into a population, and the viability of that population (NC DWM Work Group workshop meeting notes provided by Sarah McRae USFWS). This evaluation factored in several parameters, including adult survival and life expectancy, the relationship between reproduction levels and population density, the number of glochidia per gravid female, as well as glochidia and juvenile survival. Based on knowledge of the species, and propagation techniques, it was estimated that approximately 5,000 DWM individuals could be propagated per year.

Based on these parameters, several models were evaluated with regards to the number of individuals released into the population and the number of years of release to achieve a lambda = 1. In ecology, lambda denotes the long term intrinsic growth of a population, often calculated as the dominant eigenvalue of the age/size class matrix. A lambda value of < 1 equates to population decline. Three scenarios resulted in lambda values = 1:

1) Release of 300 individuals ages 1-5 for 10 years
2) Release 900 at age 1 for 10 years
3) Release of 600 at age 2 for 10 years

The consensus of the group is that age 3 individuals are best suited for release, and it would take a minimum of a ten-year release schedule to potentially achieve viability in Swift Creek.

Other scenarios are being explored that factor in different magnitudes of release, different periods of release, and using the model in reverse (determine propagation capabilities, then calculate under what conditions (lambda = 1)), which would result in persistence.

As mentioned in Section 7.6, an ongoing commitment in developing a Swift Creek DWM population augmentation plan and acquiring the funds needed to implement this plan is underway, and choosing potential augmentation sites (Section 6.3) and collecting DWM individuals for brood stock was a component of the Phase 2 portion of this study. At the time of writing this report, three individuals have been collected in Swift Creek and were transported to the NCWRC fish hatchery in Marion, NC to serve as brood stock individuals.

Additionally, the USFWS and NCDOT have been in coordination with regards to logistics (location, costs, etc.) of developing a propagation facility in the Raleigh area as part of a conservation measure to help offset anticipated impacts to the Swift Creek DWM population resulting from the construction of the Triangle Expressway. Again, it is important to consider that a propagation effort in and of itself will not maintain population viability. Rather, physical habitat and water quality will also need to be sufficient to maintain population viability.

8.3.Continued Targeted Water Quality Monitoring

Water quality degradation due to copper contamination has been identified as a potential factor limiting DWM population viability. Continued water quality monitoring will aid in determining if contamination from copper is a chronic problem in Swift Creek, or an irregular occurrence, and whether it is localized, or throughout. In addition, uncovering the source(s) of contamination should also be investigated. Having this knowledge will be useful in determining potential stocking locations, as well as in developing measures to reduce the levels of contamination. To fully answer the question of whether water quality conditions in Swift Creek are a limiting factor for the DWM population, long-term toxicity analysis on DWM, analyzing growth, survival, and reproduction, is needed. In the absence of that data, similar analysis on other species of the same genus and/or associate species could be done instead. Lastly, developments through the use of the BLM to understand toxicity from other heavy metals should be monitored.

8.4.Monitoring of Sediment Toxicity within Swift Creek

The water quality sampling component of this study identified copper as a potential toxicant impacting the freshwater mussel fauna of Swift Creek. In addition to water quality contamination monitoring, evaluation of heavy metals within the sediments of Swift Creek will help further determine if copper and other metals are limiting population viability, and whether the contamination is an ongoing water quality issue, or a legacy effect. Freshwater bivalves are known for their ability to accumulate heavy metals in their tissues at several orders of magnitude above ambient water concentrations, and toxic concentrations of dissolved metals are more often associated with sediments rather than surface waters (Thorp and Rogers, 2015). The level of accumulation within the tissues of freshwater mussels is influenced by multiple factors including other sediment constituent metals and organic matter (Tessier et al.1984). Analysis of metal concentrations in tissues of associate mussel species within Swift Creek could help further determine if heavy metal contamination is impacting population viability.

8.5.Establishing a Lower SCW DWM Stakeholders Group

As mentioned in various sections of this report there have been numerous efforts implemented to conserve the SCW. However, these efforts have often been carried out in a vacuum by addressing a small area, or a single source of degradation. As mentioned, the Neuse 01 RWP is using a more holistic approach to characterize watershed conditions to guide improvement and mitigation efforts that will maximize ecological uplift. One of the goals of the Neuse 01 RWP was to identify traditional and non-traditional mitigation and water quality improvement measures. The entire occupied range of the DWM in Swift Creek is encompassed in two of the top five subwatersheds identified as Important Aquatic Habitats. While there is a Stakeholders

Group assembled as part of the Neuse 01 RWP, forming a stakeholders group specifically for the lower SCW is also recommended.

Establishing a specific stakeholders group that has a vested interest in maintaining a DWM population in Swift Creek would be useful in helping to identify and guide mitigation and conservation efforts and will also help to spread the burden of population management to multiple entities rather than a single agency. The stakeholder group could provide input on how to best direct available resources and to identify potential partners and funding sources.

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Appendix E

Aquatic Species Survey Report 2017

AQUATIC SPECIES SURVEY REPORT

Complete 540
Triangle Expressway Southeast Extension

Wake, Johnston, & Harnett Counties

STIP Project Nos. R-2721, R-2828, and R-2829
State Project Nos. 6.401078, 6.401079, and 6.401080
Federal Aid Project Nos. STP-0540(19), STP-0540(20), and STP-0540(21)
WBS Nos. 37673.1.TA2, 35516.1.TA2, and 35517.1.TA1

Prepared for:

North Carolina Department of Transportation
North Carolina Turnpike Authority

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Three Oaks Engineering, Inc.

June 28, 2017

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Appendix A. Figures:

1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT), in cooperation with the Federal Highway Administration (FHWA), proposes transportation improvements to NC 540, a project known as the "Complete 540 – Triangle Expressway Southeast Extension," in Wake and Johnston Counties, North Carolina. Project construction will impact streams within the Neuse River Basin and the Cape Fear River Basin, which could potentially result in impacts to aquatic species. Surveys had previously been conducted for this project in the Swift Creek watershed (part of the Neuse River Basin) and documented in Freshwater Mussel Survey Report: Triangle Expressway Southeast Extension (Catena Group 2012). Since those surveys were completed, the Future Land Use Study Area (FLUSA) for the Complete 540 Project was extended into additional areas and watersheds not surveyed for the original report. The FLUSA, which includes portions of Wake, Johnston, and Harnett Counties, as well as the limits of the study area from the initial report, are provided in Figure 1.

As of April 6, 2017, the US Fish and Wildlife Service (USFWS) list eight federally protected species as occurring in Wake, Johnston, and Harnett Counties (Table 1). Yellow Lance (*Elliptio lanceolata*) was proposed as threatened on April 5, 2017, and as such will be included in the Biological Assessment (BA) being prepared for the project. Additionally, the USFWS is expected to publish findings on three other petitioned aquatic species that potentially warrant listing as Threatened or Endangered species under the Endangered Species Act of 1973, as amended. These three species have been reported in watersheds within the FLUSA: Atlantic Pigtoe (*Fusconaia masoni*), Carolina Madtom (*Noturus furiosus*), and Neuse River Waterdog (*Necturus lewisi*). If the finding recommends the other three species for listing, it is anticipated that they would be proposed for listing before April 2018. Given the high potential that some, or all, of these species will become listed prior to the completion of the Final Environmental Impact Statement (FEIS), it was determined to be prudent to include the baseline for these three species in the BA.

Table 1. Federally Listed Species; Wake, Johnston, and Harnett Counties, North Carolina

Scientific Name	Common Name	Status	County
Alasmidonta heterodon	Dwarf Wedgemussel	E	W, J
Elliptio lanceolata	Yellow Lance	Proposed	W, J
Elliptio steinstansana	Tar River Spinymussel	E	J
Fusconaia masoni	Atlantic Pigtoe	Petitioned	W, J, H
Haliaeetus leucocephalus	Bald Eagle	BGPA	W, J, H
Lysimachia asperulaefolia	Rough-leaved Loosestrife	E	H
Myotis septentrionalis	Northern Long-eared Bat	T	W
Necturus lewisi	Neuse River Waterdog	Petitioned	W, J
Notropis mekistocholas	Cape Fear Shiner	E	H
Noturus furiosus	Carolina Madtom	Petitioned	W, J
Picoides borealis	Red-cockaded Woodpecker	E	W, J, H
Rhus michauxii	Michaux's Sumac	E	W, J

BGPA – Bald and Golden Eagle Protection Act, T – Threatened, E – Endangered, W – Wake, J- Johnston, H - Harnett

This report was prepared to provide the survey results of the additional areas within the FLUSA and to provide species information for the Proposed Yellow Lance and the Petitioned Atlantic Pigtoe, Carolina Madtom, and Neuse River Waterdog to be included in the BA.

1.1 Elemental Occurrences in the FLUSA

According to the NC Natural Heritage Program database (NCNHP 2017), accessed May 24, 2017, there are two element occurrences (EO) of Dwarf Wedgemussel (DWM) in the FLUSA, one current and one historical (Figure 2-1). The Swift Creek/White Oak Creek/Middle Creek population (EO ID: 13799) was first observed in March 1991 and last observed in 2016 by Three Oaks. A historical occurrence (EO ID: 7699), located in the mainstem Neuse River, was first and last observed in 1951.

There are three current EOs for the Yellow Lance in the FLUSA (Figure 2-2). In Swift Creek, EO ID: 21894, was first observed in August 1992 and last observed in November 2015. Downstream of this EO in Swift Creek is another EO (EO ID: 21890), which was first observed in March 1991 and last observed in July 2002. There is an EO in Middle Creek (EO ID: 21892), which was first observed in September 1992 and officially last observed in July 1999; however, an individual was found in 2011 (Catena 2012). It is unclear why this record is not currently reflected in the NCNHP database.

There are four EOs for the Atlantic Pigtoe in the FLUSA, three current and one historical (Figure 2-3). The EO in Swift Creek/White Oak Creek/Little Creek (EO ID: 11695) was first observed in March 1991 and last observed in November 2015. An EO in Middle Creek (EO ID: 4770) was first observed in May 1992 and last observed in June 2003, until an individual was found during this survey effort. An EO upstream in Middle Creek (EO ID: 34956) was first and last observed in July 2004. A historical EO in Walnut Creek (EO ID: 11071) was first and last observed in 1951. Additionally, a historical EO in Black Creek (EO ID: 4370), located directly downstream of the FLUSA, was first and last observed in 1951.

There are two historical EOs for the Carolina Madtom in the FLUSA (Figure 2-4). The EO in Swift Creek/Middle Creek (EO ID: 9621) was first observed in June 1961 and last observed in May 1985. The EO in Neuse River/Crabtree Creek (EO ID: 10676) was first observed in July 1897 and last observed in August 1902.

There are four EOs for the Neuse River Waterdog in the FLUSA, including two current and two historical (Figure 2-5). The Swift Creek/Middle Creek (EO ID: 1633) population was first observed in April 1979 and last observed in February 2017, as part of this survey effort. Middle Creek above I-40 (EO ID: 34764) contains another Neuse River Waterdog record; and was first observed in February 2001 and last observed in February 2014. Further upstream in Middle Creek is a historical EO (ID: 8258) that was first and last observed in March 1954. The other historical EO (ID: 8259) is in the mainstem Neuse River and was first observed in April 1919 and last observed in January 1987.

2.0 WATERS IMPACTED

The project will impact streams in both the Upper Neuse River Basin and the Cape Fear River Basin. Subbasins in the Neuse River Basin are Middle Creek (HUC# 0302020109), Swift Creek (HUC# 0302020110), Walnut Creek-Neuse River (HUC# 0302020111), Milburnie Lake-Neuse River (HUC# 0302020107), Crabtree Creek (HUC# 0302020108), and Black Creek (HUC#

0302020112). Subbasins in the Cape Fear River Basin are Buckhorn Creek-Cape Fear River (HUC# 0303000401), Buies Creek-Cape Fear River (HUC# 0303000405), and Upper South River (HUC# 0303000601).

2.1 303(d) Classification

The North Carolina Department of Environmental Quality (NCDEQ, formerly NC Department of Environment and Natural Resources, NCDENR) - Division of Water Resources 2014 Final 303(d) list of impaired streams includes 18 streams within the Neuse River Subbasins of the FLUSA (Table 2, Figure 3, NCDENR 2014). As of the writing of this report, the 2016 303(d) list had not been finalized, though a draft was submitted to the United States Environmental Protection Agency. If the draft list is finalized, there are potentially several streams that will be delisted (see notes below Table 2).

Table 2. Neuse River Basin Impaired (Category 5) Streams 2014.

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Middle Creek (HUC# 0302020109)				
Middle Creek	27-43-15-(1)b1	3 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2008)
Middle Creek	27-43-15-(1)b2	1.6 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)
Middle Creek	27-43-15-(4)a1	4.5 FW Miles	Poor Bioclassification	Fish Community (2014)
Terrible Creek	27-43-15-8-(2)	7.8 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)
Swift Creek (HUC# 0302020110)				
Swift Creek	27-43-(1)d	2.4 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2008)
Swift Creek (Lake Benson)	27-43-(5.5)a	0.9 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2008)
UT to Swift Creek (Lake Benson)	27-43-(5.5)but7	2.7 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2014)
Swift Creek	27-43-(8)a	20.6 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (2012)
Little Creek	27-43-12	11.4 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (1998)
Walnut Creek-Neuse River (HUC# 0302020111)				
Walnut Creek*	27-34-(4)b	3.7 FW Miles	Exceeding Criteria	Copper (2008)
Walnut Creek	27-34-(4)b	3.7 FW Miles	Exceeding Criteria	PCB Fish Tissue Advisory (2012)
Neuse River*	27-(22.5)c	3.9 FW Miles	Exceeding Criteria	Copper (2008)
Neuse River	27-(22.5)c	3.9 FW Miles	Exceeding Criteria	PCB Fish Tissue Advisory (2010)
Beddingfield Creek	27-37	3.7 FW Miles	Fair Bioclassification	Ecological/Bio Int, Benthos (2014)
Neuse River*	27-(36)	4.3 FW Miles	Exceeding Criteria	Copper (2008)
Neuse River*	27-(36)	4.3 FW Miles	Exceeding Criteria	Zinc (2008)
Neuse River*	27-(38.5)	9.7 FW Miles	Exceeding Criteria	Copper (2012)

Table 2. Neuse River Basin Impaired (Category 5) Streams 2014 (continued).

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Black Creek (HUC# 0302020112)				
None				
Milburnie Lake-Neuse River (HUC# 0302020107)				
None				
Crabtree Creek (HUC# 0302020108)				
Crabtree Creek	27-33-(10)c	2.75 FW Miles	Exceeding Criteria	PCB Fish Tissue Advisory (2012)

FW – Freshwater Miles, Bio Int – Biological Integrity * Indicates potential delisting based on Draft 2016 303(d) List

The 2014 303(d) list of impaired streams includes five streams within the Cape Fear subbasins of the FLUSA (Table 3, Figure 3, NCDENR 2014). Kenneth Creek will potentially be delisted for certain parameters with the finalization of the draft 2016 303(d) list (see notes below Table 3).

Table 3. Cape Fear River Basin Impaired (Category 5) Streams 2014.

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Buckhorn Creek-Cape Fear River (HUC# 03030004010)				
None				
Buies Creek-Cape Fear River (HUC# 0303000405)				
Kenneth Creek*	18-16-1-(2)	3.88 FW Miles	Fair Bioclassification	Ecological/Bio Int Benthos (1998)
Kenneth Creek*	18-16-1-(2)	3.88 FW Miles	Exceeding Criteria	pH (2012)
Kenneth Creek	18-16-1-(2)	3.88 FW Miles	Exceeding Criteria	Dissolved Oxygen (2014)
Neills Creek (Neals Creek)	18-16-(0.3)	2.65 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2006)
Neills Creek (Neals Creek)	18-16-(0.7)a	1.98 FW Miles	Poor Bioclassification	Ecological/Bio Int Benthos (2006)
Upper South River (HUC# 0303000601)				
None				

FW-Freshwater Miles, Bio Int – Biological Integrity * Indicates potential delisting based on Draft 2016 303(d) List

2.2 National Pollutant Discharge Elimination System Dischargers

The National Pollutant Discharge Elimination System (NPDES) provides permits for the discharge of pollutants into Waters of the United States under the Clean Water Act. There are 28 NPDES individual permit discharges and 53 NPDES general permit discharges in the Neuse River subbasins within the study area (Table 4, Figure 3, USEPA 2017). Individual NPDES permits are issued on a case by case basis and are site specific. General permits, on the other hand, cover discharges with similar operations and types of discharges that are applicable state-wide. The requirements of a general permit are defined and known by the permittee. In general, an individual permit will take longer to be issued than a general permit (NCDEQ: Permitting Process). There are two NPDES individual permit discharges and 16 NPDES general permit discharges in the Cape Fear River subbasins within the study area (Table 5, Figure 3, USEPA 2017).

Table 4. NPDES Individual Permitted Discharges in the Upper Neuse River Subbasin within FLUSA

Permit	Facility	Receiving Stream	Flow (GPD)	Owner
Middle Creek (HUC# 0302020109)				
NC0064050	Apex WRF	Middle Creek	3,600,000	Town of Apex
NC0022217	Apex Terminal	Middle Creek	Not limited	Motiva Enterprises LL
NC0062740	Briarwood Farms WWTP	Middle Creek	40,000	Aqua NC, Inc.
NC0082996	Hollybrook WTP	Middle Creek	Not limited	Aqua NC, Inc.
NC0088862	Sunset Forest Subdivision Well #1	Basal Creek	Not limited	Aqua NC, Inc.
NC0086690	Stansted Well #2 (WTP)	Basal Creek	Not limited	Aqua NC, Inc.
NC0065102	South Cary WRF	Middle Creek	16,000,000	Town of Cary
NC0062715	Crooked Creek WWTP	Middle Creek	150,000	Aqua NC, Inc.
NC0061638	Amherst WWTP	Middle Creek	53,000	Carolina Water Service, Inc. of North Carolina
NC0066150	Brighton Forest WWTP	Middle Creek	117,000	Town of Fuquay-Varina
NC0066516	Terrible Creek WWTP	Terrible Creek	6,000,000	Town of Fuquay-Varina
NC0073679	Oak Hollow WTP	Middle Creek	Not limited	Carolina Water Service, Inc. of North Carolina
NC0087998	Rand Meadows Phase II	Juniper Branch	Not limited	Aqua NC, Inc.
NC0088714	Lassiter Farm Subdivision WTP	Ditch Branch	Not limited	Aqua NC, Inc.
NC0088889	Hopson Downs Subdivision Well #4	Basal Creek	Not limited	Aqua NC, Inc.
Swift Creek (HUC# 0302020110)				
NC0060526	Pope Industrial Park	Swift Creek	8,000	Pope Industrial Park II Ltd Partnership
NC0088285	Dempsey E Benton WTP	Swift Creek	Not limited	City of Raleigh Public Utilities Department
NC0055701	Nottingham WTP	Swift Creek	Not limited	Aqua NC, Inc.
NC0049034	Mount Auburn Training Center	White Oak Creek	2,400	Wake County
NC0025453	Little Creek WRF	Neuse River	2,500,00	Town of Clayton
Walnut Creek-Neuse River (HUC# 0302020111)				
NC0038784	Neuse River Village WWTP	Neuse River	35,000	Aqua NC, Inc.
NC0040266	Knightdale Estates MHP WWTP	Neuse River	25,000	Knightdale Estate MHP LP
NC0056391	Cross Creek Mobile Estates	Neuse River	70,000	Aqua NC, Inc.
NC0065706	Cottonwood/Baywood WWTP	Poplar Creek	115,000	Crosby Utilities, Inc.
NC0051322	Ashley Hills WWTP	Poplar Creek	495,000	Carolina Water Service Inc. of NC
NC0062219	Kings Grant Subdivision WWTP	Poplar Creek	210,000	Carolina Water Service Inc. of NC
NC0029033	Neuse River Resource Recovery Facility	Neuse River	75,000,000	City of Raleigh Public Utilities Department
NC0064378	Willowbrook WWTP	Beddingfield Creek	60,000	Carolina Water Service Inc. of NC
Black Creek (HUC# 0302020112)				
None				
Milburnie Lake-Neuse River (HUC# 0302020107)				
None				
Crabtree Creek (HUC# 0302020108)				
None				

WRF = Water Reclamation Facility, WTP = Water Treatment Plant, WWTP = Wastewater Treatment Plant

Table 5. NPDES Individual Permitted Discharges in the Cape Fear River Subbasin within FLUSA

Permit	Facility	Receiving Stream	Flow (GPD)	Owner
Buckhorn Creek-Cape Fear River (HUC# 03030004010)				
NC0063096	Holly Springs WWTP	Utley Creek	8,000,000	Town of Holly Springs
NC0055051	Avocet WWTP	Buckhorn Creek	90,000	Aqua NC, Inc.
Buies Creek-Cape Fear River (HUC# 0303000405)				
None				
Upper South River (HUC# 0303000601)				
None				

WWTP = Wastewater Treatment Plant

3.0 TARGET FEDERALLY PROTECTED SPECIES DESCRIPTIONS

3.1 *Alasmidonta heterodon* (Dwarf Wedgemussel)

3.1.1. Species Characteristics

The DWM was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortmann (1919) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900).

The specific epithet *heterodon* refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. The DWM is generally small, with a shell length ranging between 25 millimeters (mm) (1.0 inch) and 38 mm (1.5 inches). The largest specimen reported by Clarke (1981) was 56.5 mm (2.2 inches) long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark brown; nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. Many mussel species have specific fish hosts, which must be present to complete their life cycle. Based upon laboratory infestation experiments, Michaelson and Neves (1995) determined that potential fish hosts for the DWM in North Carolina include the Tessellated Darter (*Etheostoma olmstedi*) and the Johnny Darter (*E. nigrum*). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

3.1.2. Distribution and Habitat Requirements

The historic range of the DWM is confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River in North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages, in 11 states and one Canadian Province (USFWS 1993). When the recovery plan for this species was written, the DWM was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The most recent assessment (2013 5-Year Review) indicates that the DWM is currently found in 16 major drainages, comprising approximately 75 "sites" (one site may have multiple occurrences). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by multiple flood events between 2004 and 2006 are still being studied (USFWS 2013).

Strayer et al. (1996) conducted range-wide assessments of remaining DWM populations, and assigned a population status to each of the populations. The status rating is based on range size, number of individuals and evidence of reproduction. Seven of the 20 populations assessed were considered “poor,” and two others are considered “poor to fair” and “fair to poor,” respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however, they are believed to have been extirpated from the mainstem of the Neuse River.

The DWM inhabits creeks and rivers of varying sizes (down to approximately two meters wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993). In North Carolina, DWMs often occur within submerged root mats along stable streambanks. The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

3.1.3. Threats to Species

The cumulative effects of several factors, including sedimentation, point and non-point discharges, and stream modifications (impoundments, channelization, etc.) have contributed to the decline of this species throughout its range. Except for the Neversink River population in New York, which has an estimated population of over 80,000 DWM individuals, all other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes.

Siltation resulting from substandard land-use practices associated with activities such as agriculture, forestry, and land development has been recognized as a major contributing factor to degradation of mussel populations. 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, Marking and Bills 1979). Sediment accumulations of less than one inch have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the DWM because of accelerated sedimentation and erosion (Smith 1981).

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 may 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). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia (parasitic larval form). 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 the river basins within the DWM's range have been impounded. This is believed to be a major factor contributing to the decline of the species (Master 1986).

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 DWM. 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 Widlak 1987, Alderman 1995). The Zebra Mussel, native to the drainage basins of the Black, Caspian, and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels; and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The Zebra Mussel is not currently known from any river supporting DWM population, nor is it found in the Neuse River basin.

3.2 *Elliptio lanceolata* (Yellow Lance)

3.2.1. Species Characteristics

The Yellow Lance was described from the Tar River at Tarboro, North Carolina in 1828, by I. Lea (Lea 1828). Johnson (1970) synonymized this species with 25 other named species of lance-shaped Elliptio mussels into *Elliptio lanceolata* species complex. Genotypic and phenotypic analysis suggests that some of these formally described species are valid, including *Elliptio lanceolata* (Bogan et al. 2009). This species differs from other lanceolate Elliptios by having a "waxy" bright yellow periostracum that lacks rays. Some older specimens are brown towards the posterior end of the shell. The periostracum can also have brown growth rests. Yellow

Lances have a distinct pallial line and adductor muscle scars. The posterior ridge is distinctly rounded and curves dorsally towards the posterior end. The nacre ranges from an iridescent blue on the posterior end, sometimes becoming white or salmon colored on the anterior end. The lateral teeth are long, with two on the left and one on the right. Each valve also has two psuedocardinal teeth. On the left valve one tooth is before the other with the posterior tooth tending to be vestigial. On the right valve, the two teeth are parallel and the more anterior one is vestigial (Adams et al 1990).

The Yellow Lance is a tachytictic (short-term) breeder, brooding young in early spring and releasing glochidia in early summer. White Shiner (*Luxilus albeolus*) and Pinewoods Shiner (*Lythrurus matuntinus*) are potential fish hosts for Yellow Lance (Eads and Levine 2009).

3.2.2. Distribution and Habitat Requirements

The taxonomy of this species has changed several times and, therefore, so has its range. The Yellow Lance is currently thought to be distributed in the Atlantic Slope river basins from the Neuse River Basin in North Carolina north to the Rappahannock River Basin in Virginia, except for the Roanoke River Basin, the Patuxent River Basin in Maryland, and possibly the Potomac River Basin in Virginia and Maryland (USFWS 2017). It is in considerable decline throughout its range; however, extant populations still occur in all historic river basins, except possibly the Potomac (USFWS 2017). This species has been found in multiple physiographic provinces, from the foothills of the Appalachian Mountains, through the Piedmont, and into the Coastal Plain. It is found in small streams to large rivers, in substrates primarily consisting of clean sand, and occasionally gravel, with high dissolved oxygen content (USFWS 2017, Adams et al 1990). No remaining populations appear below point source pollution or other nutrient-rich areas (Alderman 2003). Associate mussel species include Atlantic Pigtoe, Tar River Spinymussel (*Elliptio steinstansana*), Yellow Lampmussel (*Lampsilis cariosa*), Notched Rainbow (*Villosa constricta*), Triangle Floater (*Alasmidonta undulata*), Paper Pondshell (*Utterbackia imbecillis*), Eastern Lampmussel (*Lampsilis radiata*), Creeper (*Strophitus undulatus*), and other Elliptio species (Adams et al 1990).

3.2.3. Threats to Species

Threats to the Yellow Lance and many other species are similar to those described above for the DWM. Factors that influence long term viability of this species are discussed in detail in the USFWS Yellow Lance Species Status Review (2017).

3.2.4. Species Listing

Yellow Lance was petitioned for federal listing under the Endangered Species Act of 1973, as amended (ESA) within the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the Center for Biological Diversity (CBD 2010), and is state listed as Endangered in North Carolina. On April 5, 2017, the USFWS proposed listing Yellow Lance as threatened. Following the proposal, there was a 60-day comment period for the public to provide input to help USFWS in making its final decision. The USFWS usually has one year after a species is proposed for listing under the ESA to make a final determination on listing the species as threatened or endangered.

4.0 OTHER TARGET SPECIES DESCRIPTIONS

4.1 *Fusconaia masoni* (Atlantic Pigtoe)

4.1.1. Species Characteristics

The Atlantic Pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Although larger specimens exist, the Atlantic Pigtoe seldom exceeds 50 mm (about 2 inches) in length. This species is tall relative to its length, except in headwater stream reaches where specimens may be elongated. The hinge ligament is relatively short and prominent. The periostracum is normally brownish, has a parchment texture, and young individuals may have greenish rays across the entire shell surface. The posterior ridge is biangulate. The interdentum in the left valve is broad and flat. The anterior half of the valve is thickened compared with the posterior half, and, when fresh, nacre in the anterior half of the shell tends to be salmon colored, while nacre in the posterior half tends to be more iridescent. The shell has full dentation. In addition to simple papillae, branched and arborescent papillae are often seen on the incurrent aperture. In females, salmon colored demibranchs are often seen during the spawning season. When fully gravid, females use all four demibranchs to brood glochidia (VDGIF 2014).

The Atlantic Pigtoe is a tachytictic (short-term) breeder, brooding young in early spring and releasing glochidia in early summer. The Bluegill (*Lepomis macrochirus*) and Shield Darter (*Percina peltata*) have been identified as potential fish hosts for this species (O'Dee and Waters 2000). Additional research has found Rosefin Shiner (*Lythrurus ardens*), Creek Chub (*Semotilus atromaculatus*), and Longnose Dace (*Rhynichthys cataractae*) are also suitable hosts (Wolf 2012). Eads and Levine (2011) found White Shiner, Satinfin Shiner (*Cyprinella analostana*), Bluehead Chub (*Nocomis leptocephalus*), Rosyside Dace (*Clinostomus funduloides*), Pinewoods Shiner, Creek Chub, Swallowtail Shiner (*Notropis procne*), and Mountain Redbelly Dace (*Chrosomus oreas*) to also be suitable hosts for Atlantic Pigtoe.

4.1.2. Distribution and Habitat Requirements

Johnson (1970) reported the range of the Atlantic Pigtoe extended from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia; however, recent curation of the H. D. Athearn collection uncovered valid specimens from the Altamaha River in Georgia (Sarah McRae, USFWS, personal communication). It is presumed extirpated from the Catawba River Basin in North and South Carolina south to the Altamaha River Basin. The general pattern of its current distribution indicates that the species is currently limited to headwater areas of drainages and most populations are represented by few individuals. In North Carolina, aside from the Waccamaw River, it was once found in every Atlantic Slope river basin. Except for the Tar River, it is no longer found in the mainstem of the rivers within its historic range (Savidge et al. 2011). It is state listed as Endangered in Georgia, South Carolina, and North Carolina, and as Threatened in Virginia. It has a NatureServe rank of G2 (imperiled).

The Atlantic Pigtoe has been found in multiple physiographic provinces, from the foothills of the Appalachian Mountains, through the Piedmont and into the Coastal Plain, in streams less than one meter wide to large rivers. 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 lotic habitat conditions.

4.1.3. Threats to Species

Threats to the Atlantic Pigtoe are similar to those described for the DWM and have contributed to the decline of this species throughout its range. Atlantic Pigtoe appears to be particularly sensitive to pollutants and requires clean oxygen-rich water for all stages of life. All remaining Atlantic Pigtoe populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event.

4.1.4. Species Listing

Atlantic Pigtoe was petitioned for federal listing under the Endangered Species Act of 1973, as amended within the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the CBD (CBD 2010), and is listed as Endangered in North Carolina by North Carolina Wildlife Resource Commission (NCWRC).

4.2 *Noturus furiosus* (Carolina Madtom)

4.2.1. Species Characteristics

The Carolina Madtom (a small catfish) was described at Milburnie, near Raleigh, NC in the Neuse River by Jordan and Meek (Jordan 1889). The Carolina Madtom reaches a maximum size of 132 mm (5.2 inches). Compared to other Madtoms within its range, it has a relatively short stout body and a distinctive color pattern of three to four dark saddles along its back that connect a long black stripe on the side running from the snout to the tail. The adipose fin is mostly dark, making it appear that the fish has a fourth saddle. The Madtom is tan on the rest of its body and yellow to tan between the saddles. The adipose fin and caudal fin are fused together, a distinguishing characteristic from other members of the catfish family (Ictaluridae). There are no speckles on the Madtom’s belly, and the tail has two brown bands that follow the curve of the tail. The Carolina Madtom, like other catfish, has serrae on its pectoral fins and is thought to have the most potent venom of any of the catfish species (NCWRC 2010).

4.2.2. Distribution and Habitat Requirements

The Carolina Madtom is endemic to the Piedmont/Inner Coastal Plain portion of the Tar/Pamlico and Neuse River basins. It occurs in creeks and small rivers in habitats generally consisting of very shallow riffles with little current over coarse sand and gravel substrate (Lee et al. 1980). Burr et al (1989) found most records came from medium to large streams, i.e. mainstem Neuse and Tar Rivers and their major tributaries. The population in the Trent River system (part of the Neuse River basin) is isolated from the rest of the Neuse River basin by salinity levels, so it is therefore considered a separate population, though it has not been detected in Trent River in the last five years (Sarah McRae, USFWS, personal communication). In the lower portions of these rivers, Carolina Madtom is usually found over debris piles in sandy areas. During nesting season, May to July, Madtoms prefer areas with plenty of cover to build their nests with shells, rocks, sticks, bottles, and cans being suitable cover types. Males guard the nests, in which females may lay between 80 and 300 eggs.

Carolina Madtom is found in water that ranges from clear to tannin-rich, which is usually free-flowing. It is generally rare throughout its range and is apparently in decline. The Tar River population has historically been more robust than the Neuse River population (Burr et al. 1989), which has shown declines in recent years (Midway 2008). The Little River of the Neuse River Basin has the largest population of Carolina Madtom in the Neuse River Basin, with records from 2016 indicating it is present (Sarah McRae, USFWS, personal communication). A few specimens have been collected from Swift Creek, within the Neuse River Basin. Fishing Creek and Swift Creek of the Tar River Basin are also productive systems for Carolina Madtom populations, with around 14 specimens collected in the mid-1980s from Swift Creek (water levels in Fishing Creek prevented sampling during that study). In 2016, a total of 17 individuals were recorded in Swift Creek, and a total of four individuals were recorded in Fishing Creek (Sarah McRae, USFWS, personal communication). The Carolina Madtom has been observed in at least 36 localities (Burr et al 1989).

The Carolina Madtom has a lifespan of about four years, with sexual maturity being reached at around two years in females and three years in males. Sampling for Carolina Madtom is most effective at dawn and dusk when they are most active and feeding (Mayden and Burr 1981). Their diet consists mostly of benthic macroinvertebrates, which they collect by scavenging along the bottom of streams.

4.2.3. Threats to Species

Identified threats to the Carolina Madtom include water pollution and construction of impoundments (Burr et al. 1989). It is susceptible to threats due to its limited range and low population densities (Angermeier 1995, Burr and Stoekel 1999). As a bottom-dwelling fish, Carolina Madtom is susceptible to habitat loss when stream bottoms are impacted by urbanization, impoundments, deforestation, etc.

4.2.4. Species Listing

Because of its limited distribution, Carolina Madtom is listed as Special Concern and is Proposed Threatened in North Carolina. It was petitioned for federal listing under the Endangered Species Act of 1973, as amended within the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the CBD (CBD 2010).

4.3 *Necturus lewisi* (Neuse River Waterdog)

4.3.1. Characteristics

The Neuse River Waterdog is a fully aquatic salamander and was first described by C.S. Brimley in 1924 as a subspecies of the Common Mudpuppy (*N. maculosus*); it was elevated to species status in 1937 by Percy Viosca, Jr.

The Neuse River Waterdog ranges in size from 15.24 to 22.86 centimeters (cm) (6 to 9 inches) in length; record length is 27.94 cm (11 inches). It has a somewhat stocky, cylindrical body with smooth skin, a rather flattened, elongate head with a squared-off nose, and small limbs. The tail is vertically flattened with fins on both the top and bottom. Distinct from most salamanders, the Neuse River Waterdog has four toes on each foot. The Neuse River Waterdog is a rusty brown color on the dorsal side and dull brown or slate colored on the ventral side. Both dorsal and ventral sides are strongly spotted, but the ventral side tends to have fewer and smaller markings; spots are dark bluish to black. They also have a dark line running through the eye. Adults are neotenous and retain three bushy, dark red external gills usually seen in larval amphibians. Both male and female are similar in appearance and can be distinguished only through differences in the shape and structure of the cloaca (Beane and Newman 1996; Conant and Collins 1998; EDGE of Existence 2016).

Individuals become sexually mature at approximately five to six years of age. Breeding normally occurs in the spring. The male deposits a gelatinous spermatophore that is picked up by the female and used to fertilize between 30 and 50 eggs. The fertilized eggs are attached to the underside of flat rocks or other submerged objects and guarded by the female until they hatch in June or July (Conant and Collins 1998; EDGE of Existence 2016).

4.3.2. Distribution and Habitat Requirements

The Neuse River Waterdog is found only in the Neuse and Tar River basins of North Carolina (AmphibiaWeb 2006; Beane and Newman 1996; Frost 2016).

The Neuse River Waterdog inhabits rivers and larger streams, where it prefers leaf beds in quiet waters. This species needs high levels of dissolved oxygen and good water quality. The Neuse River Waterdog is generally found in backwaters off the main current, in areas with sandy or muddy substrate. Adults construct retreats on the downstream side of rocks or in the stream bank where they remain during the day. This species is active during the night, leaving these retreats to feed. The Neuse River Waterdog is carnivorous, feeding on invertebrates, small vertebrates, and carrion. The Neuse River Waterdog is most active during winter months even when temperatures are below freezing. During summer months, it will burrow into deep leaf beds and is rarely found. It has been suggested that this inactivity in summer may be an adaptation to avoid fish predators, which are more active at these times. In addition, the Neuse River Waterdog produces a defensive, toxic skin secretion that is assumed to be distasteful to predators (AmphibiaWeb 2006; Beane and Newman 1996; Conant and Collins 1998; EDGE of Existence 2016; NatureServe Explorer 2016).

4.3.3. *Threats to Species*

Any factors that reduce water quality are all threats to the Neuse River Waterdog. These can include changes that result in siltation and pollution reducing habitat quality (e.g. channelization, agricultural runoff, and industrial and urban development). Impoundments are also a threat to the dispersal of the species as it is unable to cross upland habitat; Neuse River Waterdogs do not climb and are unlikely to use fish passages (NatureServe Explorer 2016).

4.3.4. *Species Listing*

The Neuse River Waterdog was petitioned for federal listing under the Endangered Species Act of 1973, as amended within the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the CBD (CBD 2010).

5.0 SURVEY EFFORTS

5.1 Freshwater Mussel Surveys

Surveys were conducted by Three Oaks personnel on the following dates:

Personnel	10/4/16	10/19/16	11/1/16	11/2/16	11/3/16	11/4/16	2/1/17	2/2/17	2/7/17	2/8/17	3/21/17	4/14/17	5/18/17
Tim Savidge (Permit # 16/17-ES0034)			X	X	X	X						X	X
Tom Dickinson (Permit # 16/17-ES00343)	X	X		X	X		X	X	X	X	X		
Chris Sheats	X	X					X	X	X	X			
Evan Morgan	X		X	X	X								
Nathan Howell											X	X	
Mary Frazer				X		X						X	
Brian Watson				X	X	X							
John Roberts		X											
Nancy Scott				X	X								
Lizzy Stokes-Cawley												X	X
John Fridell													X
Hannah Slyce													X

5.1.1. *Survey Locations*

Survey locations were selected based on previous survey data, proximity to the FLUSA, habitat requirements of the target species and field conditions.

5.1.2. *Methodology*

Areas of appropriate habitat were searched, concentrating on the stable habitats preferred by the target species. The survey team spread out across the creek into survey lanes. Visual surveys were conducted using glass bottom view buckets (bathyscopes). Tactile methods were employed, particularly in streambanks under submerged rootmats. All freshwater bivalves were recorded and returned to the substrate. Timed survey efforts provided Catch Per Unit Effort (CPUE) data for each species. Relative abundance for freshwater snails and freshwater clam species were estimated using the following criteria:

- (VA) Very abundant > 30 per square meter
- (A) Abundant 16-30 per square meter
- (C) Common 6-15 per square meter
- (U) Uncommon 3-5 per square meter
- (R) Rare 1-2 per square meter
- (P-) Ancillary adjective "Patchy" indicates an uneven distribution of the species within the sampled site.

5.1.3. Mussel Survey Results

Mussel survey results are reported in the following sections. Each survey reach is given a unique site identification number consisting of the survey date and the initials of the person leading the survey. This identification number is provided in each section title.

5.1.3.1 Black Creek 161004.2ted

This survey in Black Creek was conducted for 3 person hours near the Jackson-King Road crossing, extending upstream to an in-stream Beaver (*Castor canadensis*) dam and associated wetland complex (Figure 4). Habitat consisted of a low velocity run and slackwater. Substrate was dominated by sand with clay banks. Water clarity was light tannic. The stream channel ranged from 12 to 20 feet wide with relatively stable banks up to 3 feet high. A wide forested buffer surrounded the site.

Table 6. CPUE for Freshwater Mussels Black Creek 161004.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio spp.*	Elliptio mussels	178	59.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	R
Campeloma decisum	Pointed Campeloma	~	C

* *E. complanata, E. cistellaeformis* and *E. icterina* forms present, with gradation in-between

5.1.3.2 Black Creek 161004.3ted

This survey was conducted for 1.5 person hours below Panther Lake upstream of the Old Stage Road crossing (Figure 4). Habitat consisted of the lake tailrace extending into a Beaver-impounded swamp downstream. Substrate was dominated by sand and gravel/cobble. Water clarity was light tannic. The stream channel was approximately 12 feet wide with banks exhibiting some erosion and undercutting up to 2 feet high. A moderate forested buffer and Beaver-impounded wetland complex surrounded the site.

Table 7. CPUE for Freshwater Mussels Black Creek 161004.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	13	8.67hr
Pyganodon cataracta	Eastern Floater	1	0.67/hr
Utterbackia imbecillis	Paper Pondshell	1	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A

5.1.3.3 Black Creek 161019.1ted

This survey in Black Creek was conducted for 2 person hours below the Raleigh Road crossing (Figure 4). Habitat consisted of run and slackwater with substrate dominated by coarse sand and gravel. Water clarity was tannic. The stream channel ranged from 20 to 30 feet wide with stable banks up to 3 feet high. A wide, mature forested buffer surrounded the site.

Table 8. CPUE for Freshwater Mussels Black Creek 161019.1ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio spp.*	Elliptio mussels	242	121.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A
Campeloma decisum	Pointed Campeloma	~	C

* *E. complanata*, *E. cistellaeformis,* and *E. icterina* forms present, with gradation in-between

5.1.3.4 Black Creek 161019.2ted

This survey in Black Creek was accessed from private land and conducted for 1.8 person hours (Figure 4). Habitat consisted primarily of run with substrate dominated by fine sand. Water clarity was tannic. The stream channel ranged from 20 to 35 feet wide with stable banks up to 3 feet high. A wide, mature forested buffer surrounded the site.

Table 9. CPUE for Freshwater Mussels Black Creek 161019.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio spp.*	Elliptio mussels	43	23.89/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	C

* *E. complanata*, *E. cistellaeformis,* and *E. icterina* forms present, with gradation in-between

5.1.3.5 Black Creek 161019.3ted

This survey in Black Creek was conducted for 2 person hours upstream of the NC 50 crossing (Figure 4). Habitat consisted primarily of run with substrate dominated by compact fine sand and detritus. Water clarity was light tannic. The stream channel ranged from 20 to 25 feet wide with stable banks up to 3 feet high. A wide, mature forested buffer surrounded the site. Mussels were found in very low densities for the available habitat.

Table 10. CPUE for Freshwater Mussels Black Creek 161019.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	26	13.0/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	R
Campeloma decisum	Pointed Campeloma	~	R

5.1.3.6 Black Creek 161019.4ted

This survey in Black Creek was conducted for 2.25 person hours downstream of the Old Fairground Road crossing (Figure 4). Habitat consisted of deeper run and pool with primarily sand and clay substrate. Water clarity was light tannic. The stream channel ranged from 20 to 35 feet wide with eroded banks 3 to 6 feet high. The channel was heavily scoured in areas with large deposits of woody debris. A wide, forested floodplain buffer surrounded the site.

Table 11. CPUE for Freshwater Mussels Black Creek 161019.4ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	44	19.56/hr
Utterbackia imbecillis	Paper Pondshell	1	0.44/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	R

5.1.3.7 Middle Creek 161102.1ted

This survey in Middle Creek was conducted for 5.5 person hours in a reach extending upstream from the NC 50 crossing (Figure 4). Habitat consisted of a sequence of riffle, run, and pool with primarily sand substrate. The stream channel ranged from 30 to 40 feet wide with variably stable to eroded banks 3 to 10 feet high. Stable patches of cobble and gravel as well as clay and rootmats along stream banks were associated with higher mussel density and diversity. Stream conditions were low and clear. A moderately wide, mature, forested buffer was present to surrounding residential development.

Table 12. CPUE for Freshwater Mussels Middle Creek 161102.1ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	0.73/hr
Elliptio complanata	Eastern Elliptio	172	31.27/hr
Elliptio congaraea	Carolina Slabshell	3	0.55/hr
Elliptio icterina	Variable Spike	91	16.55/hr
Lampsilis radiata	Eastern Lampmussel	4	0.73/hr
Strophitus undulatus	Creeper	5	0.91/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A

5.1.3.8 Middle Creek 161102.2ted

This survey in Middle Creek was conducted for 2.25 person hours in a short reach upstream from NC 50 as accessed from surrounding residential development (Figure 4). Habitat consisted of run with mixed sand, gravel, and cobble substrate. The stream channel ranged from 20 to 30 feet wide with relatively stable banks 3 to 6 feet high. Stream conditions were low and clear. A moderately wide, mature, forested buffer was present and extended to surrounding residential development.

Table 13. CPUE for Freshwater Mussels Middle Creek 161102.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	91	40.44/hr
Elliptio congaraea	Carolina Slabshell	3	1.33/hr
Elliptio icterina	Variable Spike	37	16.44/hr
Elliptio sp c.f. mediocris	No common name	1	0.44/hr
Strophitus undulatus	Creeper	2	0.89/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A

5.1.3.9 Middle Creek 161102.3ted

This survey in Middle Creek was conducted for 1.5 person hours upstream from Barber Bridge Road (Figure 4). Habitat consisted of a sequence of run and pool with primarily unconsolidated sand substrate. The stream channel ranged from 15 to 30 feet wide with unstable banks 6 to 10 feet high. A large amount of recent windthrow and woody debris deposits were present. Stream conditions were low and clear. A wide forested buffer surrounded the reach.

Table 14. CPUE for Freshwater Mussels Middle Creek 161102.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	16	10.67/hr
Elliptio icterina	Variable Spike	3	2.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.10 Black Creek 161103.1ted

This survey in Black Creek was conducted for 4.6 person hours below the Raleigh Road crossing (Figure 4). Habitat consisted of run and pool with substrate dominated by coarse sand and gravel. Water clarity was light tannic. The stream channel ranged from 20 to 30 feet wide with stable banks up to 3 feet high. A wide, mature forested buffer surrounded the site.

Table 15. CPUE for Freshwater Mussels Black Creek 161103.1ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio spp.*	Elliptio mussels	163	35.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A
Campeloma decisum	Pointed Campeloma	~	C

* *E. complanata*, *E. cistellaeformis*, and *E. icterina* forms present, with gradation in-between

5.1.3.11 Black Creek 161103.2ted

This survey in Black Creek was conducted for 2.6 person hours below the Raleigh Road crossing (Figure 4). Habitat consisted of run and riffle with substrate dominated by coarse sand and gravel. Water clarity was light tannic. The stream channel ranged from 20 to 30 feet wide with stable banks up to 3 feet high. A wide, mature forested buffer surrounded the site.

Table 16. CPUE for Freshwater Mussels Black Creek 161103.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio spp.*	Elliptio mussels	268	103.08/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A
Campeloma decisum	Pointed Campeloma	~	U

* *E. complanata*, *E. cistellaeformis*, and *E. icterina* forms present, with gradation in-between

5.1.3.12 Middle Creek 161103.3ted

This survey in Middle Creek was conducted for 2.25 person hours in a sharp bend with steep surrounding topography and rocky outcroppings (Figure 4). Habitat consisted of deeper run with mixed sand, gravel, and cobble substrate. The stream channel ranged from 30 to 40 feet wide with relatively stable banks up to 3 feet high. Stream conditions were low and clear. A moderately wide, mature forested buffer was present to surrounding residential development.

Table 17. CPUE for Freshwater Mussels Middle Creek 161103.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.44/hr
Elliptio complanata	Eastern Elliptio	101	44.89/hr
Elliptio congaraea	Carolina Slabshell	6	2.67/hr
Elliptio icterina	Variable Spike	26	11.56/hr
Strophitus undulatus	Creeper	7	3.11/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A

5.1.3.13 Middle Creek 161103.4ted

This survey in Middle Creek was conducted for 2.35 person hours upstream from the Middle Creek 1061103.3ted site (Figure 4). Habitat consisted of a sequence of riffle, run and pool with primarily mixed sand and gravel substrate. The stream channel ranged from 30 to 40 feet wide with relatively unstable banks up 3 to 6 feet high. Stream conditions were low and clear. A moderately wide, mature forested buffer was present to surrounding residential development.

Table 18. CPUE for Freshwater Mussels Middle Creek 161103.4ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	64	27.23/hr
Elliptio congaraea	Carolina Slabshell	2	0.85/hr
Lampsilis radiata	Eastern Lampmussel	1	0.43/hr
Strophitus undulatus	Creeper	1	0.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	A

5.1.3.14 White Oak Creek 161101.1tws

This survey in White Oak Creek was conducted for 4.4 person hours within a former Beaver marsh downstream of NC 42 (Figure 4). Beaver dams appear to have been breached for several months. Habitat consisted of riffle, run, and pool with mixed sand and pebble substrate. The stream channel ranged from 5 to 7 feet wide with relatively stable banks up to 1 foot high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear.

A wide (greater than 500 feet), forested/shrub brush buffer was present on each side of White Oak Creek throughout the survey reach. The buffer abuts a residential development about 600 feet upslope from the left descending bank.

Table 19. CPUE for Freshwater Mussels White Oak Creek 161101.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	189	42.95
Elliptio icterina	Variable Spike	8	1.82
Lampsilis radiata	Eastern Lampmussel	1	0.23
Pyganodon cataracta	Eastern Floater	14	3.18
Utterbackia imbecillis	Paper Pondshell	1	0.23
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-C

5.1.3.15 White Oak Creek 161101.2tws

This survey in White Oak Creek started at the end of 161101.1tws and continued through a large overwash area just below the NC 42 bridge (Figure 4). The survey was conducted for 4.1 person hours. Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 5 to 8 feet wide with unstable banks up to 1 foot high. Stream conditions were normal and clear. A moderately wide forested buffer was present to surrounding residential and commercial development.

Table 20. CPUE for Freshwater Mussels White Oak Creek 161101.2tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	283 (14 shells)	69.02
Elliptio congaraea	Carolina Slabshell	22 (4 shells)	5.37
Elliptio icterina	Variable Spike	14 (2 shells)	3.41
Elliptio roanokensis	Roanoke Slabshell	(1 shell)	0
Lampsilis radiata	Eastern Lampmussel	16 (4 shells)	3.90
Pyganodon cataracta	Eastern Floater	20 (11 shells)	4.88
Utterbackia imbecillis	Paper Pondshell	10 (1 shell)	2.44
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-C

5.1.3.16 White Oak Creek 161101.3tws

This survey in White Oak Creek was conducted upstream of NC 42 in the tailrace of Austin Pond (Figure 4). The survey was conducted for 2.76 person hours. Habitat consisted of riffle, run, and pool with a cobble and sand substrate. The stream channel ranged from 5 to 13 feet wide with unstable banks ranging from 1 to 1.25 feet high. Stream conditions were normal and clear. A moderately wide forested buffer was present to surrounding residential development.

Table 21. CPUE for Freshwater Mussels White Oak Creek 161101.3tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	121	43.84
Elliptio icterina	Variable Spike	7	2.54
Lampsilis radiata	Eastern Lampmussel	1	0.36
Pyganodon cataracta	Eastern Floater	19	6.88
Utterbackia imbecillis	Paper Pondshell	14	5.07
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-U

5.1.3.17 Middle Creek 161102.1tws

This survey in Middle Creek was conducted downstream of Smith Road (SR 1507) for 5.13 person hours (Figure 4). Habitat consisted of riffle, run, and pool with an unconsolidated sand and pebble substrate. The stream channel ranged from 11 to 14 feet wide with unstable banks ranging from 3 to 4 feet high. Stream conditions were normal and clear. A wide forested buffer was present to surrounding agriculture and residential development.

Table 22. CPUE for Freshwater Mussels Middle Creek 161102.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	63	12.28
Elliptio congaraea	Carolina Slabshell	4	0.78
Elliptio icterina	Variable Spike	3	0.58
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-U
Elimia catenaria	Gravel Elimia	~	P-U

5.1.3.18 Middle Creek 161102.2tws

This survey in Middle Creek was conducted downstream of Smith Road (SR 1507) beginning at the end of 161102.1tws for 3.27 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 11 to 13 feet wide with banks ranging from 2.5 to 4 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A wide forested buffer was present to surrounding agriculture and residential development.

Table 23. CPUE for Freshwater Mussels Middle Creek 161102.2tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	85	25.99
Elliptio congaraea	Carolina Slabshell	15	4.59
Elliptio icterina	Variable Spike	5	1.53
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	U
Elimia catenaria	Gravel Elimia	~	P-C

5.1.3.19 Middle Creek 161102.3tws

This survey in Middle Creek was conducted downstream of Smith Road (SR 1507) beginning at the end of 161102.2tws for 5.27 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 10 to 14 feet wide with banks ranging from 3 to 4 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A wide forested buffer was present to surrounding agriculture and residential development. One individual of the targeted Atlantic Pigtoe was found.

Table 24. CPUE for Freshwater Mussels Middle Creek 161102.3tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	133	25.24
Elliptio congaraea	Carolina Slabshell	20	3.80
Elliptio fisheriana	Northern Lance	7	1.33
Elliptio icterina	Variable Spike	21	3.98
Elliptio roanokensis	Roanoke Slabshell	1	0.19
Fusconaia masoni	Atlantic Pigtoe	1	0.19
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-U
Elimia catenaria	Gravel Elimia	~	P-C

5.1.3.20 Middle Creek 161102.4tws

This survey in Middle Creek was conducted downstream of Smith Road (SR 1507) beginning at the end of 161102.3tws for 4 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 10 to 14 feet wide with banks ranging from 3 to 4 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A moderately wide forested buffer was present to surrounding agriculture and residential development.

Table 25. CPUE for Freshwater Mussels Middle Creek 161102.4tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	37	9.25
Elliptio congaraea	Carolina Slabshell	23	5.75
Elliptio icterina	Variable Spike	2	0.50
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	P-U
Elimia catenaria	Gravel Elimia	~	P-U

5.1.3.21 Middle Creek 161103.1tws

This survey in Middle Creek was conducted downstream of Crantock Road (SR 1504) for 3.5 person hours (Figure 4). Habitat consisted of riffle and run with a gravel and sand substrate. The stream channel ranged from 11 to 14 feet wide with banks ranging from 3 to 4.25 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A moderately wide forested/shrub-brush buffer was present to surrounding agriculture.

Table 26. CPUE for Freshwater Mussels Middle Creek 161103.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	77	22.00
Elliptio congaraea	Carolina Slabshell	143	40.86
Elliptio icterina	Variable Spike	15	4.29
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Elimia catenaria	Gravel Elimia	~	P-C

5.1.3.22 Middle Creek 161103.2tws

This survey in Middle Creek was conducted downstream of Crantock Road (SR 1504) starting at the endpoint of 161103.1tws for 2.6 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 12 to 14 feet wide with banks ranging from 2.5 to 4 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A moderately wide forested/shrub-brush buffer was present to surrounding agriculture. Relict shells of the Dwarf Wedgemusel, Yellow Lance, Atlantic Pigtoe and Notched Rainbow were found along a recently eroded bank. These four species have become increasingly rare in the Swift/Middle Creek subbasin. These shells were very fragile and many fell apart once they were handled. It is possible that these shells were buried within the bank for several years, and were recently exposed as the bank eroded. While the presence of relict shells is often considered to represent extant populations, these particular shells should not be considered to represent recent occupancy.

Table 27. CPUE for Freshwater Mussels Middle Creek 161103.2tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	0 (1 shell)	0
Elliptio complanata	Eastern Elliptio	31	11.92
Elliptio congaraea	Carolina Slabshell	17	6.54
Elliptio icterina	Variable Spike	1	0.38
Elliptio lanceolata	Yellow Lance	0 (2 shells)	0
Fusconaia masoni	Atlantic Pigtoe	0 (1 shell)	0
Villosa constricta	Notched Rainbow	0 (1 shell)	0
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Elimia catenaria	Gravel Elimia	~	P-C

5.1.3.23 Middle Creek 161103.3tws

This survey in Middle Creek was conducted upstream of Crantock Road (SR 1504) starting at the endpoint of 161103.2tws for 4.15 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel ranged from 11 to 18 feet wide with banks ranging from 2.5 to 3.75 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A narrow to moderately wide forested/shrub-brush buffer was present to surrounding agriculture and residential structures.

Table 28. CPUE for Freshwater Mussels Middle Creek 161103.3tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	149	35.90
Elliptio congaraea	Carolina Slabshell	39	9.40
Elliptio fisheriana	Northern Lance	1	0.24
Elliptio icterina	Variable Spike	18	4.34
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Elimia catenaria	Gravel Elimia	~	P-U

5.1.3.24 Middle Creek 161103.4tws

This survey in Middle Creek was conducted upstream of Crantock Road (SR 1504) starting at the endpoint of 161103.3tws for 2.85 person hours (Figure 4). Habitat consisted of run and pool with a sand and pebble substrate. The stream channel ranged from 11 to 13 feet wide with banks ranging from 2.5 to 3.75 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A narrow to moderately wide forested/shrub-brush buffer was present to surrounding agriculture.

Table 29. CPUE for Freshwater Mussels Middle Creek 161103.4tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	57	20.00
Elliptio congaraea	Carolina Slabshell	17	5.96
Elliptio icterina	Variable Spike	9	3.16
Lampsilis radiata	Eastern Lampmussel	1	0.35
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Elimia catenaria	Gravel Elimia	~	P-U

5.1.3.25 Middle Creek 161104.1tws

This survey in Middle Creek was conducted downstream of Barber Bridge Road (SR 2739) for 3 person hours (Figure 4). Habitat consisted of run and pool with a sand and cobble substrate. The stream channel ranged from 7 to 10 feet wide with banks ranging from 2.5 to 3.5 feet high. Banks were unstable. Stream conditions were normal and slightly turbid. A wide forested buffer was present to surrounding residential development.

Table 30. CPUE for Freshwater Mussels Middle Creek 161104.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.33
Elliptio complanata	Eastern Elliptio	15	5.0
Strophitus undulatus	Creeper	4	1.33
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.26 Middle Creek 161104.2tws

This survey in Middle Creek was conducted upstream of Barber Bridge Road (SR 2739) starting at the endpoint of 161104.1tws for 6 person hours (Figure 4). Habitat consisted of riffle, run, and pool with a sand and cobble substrate. The stream channel ranged from 7 to 10 feet wide with banks ranging from 2.5 to 3 feet high. Banks were unstable. Stream conditions were normal flow and slightly turbid. A narrow to moderately wide forested/shrub-brush buffer was present to surrounding residential development.

Table 31. CPUE for Freshwater Mussels Middle Creek 161104.2tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	0.67
Elliptio complanata	Eastern Elliptio	146	24.33
Elliptio congaraea	Carolina Slabshell	1	0.17
Elliptio icterina	Variable Spike	62	10.33
Strophitus undulatus	Creeper	1	0.17
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	P-C

5.1.3.27 UT Black Creek 170201.1ted

This survey was conducted for 0.75 person hour in a short flowing reach between impoundments (Figure 4). Habitat consisted of silt/mud backwaters of the downstream impoundment transitioning into a sequence of riffle, run, and pool with gravel and sand dominated substrate, much of which had been recently redeposited or washed out by Hurricane Matthew. In the flowing section, the stream ranged from 10 to 15 feet wide. Where present, banks were heavily scoured. There was no buffer present to surrounding residential development and road along portions of the evaluated reach. No evidence of mollusks was observed.

5.1.3.28 Black River 170201.2ted

This survey was conducted for 0.5 person hour in limited flowing areas below instream Beaver dams (Figure 4). The Black River in the surveyed section consisted of a wide cypress swamp floodplain, most of which had no discernable flow due to Beaver impacts. Substrates in these Beaver dam tailraces consisted primarily of silt and mud with occasional patches of sand and clay underlain. A wide, forested floodplain buffer surrounded the site. No evidence of mollusks was observed.

5.1.3.29 Neills Creek 170201.3ted

This survey was conducted for 1.5 person hours upstream of the Chalybeate Springs Road (SR 1441) crossing (Figure 4). Habitat consisted of a moderate gradient sequence of riffle, run, and pool with a predominately sand and quartz substrate. The stream channel ranged from 9 to 20 feet wide with banks 2 to 4 feet high that exhibited areas of erosion and undercutting. A wide forested buffer surrounded the site. No evidence of mollusks was observed.

5.1.3.30 Buckhorn Creek 170201.4ted

This survey was conducted for 1.0 person hour downstream of the Sweet Springs Road (SR 1117) crossing (Figure 4). Habitat consisted of a moderate gradient sequence of riffle, run, and pool with a predominately gravel and sand substrate. The stream channel ranged from 20 to 25 feet wide with unstable banks 10 to 15 feet high. A wide forested buffer surrounded the site.

Table 32. CPUE for Freshwater Mussels Buckhorn Creek 170201.4ted

Scientific Name	**Common Name**	**#live (#shell)**	**Abundance/ CPUE**
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	24	24.0/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.31 Hectors Creek 170202.1ted

This survey was conducted for 1.5 person hours downstream of the Rawls Church Road (SR 1415) crossing (Figure 4). Habitat consisted of a sequence of riffle, run, and pool with sand, gravel, and cobble substrate. The stream channel ranged from 10 to 15 feet wide with banks exhibiting some erosion and undercutting 3 to 6 feet high. A wide, forested buffer surrounded the site.

Table 33. CPUE for Freshwater Mussels Hectors Creek 170202.1ted

Scientific Name	**Common Name**	**#live (#shell)**	**Abundance/ CPUE**
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	1	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.32 Kenneth Creek 170202.2ted

This survey was conducted for 2.5 person hours downstream of the Rawls Church Road (SR 1415) crossing (Figure 4). Habitat consisted of a sequence of riffle, run, and pool with a variable mix of silt, sand, gravel, and cobble substrates. A few stabilizing outcrops of bedrock were also present. The stream channel ranged from 20 to 30 feet wide with eroded banks 6 to 12 feet high; recent scour and substrate redeposits, most likely attributable to hurricane Matthew, were present throughout. A moderately wide forested buffer surrounded the site.

Table 34. CPUE for Freshwater Mussels Kenneth Creek 170202.2ted

Scientific Name	**Common Name**	**#live (#shell)**	**Abundance/ CPUE**
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	63	25.2/hr
Villosa delumbis	Eastern Creekshell	2	0.8/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.33 Kenneth Creek 170202.3ted

This survey was conducted for 0.75 person hour upstream of the Chalybeate Springs Road (SR 1441) crossing (Figure 4). Habitat consisted of deeper run and pool with a mix of silt, sand, and gravel substrate. The stream channel ranged from 12 to 20 feet wide with eroded banks 10 to 12 feet high. The channel was heavily scoured, often to saprolite. A narrow to moderately wide forested buffer surrounded the site. No mussel evidence was observed.

Table 35. CPUE for Freshwater Mussels Kenneth Creek 170202.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
N/A	N/A	~	~
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.34 Hectors Creek 170202.4ted

This survey was conducted for 1.33 person hours upstream of the Baptist Grove Road (SR 1427) crossing (Figure 4). Habitat consisted of a shallow sequence of primarily run and pool with substrates of fine sand, gravel, and bedrock. The stream channel ranged from 12 to 20 feet wide with relatively stable banks 3 to 6 feet high. A wide, forested buffer surrounded the site.

Table 36. CPUE for Freshwater Mussels Hectors Creek 170202.4ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	16	12.0/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	U
Campeloma decisum	Pointed Campeloma	~	R

5.1.3.35 Little White Oak Creek 170207.1ted

This survey was conducted for 1.0 person hour downstream of the Friendship Road (SR 1149) crossing (Figure 4). Habitat consisted of a shallow sequence of riffle, run, and pool with primarily sand and pebble substrate. The small stream channel ranged from 10 to 15 feet wide with variably stable to unstable banks up to 6 feet high. A wide, forested floodplain buffer surrounded the site. No mollusks were observed during the efforts.

5.1.3.36 White Oak Creek 170207.2ted

This survey was conducted for 1.25 person hours upstream of the New Hill Road (SR 1152) crossing (Figure 4). Downstream and through the road crossing the stream presented as pool habitat with no visible flow. Habitat in the evaluated reach consisted of lotic sequence of run and pool with primarily silt, sand, and pebble substrates. The stream channel ranged from 20 to

30 feet wide with eroded banks up to 6 feet high. The channel was heavily scoured in areas with large deposits of woody debris. A wide, forested floodplain buffer surrounded the site. No mollusks were observed during the survey.

5.1.3.37 Kenneth Creek 170207.3ted

This survey was conducted for 2.53 person hours upstream of the Rawls Church Road (SR 1415) crossing (Figure 4). Habitat consisted of a sequence of riffle, run, and pool with a variable mix of silt, sand, gravel, and cobble substrates. The stream channel ranged from 15 to 25 feet wide with generally unstable banks 6 to 12 feet high. A wide forested buffer surrounded the site.

Table 37. CPUE for Freshwater Mussels Kenneth Creek 170207.3ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	33	13.04/hr
Villosa delumbis	Eastern Creekshell	4	1.58/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.38 Big Branch 170207.4ted

This survey was conducted for 1.5 person hours downstream of the Woods Creek Road (SR 1154) crossing (Figure 4). Habitat consisted of a shallow sequence of riffle, run, and pool with primarily unconsolidated sand substrate. The small stream channel ranged from 10 to 15 feet wide with banks exhibiting some erosion and undercutting 3 to 6 feet high. A relatively narrow forested buffer surrounded the site; managed pine plantation and a golf course were present in the immediate area beyond the site. No mollusks were observed during the efforts.

5.1.3.39 Little Creek 170208.1ted

This survey was conducted for 7.16 person hours in a reach accessed from a gas line right of way off Creekside Drive (Figure 4). Habitat consisted of a riffle, run, and pool sequence with substrates of silt, sand, gravel, and clay. A large amount of woody debris was present in pools and along banks in areas. The stream channel ranged from 15 to 25 feet wide with variably stable to eroded banks 3 to 6 feet high. A wide, forested floodplain buffer was present to surrounding agricultural and residential land uses.

Table 38. CPUE for Freshwater Mussels Little Creek 170208.1ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	210	29.33/hr
Elliptio icterina	Variable Spike	48	6.70/hr
Elliptio sp c.f. *mediocris*	No common name	4	0.56/hr
Elliptio congaraea	Carolina Slabshell	2	0.28/hr
Strophitus undulatus	Creeper	2	0.28/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	R

5.1.3.40 Cary Branch 170208.2ted

This survey was conducted for 1.2 person hours downstream of the Rex Road (SR 1127) crossing (Figure 4). Habitat consisted of a sequence of riffle, run, and pool with primarily sand, gravel, and clay substrates. The stream channel ranged from 15 to 20 feet wide with eroded banks 6 to 10 feet high. The channel was heavily scoured in areas. A wide, forested buffer surrounded the site.

Table 39. CPUE for Freshwater Mussels Cary Branch 170208.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	1	0.83/hr
Uniomerus carolineanus	Florida Pondhorn	4	3.33/hr

5.1.3.41 Neuse River 170321.1ted

This survey consisted of a concentrated search for live mussels in run habitat and river margins near an island upstream of the US 64 Business crossing and shoreline searches for shells in muskrat middens downriver from Milburnie dam to the island (Figure 4). Active surveys for live mussels were conducted for 1.0 person hour during which the species below were found. Habitat consisted of run and pool with primarily sand substrate, silt margins, and areas of gravel, cobble, and boulder. The river channel was generally over 100 feet wide with variably stable banks ranging from 10 to 12 feet high. A narrow to moderately wide forested floodplain buffer was present to surrounding greenway and residential land uses.

Table 40. CPUE for Freshwater Mussels Neuse River 170321.1ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.0/hr
Elliptio congaraea	Carolina Slabshell	4	4.0/hr
Elliptio complanata	Eastern Elliptio	40	40.0/hr
Elliptio icterina	Variable Spike	2	2.0/hr
Elliptio roanokensis	Roanoke Slabshell	47	47.0/hr
Lampsilis radiata	Eastern Lampmussel	2	2.0/hr
Pyganadon cataracta	Eastern Floater	1	1.0/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	VA

5.1.3.42 Neuse River 170321.2ted

This survey was conducted for 7 person hours downstream of the Poole Road crossing (Figure 4). Surveys were concentrated on shallow river margins and runs known to be occupied by the Green Floater (*Lasmingona subviridis*) and other rare associates. Habitat consisted primarily of silt and sand with areas of gravel, cobble, and boulder in higher velocity runs. A large amount of woody debris was present. The river channel was generally over 100 feet wide with variably stable banks ranging from 10 to 12 feet high. A wide, mature forested floodplain buffer surrounded the site.

Table 41. CPUE for Freshwater Mussels Neuse River 170321.2ted

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	0 (2 shell)	~
Elliptio congaraea	Carolina Slabshell	8	1.14/hr
Elliptio complanata	Eastern Elliptio	16	2.29/hr
Elliptio roanokensis	Roanoke Slabshell	157	22.43/hr
Lampsilis radiata	Eastern Lampmussel	9	1.29/hr
Lasmingona subviridis	Green Floater	0 (1 shell)	~
Utterbackia imbecillis	Paper Pondshell	1	0.14/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	VA
Campeloma decisum	Pointed Campeloma	~	R
Elimia catenaria	Gravel Elimia	~	R

5.1.3.43 Black Creek 170414.1tws

This survey in Black Creek was conducted for 2 person hours above the Federal Road (SR 1331) crossing (Figure 4). Habitat consisted of run and pool with substrate dominated by sand and pebble. Water clarity was light tannic. The stream channel was approximately 13 feet wide with banks up to 2 feet high. Some erosion and undercutting was present along the banks. A moderate forested buffer surrounded the site.

Table 42. CPUE for Freshwater Mussels Black Creek 170414.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	76	38.0/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	C

5.1.3.44 Neuse River 170414.2tws

This survey was conducted for 3 person hours downstream of the Poole Road (SR 1007) crossing (Figure 4). Habitat consisted primarily of riffle and run with substrate dominated by gravel and cobble in higher velocity runs. Water conditions were slightly turbid during the survey. The stream channel was approximately 100 feet wide with stream banks approximately 8 feet high. Some erosion and undercutting was present along the banks. A moderate forested floodplain buffer surrounds the site.

Table 43. CPUE for Freshwater Mussels Neuse River 170414.2tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	0 (1 shell)	~
Elliptio cistellaeformis	Box spike	10	3.33/hr
Elliptio complanata	Eastern Elliptio	92	30.67/hr
Elliptio congaraea	Carolina Slabshell	6	2.0/hr
Elliptio icterina	Variable Spike	14	4.67/hr
Elliptio roanokensis	Roanoke Slabshell	104	34.67/hr
Lampsilis radiata	Eastern Lampmussel	7	2.33/hr
Lasmigona subvirdis	Green Floater	1 (1 shell)	0.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C

5.1.3.45 Little Creek 170518.1tws

The Little Creek survey at Steel Bridge Road (SR 1562) was conducted for 4 person hours (Figure 4). Habitat consisted of riffle, run, and pool with substrate dominated by sand and cobble. Little Creek was approximately 20 feet wide with bank height of approximately 3 feet. Some erosion and undercutting was present along the banks. During the survey, the water was light tannic. There was a moderate forested buffer surrounding the survey site.

Table 44. CPUE for Freshwater Mussels Little Creek 170518.1tws

Scientific Name	Common Name	#live (#shell)	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	189	47.25/hr
Elliptio icterina	Variable Spike	19	4.75/hr
Elliptio sp c.f. mediocris	No common name	2	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	C
Campeloma decisum	Pointed Campeloma	~	C

5.2 Carolina Madtom Surveys

Fish surveys targeting the Carolina Madtom were conducted by Three Oaks personnel on the following dates:

Personnel	4/12/17	4/13/17	4/14/17	5/11/17	5/17/17	5/18/17	5/19/17
Tim Savidge (Permit # 16-ES0034)		X	X		X	X	X
Tom Dickinson (Permit # 16/17-ES00343)	X			X			
John Fridell					X	X	X
John Roberts	X	X		X			
Nathan Howell		X	X	X			
Mary Frazer	X	X	X				
Matt Haney (NCDOT)		X					
Lizzy Stokes-Cawley			X		X	X	X
Hannah Slyce					X	X	X
Nancy Scott	X			X			

5.2.1. Survey Locations

Survey locations were selected based on previous survey data, proximity to the FLUSA, habitat requirements for the target species and field conditions.

5.2.2. Methodology

Two fish survey methodologies were employed. The primary methodology used was based on the NCWRC Carolina Madtom protocol, which involved conducting visual surveys in varying reaches of target streams. The survey team spread out across the creek into survey lanes with each surveyor covering no more than approximately 5 meters of wetted width. Visual surveys were conducted using mask and snorkel and/or glass bottom view buckets (bathyscopes). All habitat types in the survey reach (riffle, run, pool, slack-water, etc.) were sampled. Instream debris (rocks, logs, bark, mussel shells, leaf packs, bottles and other artificial cavities) was repositioned to look for inhabitants. Presence of fish species observed was noted at each survey location.

Electrofishing was also employed at some locations. In some instances, this method was used to supplement and assess the effectiveness of the visual surveys. In these instances, electrofishing surveys were conducted in the exact reach where a visual survey had previously been conducted. In other situations, where habitat conditions were not conducive for visual surveys (i.e. very shallow riffles, very swift runs, etc.) electrofishing was the sole methodology. Fish Surveys were conducted using a single Smith Root LR-24 backpack electrofishing unit and dip nets. Crew members not operating the electrofishing units collected stunned fish with dip nets. Passive seining, with two biologists holding the seine in riffle and run habitat while the other biologists shocked downstream into the seine, was employed at the Middle Creek site above Crantock Road. All habitat types in the survey reach (riffle, run, pool, slack-water, etc.) were sampled, with special attention given to habitats preferred by the Carolina Madtom. Stunned fish were placed into buckets and were identified, counted and released onsite.

5.2.3. Visual Fish Survey Results

5.2.3.1 Swift Creek 170412.1ted

This survey in Swift Creek was conducted for 7.67 person hours as accessed from Swift Creek Nursery off Cleveland Road (Figure 5). Habitat consisted of run and riffle with substrate dominated by gravel, sand, and cobble. Water clarity was clear. The stream channel was approximately 50 feet wide with banks up to 12 feet high. A wide, forested buffer surrounded the site.

Table 45. Freshwater Fish Observed at Swift Creek 170412.1ted

Scientific Name	Common Name
Anguilla rostrata	American Eel
Etheostoma flabellare	Fantail Darter
Etheostoma nigrum	Johnny Darter
Etheostoma vitreum	Glassy Darter
Hypentelium nigricans	Northern Hogsucker
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Noturus insignis	Margined Madtom
Notropis sp.	a Shiner
Percina roanoka	Roanoke Darter

5.2.3.2 Swift Creek 170412.2ted

This survey in Swift Creek was conducted for 2.0 person hours upstream from Barber Mill Road (SR 1555, Figure 5). Habitat consisted of run and riffle with substrate dominated by gravel, sand, and cobble. Water clarity was clear. The stream channel was approximately 60 feet wide with banks up to 10 feet high. A moderate forested buffer surrounded the site.

Table 46. Freshwater Fish Observed at Swift Creek 170412.2ted

Scientific Name	Common Name
Etheostoma nigrum	Johnny Darter
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill

5.2.3.3 Swift Creek 170412.3ted

This survey in Swift Creek was conducted for 2.0 person hours upstream from Barber Mill Road (SR 1555, Figure 5). Habitat consisted of run and pool with substrate dominated by gravel, sand, and cobble. Water clarity was clear. The stream channel was approximately 60 feet wide with banks up to 10 feet high. A moderate forested buffer surrounded the site.

Table 47. Freshwater Fish Observed at Swift Creek 170412.3ted

Scientific Name	Common Name
Etheostoma nigrum	Johnny Darter
Hypentelium nigricans	Northern Hogsucker
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Percina roanoka	Roanoke Darter

5.2.3.4 Swift Creek 170517.2tws

This survey in Swift Creek was conducted for 2.67 person hours above the Steel Bridge Road (SR 1562) crossing (Figure 5). Habitat consisted of run and riffle with substrate dominated by cobble and gravel. Water clarity was clear. The stream channel was approximately 35 feet wide with banks up to 7 feet high. A moderate forested buffer surrounded the site.

Table 48. Freshwater Fish Observed at Swift Creek 170517.2tws

Scientific Name	Common Name
Anguilla rostrata	American Eel
Cyprinella analostana	Satinfin Shiner
Etheostoma olmstedi	Tessellated Darter
Ictalurus punctatus	Channel Catfish
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Noturus insignis	Margined Madtom

5.2.3.5 Little Creek 170518.1tws

The Little Creek survey location located at Steel Bridge Road (SR 1562) was conducted for 2.0 person hours (Figure 5). Habitat consisted of riffle, run, and pool with substrate dominated by sand and cobble. Little Creek was approximately 20 feet wide with bank height of approximately 3 feet. Some erosion and undercutting was present along the banks. During the survey, the water was light tannic. There was a moderate forested buffer surrounding the survey site.

Table 49. Freshwater Fish Observed at Little Creek 170518.1tws

Scientific Name	Common Name
Anguilla rostrate	American Eel
Etheostoma olmstedi	Tessellated Darter
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Lythrurus matutinus	Pinewoods Shiner
Percina roanoka	Roanoke Darter

5.2.3.6 Black Creek 170413.3tws

This survey in Black Creek was conducted for 2.0 person hours above the Raleigh Road (SR 1330) crossing (Figure 5). Habitat consisted of run and pool with substrate dominated by coarse sand and gravel. Water clarity was light tannic. The stream channel ranged from 13 to 16 feet wide with stable banks up to 2 feet high. A wide, mature forested buffer surrounded the site.

Table 50. Freshwater Fish Observed at Black Creek 170413.3tws

Scientific Name	Common Name
Aphredoderus sayanus	Pirate Perch
Elassoma zonatum	Banded Pygmy Sunfish
Enneacanthus gloriosus	Bluespotted Sunfish
Esox niger	Chain Pickerel
Etheostoma olmstedi	Tessellated Darter
Gambusia holbrooki	Eastern Mosquitofish
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear Sunfish
Noturus gyrinus	Tadpole Madtom

5.2.3.7 Black Creek 170414.1tws

This survey in Black Creek was conducted for 2.0 person hours above the Federal Road (SR 1331) crossing (Figure 5). Habitat consisted of run and pool with substrate dominated by sand and pebble. Water clarity was light tannic. The stream channel was approximately 13 feet wide with banks up to 2 feet high. Some erosion and undercutting was present along the banks. A moderate forested buffer surrounded the site.

Table 51. Freshwater Fish Observed at Black Creek 170414.1tws

Scientific Name	Common Name
Aphredoderus sayanus	Pirate Perch
Cyprinella analostana	Satinfin Shiner
Esox niger	Chain Pickerel
Gambusia holbrooki	Eastern Mosquitofish
Noturus gyrinus	Tadpole Madtom

5.2.3.8 Middle Creek 170413.1tws

This survey in Middle Creek was conducted for 2.5 person hours in a reach downstream from Crantock Road (SR 1504, Figure 5). Habitat consisted of riffle, run, and pool with a gravel and sand substrate. The stream channel was approximately 42 feet wide with banks approximately 5 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A moderately wide forested/shrub-brush buffer was present at the survey reach.

Table 52. Freshwater Fish Observed at Middle Creek 170413.1tws

Scientific Name	Common Name
Anguilla rostrata	American Eel
Cyprinella analostana	Satinfin Shiner
Enneacanthus gloriosus	Bluespotted Sunfish
Etheostoma olmstedi	Tessellated Darter
Ictalurus punctatus	Channel Catfish
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Percina roanoka	Roanoke Darter

5.2.3.9 Middle Creek 170413.2tws

This survey of Middle Creek was conducted upstream of Crantock Road (SR 1504) for 2.03 person hours (Figure 5). Habitat consisted of riffle, run, and pool with a cobble and gravel substrate. The stream channel was approximately 39 feet wide and the banks were approximately 5 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal and clear. A narrow to moderately wide forest buffer was present at the site.

Table 53. Freshwater Fish Observed at Middle Creek 170413.2tws

Scientific Name	Common Name
Anguilla rostrata	American Eel
Etheostoma olmstedi	Tessellated Darter
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Percina roanoka	Roanoke Darter
Pylodictis olivaris	Flathead Catfish

5.2.3.10 Neuse River 170414.2tws

This survey was conducted for 2.0 person hours downstream of the Poole Road (SR 1007) crossing (Figure 5). Habitat consisted primarily of riffle and run with substrate dominated by gravel and cobble in higher velocity runs. Water conditions were slightly turbid during the survey. The stream channel was approximately 100 feet wide with stream banks approximately 8 feet high. Some erosion and undercutting was present along the banks. A moderate forested floodplain buffer surrounded the site.

Table 54. Freshwater Fish Observed at Neuse River 170414.2tws

Scientific Name	Common Name
Anguilla rostrata	American Eel
Etheostoma olmstedi	Tessellated Darter
Ictalurus punctatus	Channel Catfish
Lepomis auritus	Redbreast Sunfish
Lepomis macrochirus	Bluegill
Noturus gyrinus	Tadpole Madtom
Noturus insignis	Margined Madtom
Percina nevisense	Chainback Darter
Percina roanoka	Roanoke Darter

5.2.3.11 White Oak Creek

A visual survey of this site was not conducted using the methods described in this section. The site conditions were not conducive to a visual survey, as the stream was small and the water was turbid. Instead, the methods described in the following section were used. See section 5.2.4.4 for survey results.

5.2.4. Electrofishing Surveys

Surveys were conducted using electroshockers at select sites with the highest quality Carolina Madtom habitat observed during other efforts. The following discussion focuses on these additional surveys and the results of these surveys.

5.2.4.1 Swift Creek 170511.1ted

This survey in Swift Creek was from Swift Creek Nursery off Cleveland Road (Figure 5). Habitat consisted of run and riffle with substrate dominated by gravel, sand, and cobble. Water clarity was clear. The stream channel was approximately 50 feet wide with banks up to 12 feet high. A wide forested buffer surrounded the site.

In addition to a visual survey at this location (Section 5.2.3.1), a more comprehensive survey was performed using the electroshocking methodology. The protocol for measuring an Index of Biotic Integrity (IBI) was used at this site to determine the quality of the fish community. The survey was conducted using two electroshocking units, two people using dip nets, and three seine net blocks for a total of 6,543 electroshocking seconds. The IBI score was 52, which represents a “Good” rating.

Table 55. Freshwater Fish Observed at Swift Creek 170511.1ted

Scientific Name	**Common Name**	**Number Observed**
Anguilla rostrata	American Eel	13
Aphredoderus sayanus	Pirate Perch	4
Cyprinella analostana	Satinfin Shiner	24
Enneacanthus gloriosus	Bluspotted Sunfish	4
Erymizon oblongus	Creek Chubsucker	1
Esox niger	Chain Pickerel	2
Etheostoma flabellare	Fantail Darter	16
Etheostoma nigrum	Johnny Darter	10
Etheostoma olmstedi	Tessellated Darter	11
Etheostoma vitrium	Glassy Darter	8
Gambusia holbrooki	Eastern Mosquitofish	1
Hypentelium nigricans	Northern Hogsucker	3
Ictalurus punctatus	Channel Catfish	5
Lepomis auritus	Redbreast Sunfish	39
Lepomis cyanellus	Green Sunfish	4
Lepomis gibbosus	Pumpkinseed	1
Lepomis gulosus	Warmouth	6
Lepomis machochirus	Bluegill	50
Luxilus albeolus	White Shiner	4
Lythrurus matutinus	Pinewoods Shiner	6
Micropterus salmoides	Largemouth Bass	3
Nocomis raineyi	Bull Chub	1
Notropis amoenus	Comely Shiner	9
Notropis cummingsae	Dusky Shiner	9
Notropis hudsonius	Spottail Shiner	6
Notropis procne	Swallowtail Shiner	9
Noturus insignis	Margined Madtom	1
Percina nevisense	Chainback Darter	2
Percina roanoka	Roanoke Darter	48
Pomoxis nigromaculatus	Black Crappie	6
Pylodictis olivaris	Flathead Catfish	3
Scartomyzon cervinus	Black Jumprock	2
Semotilus atromaculatus	Creek Chub	1

5.2.4.2 Middle Creek 170517.1tws

This survey of Middle Creek was conducted upstream of Crantock Road (SR 1504) for 673 electroshocking seconds (Figure 5). A visual survey had been performed previously at this site 170413.2tws (Table 53 in Section 5.2.2.9). More species were recorded using the electrofishing methods; no species detected using visual surveys were also not found electrofishing (Table 56). No madtom species were detected using either method (Tables 53 and 56).

Table 56. Freshwater Fish Observed at Middle Creek 170517.1tws

Scientific Name	Common Name	Number Observed
Anguilla rostrata	American Eel	6
Cyprinella analostana	Satinfin Shiner	8
Enneacanthus gloriosus	Bluespotted Sunfish	5
Esox niger	Chain Pickerel	1
Etheostoma olmstedi	Tessellated Darter	11
Gambusia holbrooki	Eastern Mosquitofish	10
Lepomis auritus	Redbreast Sunfish	18
Lepomis macrochirus	Bluegill	11
Lepomis microlophus	Redear Sunfish	2
Luxilus albeolus	White Shiner	15
Notropis procne	Swallowtail Shiner	7
Percina nevisense	Chainback Darter	6
Percina roanoka	Roanoke Darter	15
Pylodictis olivaris	Flathead Catfish	1

5.2.4.3 Little Creek 170518.2tws

The survey of Little Creek, above Steel Bridge Road (SR 1562), was conducted for 587 electroshocking seconds (Figure 5). A visual survey had been performed previously at this site 170518.1tws (Table 49 in Section 5.2.2.5). More species were recorded using the electrofishing methods; no species were detected using visual surveys that were also not found electrofishing (Table 57). However, the visual surveys did not detect the Margined Madtom (Table 49), yet it was easily detected (n=7) using electrofishing (Table 57).

Table 57. Freshwater Fish Observed at Little Creek 170518.2tws

Scientific Name	Common Name	Number Observed
Ameiurus brunneus	Snail Bullhead	1
Ameiurus natalis	Yellow Bullhead	1
Anguilla rostrata	American Eel	8
Aphredoderus sayanus	Pirate Perch	2
Cyprinella analostana	Satinfin Shiner	6
Enneacanthus gloriosus	Bluespotted Sunfish	3
Esox niger	Chain Pickerel	1
Etheostoma flabellare	Fantail Darter	2
Etheostoma olmstedi	Tessellated Darter	12
Gambusia holbrooki	Eastern Mosquitofish	Present*
Ictalurus punctatus	Channel Catfish	1
Lepomis auritus	Redbreast Sunfish	7
Lepomis macrochirus	Bluegill	4
Lepomis microlophus	Redear Sunfish	2
Luxilus albeolus	White Shiner	4
Lythrurus matutinus	Pinewoods Shiner	11
Moxostoma pappillosum	V-Lip Redhorse	1
Nocomis leptocephalus	Bluehead Chub	8
Nocomis raneyi	Bull Chub	2
Notropis cummingsae	Dusky Shiner	6

Table 57. Freshwater Fish Observed at Little Creek 170518.2tws (continued)

Scientific Name	Common Name	Number Observed
Notropis hudsonius	Spottail Shiner	1
Notropis procne	Swallowtail Shiner	8
Noturus insignis	Margined Madtom	7
Percina roanoka	Roanoke Darter	6
Scartomyzon cervinus	Black Jumprock	1

* Many individuals captured, total number not recorded

5.2.4.4 White Oak Creek 170518.3tws

The survey of White Oak Creek, located at NC 42 below Austin Pond, was conducted for 489 electroshocking seconds (Figure 5). Habitat consisted of riffle, run, and pool with substrate dominated by sand and cobble. White Creek was approximately 6 to 11 feet wide in the riffle run section, and widened to 50 feet in the pool within the tailrace of Austin Pond. The unstable banks were approximately 5 feet high. During the survey, the water was slightly turbid. There was a moderate forested buffer surrounding the survey site.

Table 58. Freshwater Fish Observed at White Oak Creek 170518.3tws

Scientific Name	Common Name	Number Observed
Ameiurus brunneus	Snail Bullhead	3
Ameiurus platycephalus	Flat Bullhead	1
Anguilla rostrata	American Eel	8
Cyprinella analostana	Satinfin Shiner	12
Enneacanthus gloriosus	Bluespotted Sunfish	2
Etheostoma olmstedi	Tessellated Darter	7
Gambusia holbrooki	Eastern Mosquitofish	Present*
Lepomis auritus	Redbreast Sunfish	21
Lepomis cyanellus	Green Sunfish	6
Lepomis gulosus	Warmouth	2
Lepomis macrochirus	Bluegill	14
Lepomis microlophus	Redear Sunfish	2
Luxilus albeolus	White Shiner	3
Notropis procne	Swallowtail Shiner	1
Noturus insignis	Margined Madtom	2
Percina nevisense	Chainback Darter	1
Percina roanoka	Roanoke Darter	3

* Many individuals captured, total number not recorded

5.2.4.5 Middle Creek 170519.1tws

This survey of Middle Creek was conducted downstream of Smith Road (SR 2553) for 572 electroshocking seconds (Figure 5). Habitat consisted of riffle, run, and pool with a sand and gravel substrate. The stream channel was approximately 30 feet wide and the banks were approximately 7 feet high. The stream banks were unstable. Stream conditions were normal and clear. A narrow to moderately wide forest buffer was present. In addition to the following fish species found during the survey, an individual Neuse River Waterdog was located (see Section 5.3.3.3 for details on Waterdog surveys).

Table 59. Freshwater Fish Observed at Middle Creek 170519.1tws

Scientific Name	Common Name	Number Observed
Anguilla rostrata	American Eel	8
Cyprinella analostana	Satinfin Shiner	5
Enneacanthus gloriosus	Bluespotted Sunfish	1
Esox niger	Chain Pickerel	1
Etheostoma olmstedi	Tessellated Darter	11
Gambusia holbrooki	Eastern Mosquitofish	Present*
Lepomis auritus	Redbreast Sunfish	21
Lepomis cyanellus	Green Sunfish	2
Lepomis macrochirus	Bluegill	7
Luxilus albeolus	White Shiner	5
Nocomis leptocephalus	Bluehead Chub	7
Notropis cummingsae	Dusky Shiner	4
Notropis procne	Swallowtail Shiner	8
Percina nevisense	Chainback Darter	1
Percina roanoka	Roanoke Darter	11
Pylodictis olivaris	Flathead Catfish	3

* Many individuals captured, total number not recorded

5.2.4.6 Middle Creek 170519.2tws

This survey in Middle Creek downstream of NC 50 was conducted for 537 electroshocking seconds (Figure 5). Habitat consisted of run, riffle, and pool with sand and gravel substrate dominant. The stream channel in the surveyed reach was approximately 40 feet wide with banks 6 feet high. Some erosion and undercutting was present along the banks. Stream conditions were low and clear. A moderately wide forested buffer was present surrounding the survey reach.

Table 60. Freshwater Fish Observed at Middle Creek 170519.2tws

Scientific Name	Common Name	Number Observed
Anguilla rostrata	American Eel	5
Aphredoderus sayanus	Pirate Perch	1
Cyprinella analostana	Satinfin Shiner	10
Enneacanthus gloriosus	Bluespotted Sunfish	4
Etheostoma olmstedi	Tessellated Darter	10
Lepisosteus osseus	Longnose Gar	1
Lepomis auritus	Redbreast Sunfish	19
Lepomis macrochirus	Bluegill	11
Luxilus albeolus	White Shiner	8
Nocomis leptocephalus	Bluehead Chub	6
Nocomis raneyi	Bull Chub	1
Notropis cummingsae	Dusky Shiner	4
Notropis hudsonius	Spottail Shiner	1
Notropis procne	Swallowtail Shiner	6
Percina roanoka	Roanoke Darter	9
Pylodictis olivaris	Flathead Catfish	1

5.2.4.7 Middle Creek 170519.3tws

This survey in Middle Creek was conducted upstream of Barber Bridge Road (SR 2739) for 389 electroshocking seconds (Figure 5). Habitat consisted of riffle, run, and pool with a sand and cobble substrate. The stream channel was approximately 20 feet wide with banks ranging from 2.5 to 3 feet high. Some erosion and undercutting was present along the banks. Stream conditions were normal flow and slightly turbid. A moderate forested buffer was present surrounding the survey reach.

Table 61. Freshwater Fish Observed at Middle Creek 170519.3tws

Scientific Name	Common Name	Number Observed
Ameiurus brunneus	Snail Bullhead	1
Anguilla rostrata	American Eel	5
Cyprinella analostana	Satinfin Shiner	13
Enneacanthus gloriosus	Bluespotted Sunfish	6
Etheostoma olmstedi	Tessellated Darter	11
Lepomis auritus	Redbreast Sunfish	15
Lepomis macrochirus	Bluegill	6
Lepomis microlophus	Redear Sunfish	1
Luxilus albeolus	White Shiner	5
Notropis procne	Swallowtail Shiner	4
Noturus gyrinus	Tadpole Madtom	1
Percina roanoka	Roanoke Darter	6

5.3 Neuse River Waterdog Surveys

Surveys were conducted by Three Oaks personnel on the following dates:

Personnel	12/20/16	12/21/16	12/22/16	12/23/16	2/7/17	2/8/17	2/9/17	2/10/17
Kate Sevick (Permit #16-ES00485)	X	X			X	X	X	
Tom Dickinson (Permit # 16/17-ES00343)			X					
Tim Savidge (Permit # 16-ES0034)				X				
Nancy Scott		X					X	
Chris Sheats	X							
Nathan Howell	X			X				X
Mary Frazer	X		X		X	X		X

5.3.1. Survey Locations

Survey locations were selected based on location within the FLUSA, previous NCWRC survey data, and Three Oaks' staff knowledge of appropriate habitat and previous sightings. Surveys were conducted in December 2016, in Middle Creek (at three locations: Susan Road, Smith Road, and Crantock Road), Black Creek, Neuse River (Milburnie Dam), White Oak Creek, and Little Creek based on previous negative survey results or no available survey information. In February 2017, four additional sites were surveyed in Middle Creek (Barber Bridge Road), Swift

Creek (NC 42 and Barber Mill Road) and Neuse River (Poole Road) along with repeat sampling of two sites in Middle Creek (Susan Road and Crantock Road).

5.3.2. Methodology

Three Oaks developed methods in consultation with the USFWS and NCWRC that were designed to replicate winter trapping efforts conducted as part of the species status assessment undertaken by these agencies and collaborators. Ten baited traps were set for four soak nights at each of the survey locations. Trap sites were selected based on habitat conditions and accessibility. Undercut banks, with some accumulation of leaf pack, as well as back eddy areas within runs were the primary microhabitats selected. Traps were baited with a combination of chicken liver and hot dogs, and allowed to soak overnight. The traps were checked daily, all species found within the traps were recorded, and the traps were re-baited. If the targeted Neuse River Waterdog was found at a site, trapping efforts were discontinued.

Prior to the 2017 surveys, Three Oaks was invited to assist in a NCWRC study, in cooperation with researchers at Nash County Community College, examining the genetics of the Neuse River Waterdog. Tissue samples were collected in the field from the tail of any captured Neuse River Waterdogs and sent to NCWRC staff. In addition to new sites, Three Oaks resurveyed a few locations that had positive captures from 2016 in an effort to contribute additional data to this study.

5.3.3. Neuse River Waterdog Survey Results

The Neuse River Waterdog was found at three of the Middle Creek Sites (Susan Road, Smith Road, and Crantock Road) and in Swift Creek (Barber Mill Road). In addition, 14 fish species along with multiple crayfish were found during trapping efforts. The results for each survey location are shown below.

5.3.3.1 Middle Creek at Barber Bridge Road (170203.4kms)

This Middle Creek survey location is at Barber Bridge Road (SR 2739) in Johnston County (Figure 6). All ten traps were placed downstream of the bridge crossing. At this survey location, Middle Creek ranged from 20 to 35 feet wide with water depths of 1 to 6 feet with a sandy substrate interspersed with gravel and cobble sections. Water flow was slightly turbid and at a moderate to fast velocity. The buffer was wide, forested, and intact within the survey vicinity.

Table 62. Middle Creek at Barber Bridge Road (170203.4kms)– February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	~	~
2	~	~	~	Catfish
3	~	Blue Spotted Sunfish (1)	Blue Spotted Sunfish (1), Bluegill (1), and Crayfish (1)	~
4	~	~	~	~
5	~	~	~	~
6	~	~	~	~
7	~	~	~	White Shiner (1)
8	~	~	~	~
9	~	Crayfish (1)	~	Crayfish (2)
10	~	~	~	~

5.3.3.2 Middle Creek near Susan Road (161220.1kms and 170203.2kms)

This Middle Creek survey location is west/upstream of NC 50 and south of Susan Drive in Johnston County (Figure 6). At this survey location, Middle Creek ranged from 15 to 30 feet wide with water depths of 1 to 3 feet. The site was surveyed twice. Water flow was clear and at a moderate to fast velocity. The buffer was wide, forested, and intact within the survey vicinity which contained multiple wetlands.

Table 63. Middle Creek near Susan Road (161220.1kms)– December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	Crayfish (1)		
2	~	~		
3	~	~		
4	~	Crayfish (1)		
5	~	~		
6	Crayfish (2)	Neuse River Waterdog (1)		
7	~	Crayfish (1)		
8	~	Crayfish (1)		
9	~	Crayfish (1)		
10	~	~		

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

Table 64. Middle Creek near Susan Road (170203.2kms) – February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	Crayfish (1)			
2	Neuse River Waterdog (1)			
3	~			
4	~			
5	~			
6	~			
7	Crayfish (1)			
8	~			
9	~			
10	~			

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

5.3.3.3 Middle Creek at Smith Road (161220.2kms)

This Middle Creek survey location is upstream of the Smith Road (SR 1507) crossing in Johnston County (Figure 6). The banks are quite steep and eroding within this survey location. Middle Creek ranged from 15 to 20 feet wide with water depths of at least 6 feet. The survey location was surrounded by a forested, intact, toe-of-slope floodplain, which contained multiple wetlands. During the survey, the water was clear with a fast velocity.

Table 65. Middle Creek at Smith Road (161220.2kms) – December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	~			
2	Neuse River Waterdog (2)			
3	~			
4	Neuse River Waterdog (1)			
5	~			
6	~			
7	~			
8	~			
9	Crayfish (1)			
10	Crayfish (3)			

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

5.3.3.4 Middle Creek at Crantock Road (161220.3kms and 170203.3kms)

This Middle Creek survey location is downstream of the Crantock Road (SR 1504) crossing in Johnston County (Figure 6). It was surveyed twice. Upstream of the crossing is a breached concrete dam structure. Downstream, Middle Creek ranges from 15 to 20 feet wide with depths between 2 to 4 feet. During the survey, the water velocity was fast and clear. The site is surrounded by a forested buffer that has been logged east of the stream.

Table 66. Middle Creek at Crantock Road (161220.3kms) – December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	Neuse River Waterdog (1), Crayfish (1)			
2	~			
3	~			
4	~			
5	Neuse River Waterdog (1)			
6	~			
7	Crayfish (1)			
8	~			
9	Pirate Perch (1), Crayfish (1)			
10	Neuse River Waterdog (1), Crayfish (1)			

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

Table 67. Middle Creek at Crantock Road (170203.3kms) – February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	Crayfish (1)	~		
2	~	Spottail Shiner (1)		
3	~	~		
4	~	~		
5	~	White Shiner (1)		
6	~	Neuse River Waterdog (1)		
7	~	Bluegill (1) and Crayfish (1)		
8	~	Pirate Perch (1) and Warmouth (1)		
9	~	~		
10	~	~		

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

5.3.3.5 Black Creek (161220.4kms)

The Black Creek Survey location is approximately 0.2 river mile east/downstream of Raleigh Road (SR 1330) in Johnston County (Figure 6). Unlike the other survey locations, the Black Creek location is surrounded by a large wetland complex. Water was slightly tannic to tannic with a moderate velocity. The creek ranged from 10 to 20 feet wide with water depths from 1 to 4 feet. The survey location was surrounded by a large intact forested wetland buffer.

Table 68. Black Creek near Raleigh Rd (161220.4kms)– December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	~	~
2	~	~	~	~
3	~	~	~	~
4	~	~	~	~
5	~	~	~	~
6	~	~	~	~
7	~	~	~	Pirate Perch
8	~	~	~	~
9	~	~	~	~
10	~	~	~	~

5.3.3.6 Neuse River near Milburnie Dam (161220.5kms)

This Neuse River survey location is downstream of Milburnie Dam and upstream of New Bern Avenue (US 64) in Wake County (Figure 6). Eleven traps were placed at this site on both sides of the river based on the larger size of the system. The river ranged from 140 to 200 feet wide with depths greater than 6 feet. The water flow was clear with a fast velocity during the trapping effort. This portion of the Neuse River has a relatively intact forested buffer approximately 200 feet on either side of the river.

Table 69. Neuse River near Milburnie Dam (161220.5kms)– December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	Bluegill (1)	~	~	~
2	~	~	~	~
3	~	Sunfish (1)	Bluegill (1)	~
4	White Shiner (2)	Satinfin Shiner (1)	Satinfin Shiner (1)	~
5	~	Crayfish (1)	~	~
6	~	~	~	~
7	~	~	~	~
8	~	~	Redbreast Sunfish (1)	~
9	~	Channel Catfish (1)	~	~
10	~	~	~	~
11	~	~	Spottail Shiner (1)	~

5.3.3.7 Neuse at Poole Road (170203.6kms)

This Neuse River survey location is upstream of Poole Road (SR 1007) in Wake County (Figure 6). The river ranged from 100 to 120 feet wide with depths greater than 6 feet. The water flow was clear with a fast velocity during the trapping effort. This portion of the Neuse River has a relatively intact forested buffer approximately 200 feet on either side of the river.

Table 70. Neuse River at Poole Road (170203.6kms)– February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	Satinfin Shiner (5)	~
2	~	American Eel (1)	~	~
3	~	~	~	~
4	~	~	~	~
5	~	~	~	~
6	~	~	~	~
7	~	~	~	~
8	~	Spottail Shiner (1)	~	Catfish (1)
9	~	~	~	~
10	~	~	~	~

5.3.3.8 White Oak Creek (161220.6kms)

The White Oak Creek survey location is south/downstream of NC 42 and west of Anna Drive in Johnston County (Figure 6). Only nine traps were placed at this location because of equipment limitations. The creek ranged from 4 to 8 feet wide with water depths of approximately 2 to 6 feet. The water flow was clear with moderate velocity during the trapping effort. The buffer in this area is forested and intact.

Table 71. White Oak Creek at NS 42 (161220.6kms)– December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	~	~
2	~	~	~	~
3	Crayfish (1)	~	~	~
4	~	~	~	~
5	White Shiner (1)	Flyer (1)	~	~
6	~	~	~	~
7	~	~	~	White Shiner (2)
8	White Shiner (2)	~	~	~
9	~	~	Bluegill (2)	~

5.3.3.9 Little Creek (161220.7kms)

The Little Creek survey location is at Steel Bridge Road (SR 1562) with traps both upstream and downstream of the bridge (Figure 6). Little Creek ranged from 6 to 20 feet wide with water depths of approximately 2 to 6 feet. During the survey, the water was clear with moderate velocity. The buffer in the area is relatively intact and forested.

Table 72. Little Creek at Steel Bridge Road (161220.7kms)– December 2016

Trap #	Day 1	Day 2	Day 3	Day 4
1	Snail Bullhead (1), Creek Chub (1), Crayfish (1)	Crayfish (1)	~	~
2	~	~	Crayfish (1)	Crayfish (3)
3	Bluegill (1)	Pirate Perch (1)	~	~
4	~	~	~	~
5	~	~	~	~
6	~	~	~	Snail Bullhead (1)
7	Tessellated Darter (1), Margined Madtom (2)	Margined Madtom (1), Crayfish (1)	Margined Madtom (1)	~
8	White Shiner (2)	Snail Bullhead (3)	~	Snail Bullhead (1), Crayfish (2)
9	~	Pirate Perch (2)	Pirate Perch (1), Crayfish (1)	Crayfish (2)
10	Pirate Perch (1)	~	~	Crayfish (1)

5.3.3.10 Swift Creek at NC 42 (170203.5kms)

This Swift Creek survey location is south/downstream of NC 42 in Johnston County (Figure 6). The creek ranged from 25 to 45 feet wide with water depths of approximately 2 to 6 feet. The water flow was slightly turbid and with a moderate velocity during the trapping effort. The buffer in this area is cleared on the left descending bank and forested on the right descending bank.

Table 73. Swift Creek at NC 42 (170203.5kms)– February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	~	~
2	~	~	~	~
3	~	~	~	~
4	~	~	~	~
5	~	~	~	Crayfish
6	Crayfish (1)	~	~	~
7	~	~	American Eel (1)	NC Spiny Crayfish (1)
8	~	~	~	NC Spiny Crayfish (1)
9	~	~	Crayfish (1)	~
10	~	~	~	~

5.3.3.11 Swift Creek at Barber Mill Road (170203.4km)

This Swift Creek survey location is downstream of Barber Mill Road in Johnston County (Figure 6). The creek ranged from 15 to 25 feet wide with water depths of approximately 1 to 6 feet. The water flow was slightly turbid and with a moderate velocity during the trapping effort. The buffer in this area is poor with the right descending bank being a cutover.

Table 74. Swift Creek at Barber Mill Road (170203.4km) – February 2017

Trap #	Day 1	Day 2	Day 3	Day 4
1	~	~	Neuse River Waterdog (2)	
2	~	~	~	
3	~	~	~	
4	~	~	~	
5	~	~	~	
6	~	~	~	
7	~	~	~	
8	~	~	~	
9	~	~	~	
10	~	Crayfish (1)	American Eel (1)	

*Grey cells indicate target species presence was confirmed and additional survey days were not necessary

6.0 DISCUSSION/CONCLUSIONS

The results indicate that several streams in the study area continue to support diverse freshwater mussel and fish faunas. As discussed in Section 1.0, all target species have been reported within some of the study area streams at some point in time. The survey efforts detailed in this report serve to update and/or supplement species occurrence information within the study area streams. The information was gathered to support the development of a BA for this project, which will address direct, indirect, and cumulative effects of the proposed project on the DWM and Yellow Lance. A full analysis of the environmental baseline, discussion of species, and effects of the project on individual species will help determine the Biological Conclusions of federally protected species. The other target species, the Atlantic Pigtoe, Carolina Madtom, and Neuse River Waterdog will be included in the BA should they become proposed before the beginning of project construction.

6.1 Freshwater Mussel Surveys

Extensive mussel surveys conducted for this project in Swift Creek have documented that the DWM, Yellow Lance and Atlantic Pigtoe are still present. The data generated from these efforts have been presented in many other reports for this project. The mussel survey component of the aquatic species surveys presented in this report focused on other water bodies within the study area, as recent survey data was not available.

6.1.1 DWM

Other than one relict shell at site 161102.2tws in Middle Creek, the DWM was not found during these efforts. In addition to Swift Creek, the DWM has been found in Middle Creek, White Oak Creek (Swift Creek Tributary) and Little Creek within the study area. The last records of this species from these streams are from 1992, 1994, and 2003, respectively. Based on these and other survey efforts since 1992, it is unlikely that the DWM still occurs in Middle Creek; however, it cannot be ruled out entirely. Although it was not found in Little Creek during this survey effort, based on habitat conditions, and minimal survey efforts since 2003, the DWM could still be present in Little Creek.

While the DWM was reported from the Neuse River in the 1950's there are no recent records of occurrence. Although a diverse mussel fauna is still present in this portion of the Neuse River, the DWM was not found during this, or other recent surveys efforts; thus, it is likely extirpated from the Neuse River. Additionally, it was not found in any of the other streams surveyed during this effort, and is unlikely to occur in any of them.

6.1.2 Yellow Lance

In addition to Swift Creek, the Yellow Lance has also been recorded in Middle Creek, most recently in 2011. Other than the relicts found at site 161102.2tws, it was not found in Middle Creek during this effort. However, given the recent (2011) record, it should still be considered present in the stream. It was not found in any of the other streams surveyed during this effort, and is unlikely to occur in any of them.

6.1.3 Atlantic Pigtoe

In addition to Swift Creek, Atlantic Pigtoe has been recorded in Middle Creek and Black Creek within the study area. These survey efforts confirmed its continued presence in Middle Creek. It was not detected in Black Creek and based on the survey results, it is unlikely to still occur in the stream. Additionally, it was not found in any of the other streams surveyed during this effort, and is unlikely to occur in any of them.

6.2 Carolina Madtom Surveys

Two survey methodologies were used to determine if this species occurred in any of the study area streams. The NCWRC visual survey protocol was primarily used, and for the most part was effective in detecting other species of madtoms (i.e. tadpole madtom, margined madtom). The one exception to this was in Little Creek, where the margined madtom was found using electrofishing, but was not observed using the visual techniques. This may be a result of a limited amount of large cover (e.g. cobble, logs, etc.) in the middle of the channel, with the majority of cover consisting of submerged rootmats, which are difficult to survey visually. The Carolina Madtom was not detected during this effort and has not been confirmed from any of the study area streams for 30 years, and thus is unlikely to still occur.

The results of these survey efforts also demonstrate that multiple methodologies may be needed to obtain a complete inventory of all fish species present in a stream reach. The visual method was fairly effective at detecting benthic (stream bottom) species like darters and madtoms; however, it was not effective for many of the more pelagic (water column) species. While the electrofishing methods detected more species than the visual methods, they still did not provide a complete inventory of all species present at a site. This is evidenced by the Warmouth detected in Middle Creek at the Crantock Road site during Neuse River Waterdog trapping efforts, but not found during the visual or electrofishing efforts.

6.3 Neuse River Waterdog Surveys

The results of this survey effort confirmed the continued presence of the Neuse River Waterdog in Swift Creek and Middle Creek. Given that the species has not been reported from the Neuse River since 1987, and was not observed during this effort, it is unlikely to still occur in the Neuse River. Additionally, it was not found in any of the other streams surveyed during this effort, and is unlikely to occur in any of them.

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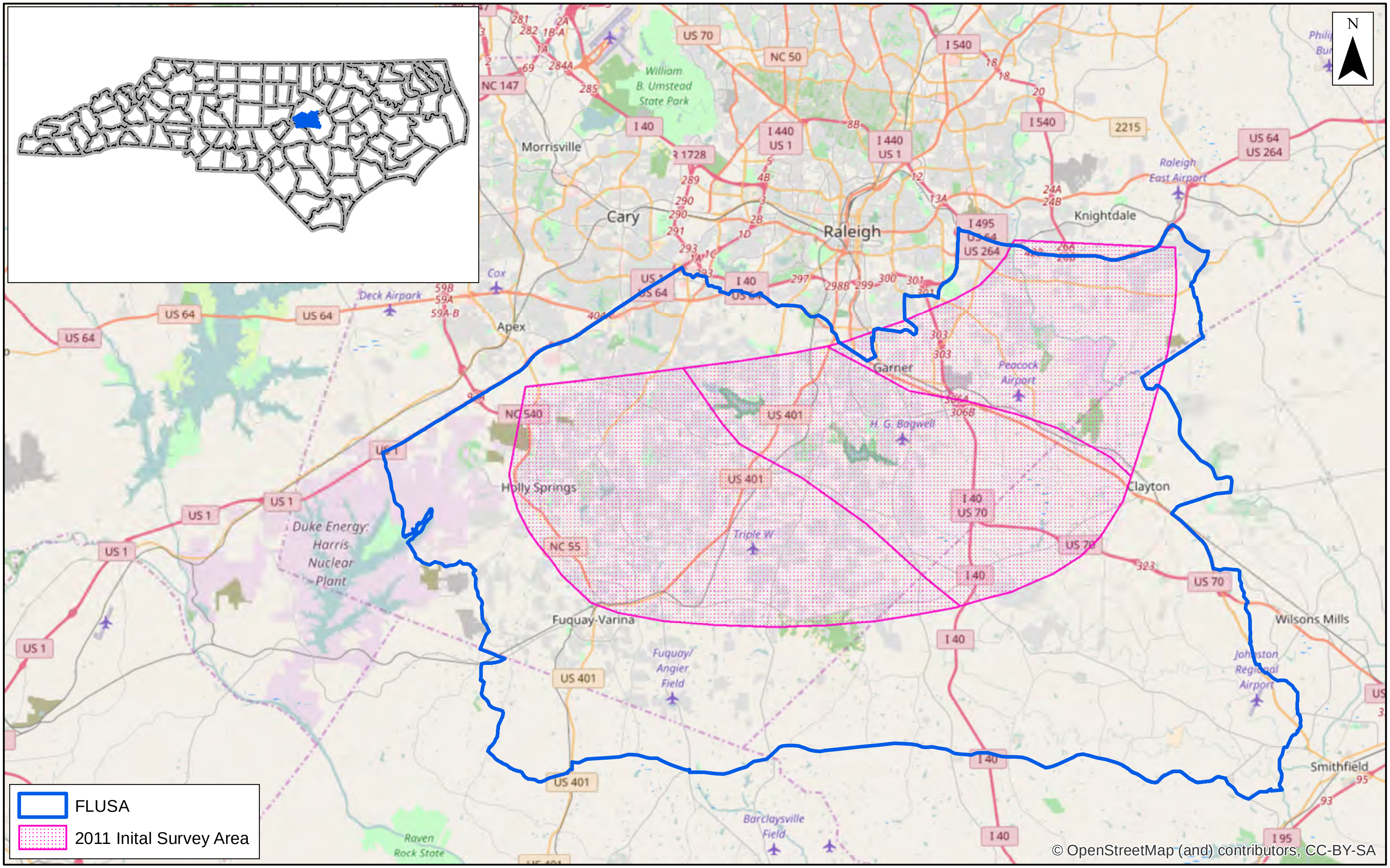
APPENDIX A

Figures



Prepared For:

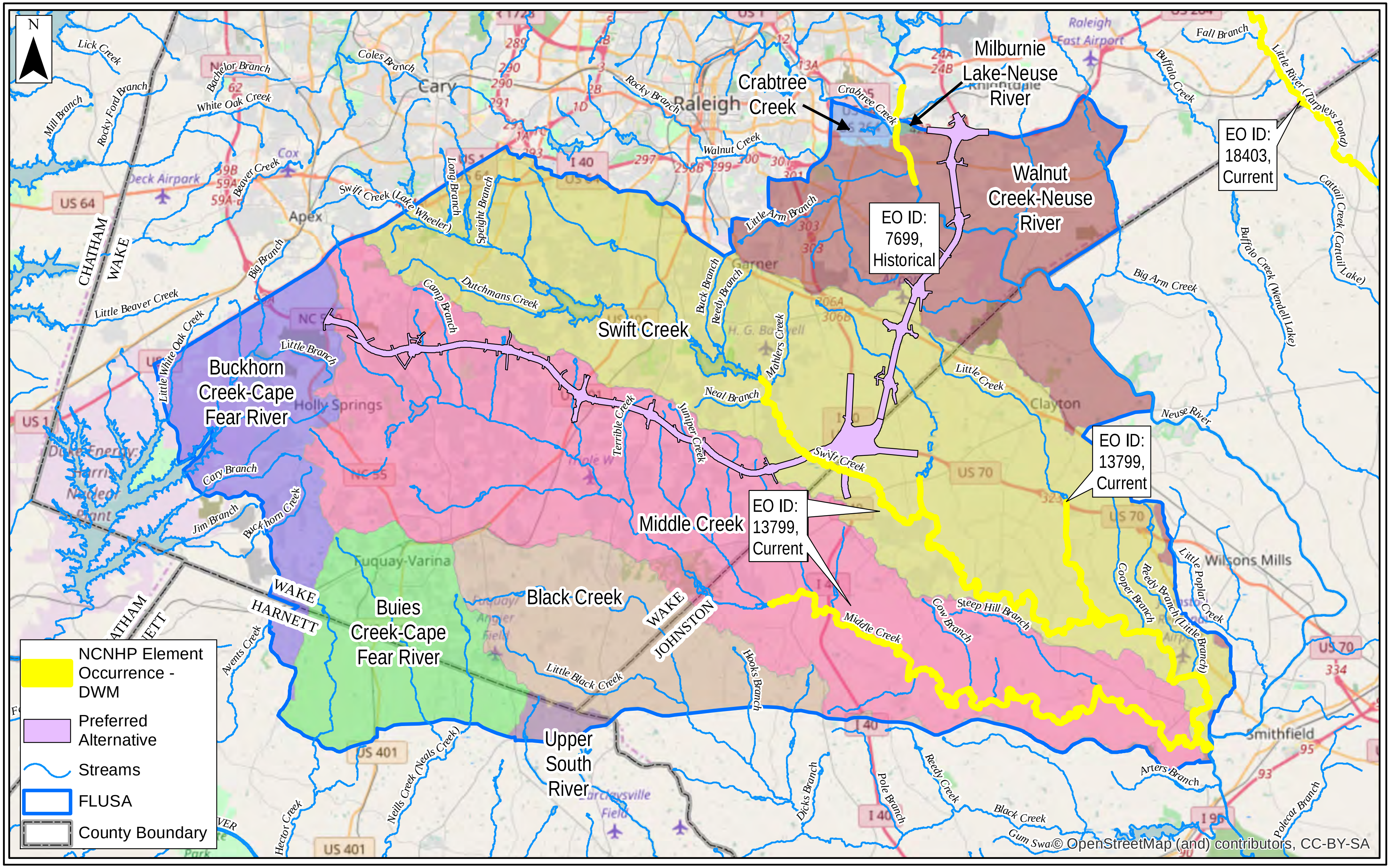
Aquatic Species Survey Report
Complete 540 Triangle Expressway
Southeast Extension

Future Land Use Study Area (FLUSA)

Wake, Johnston, & Harnett Counties, North Carolina

Date:	June 2017
Scale:	0 1 2 Miles
Job No.:	16-318
Drawn By: NMS	Checked By: KMS

Figure 1



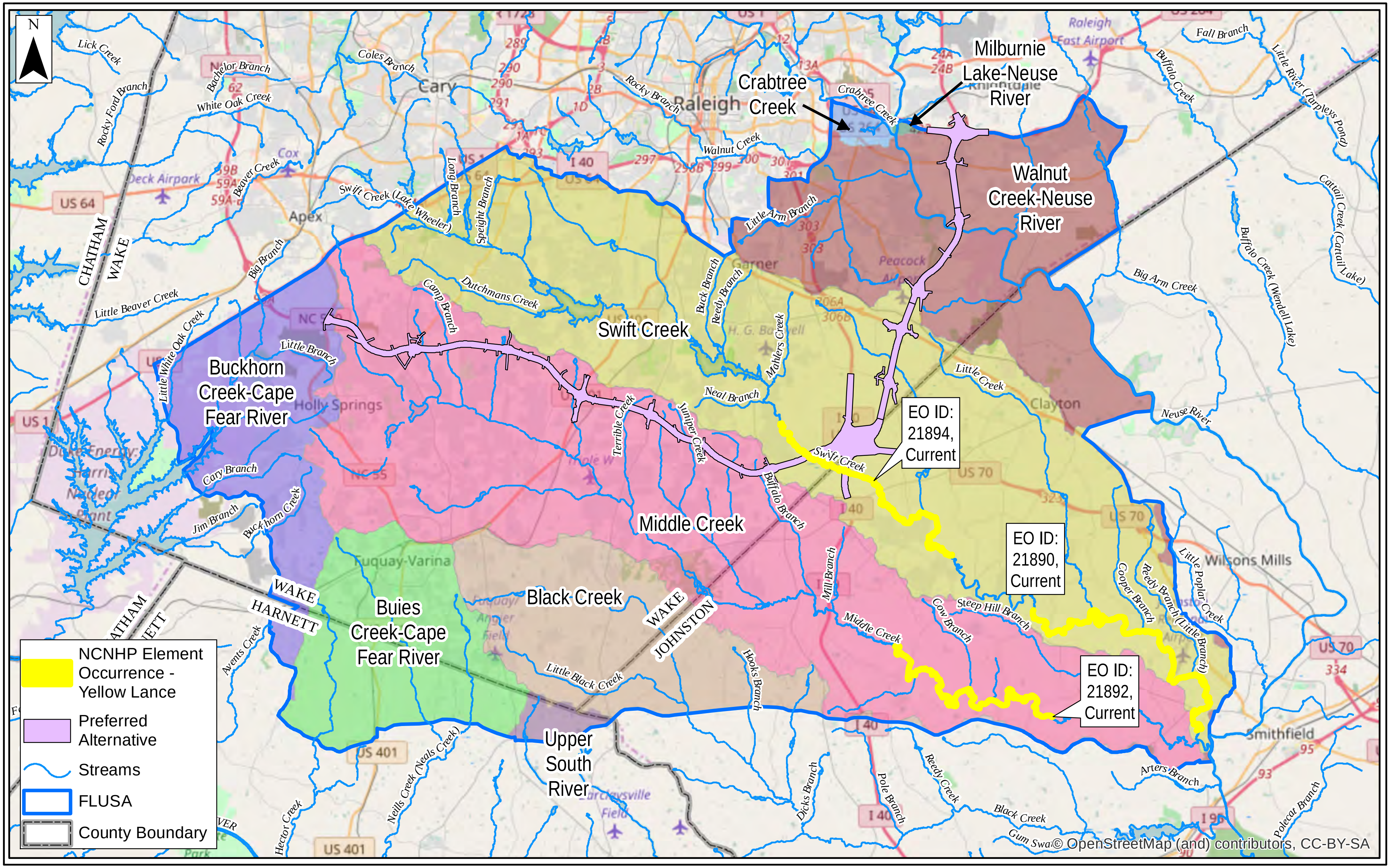
Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

North Carolina Natural Heritage Program
Element Occurrence: Dwarf Wedgemussel
Wake, Johnston, & Harnett Counties, North Carolina

Date:	June 2017
Scale:	0 1 2 Miles
Job No.:	16-318
Drawn By: NMS	Checked By: KMS

Figure
2-1



THREE OAKS ENGINEERING

Prepared For:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

North Carolina Natural Heritage Program
Element Occurrence: Yellow Lance

Wake, Johnston, & Harnett Counties, North Carolina

Date: June 2017

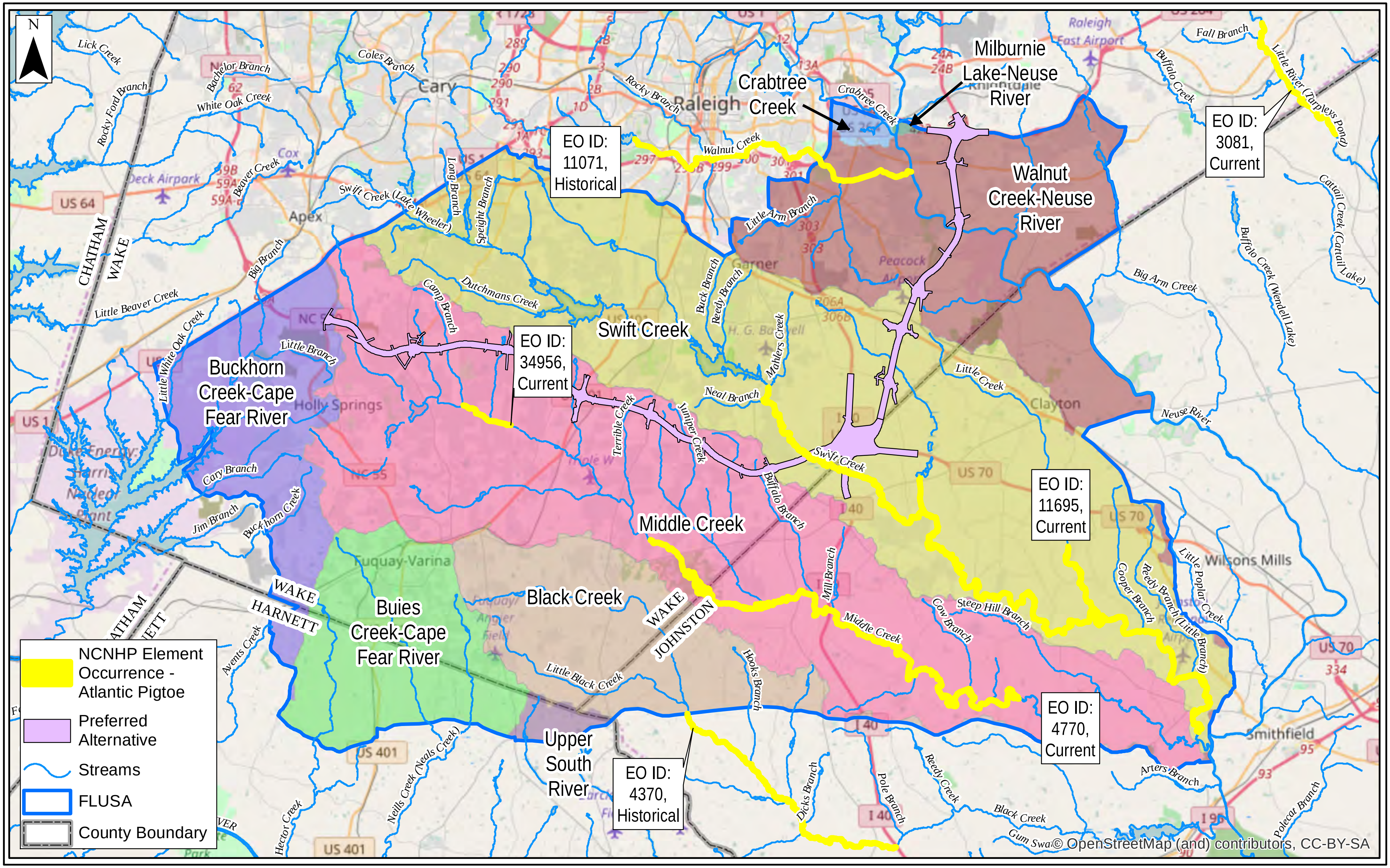
Scale: 0 1 2 Miles

Job No.: 16-318

Drawn By: NMS

Checked By: KMS

Figure 2-2



THREE OAKS ENGINEERING

Prepared For:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

North Carolina Natural Heritage Program
Element Occurrence: Atlantic Pigtoe

Wake, Johnston, & Harnett Counties, North Carolina

Date: June 2017

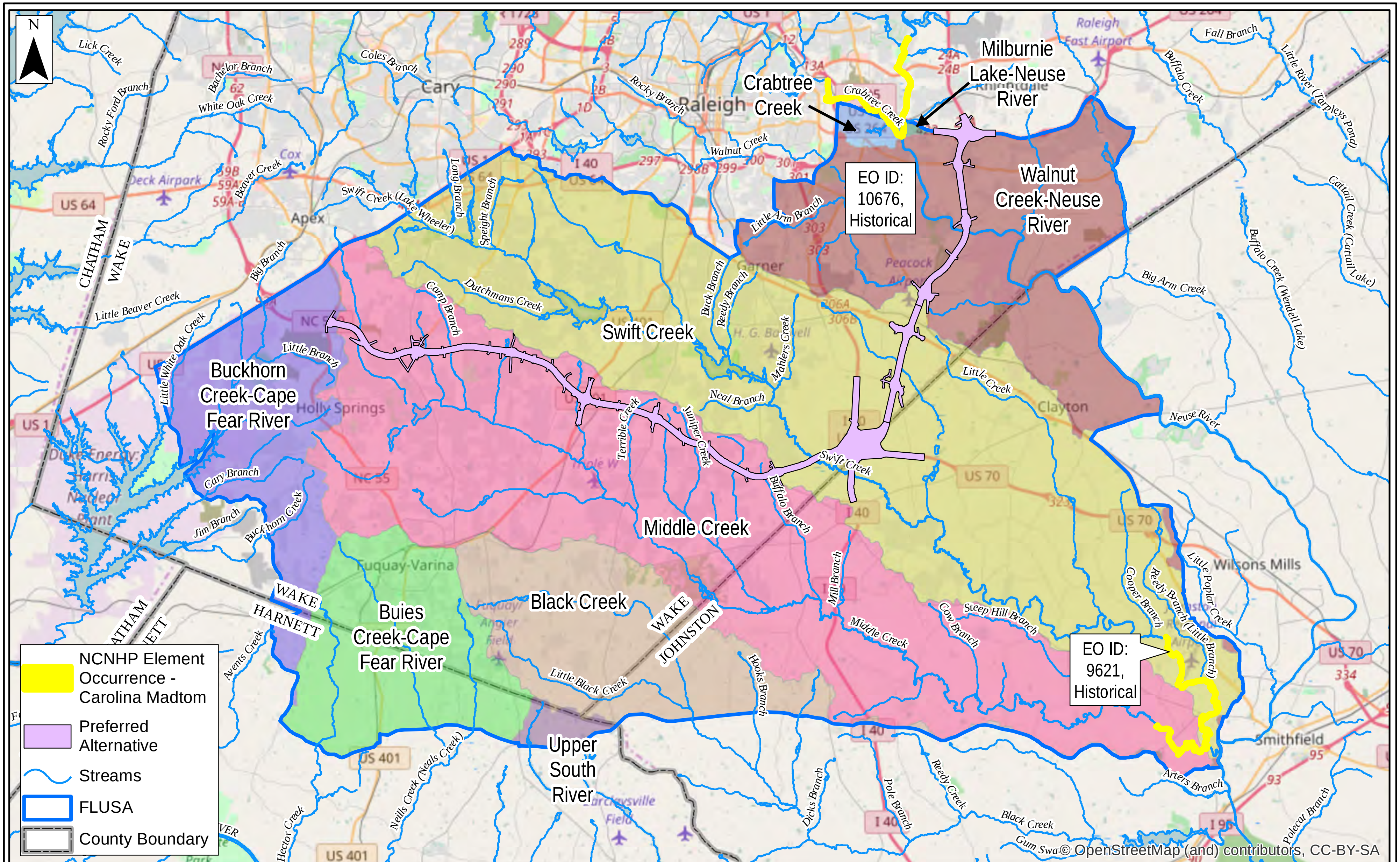
Scale: 0 1 2 Miles

Job No.: 16-318

Drawn By: NMS

Checked By: KMS

Figure 2-3



Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

North Carolina Natural Heritage Program
Element Occurrence: Carolina Madtom

Wake, Johnston, & Harnett Counties, North Carolina

Date: June 2017

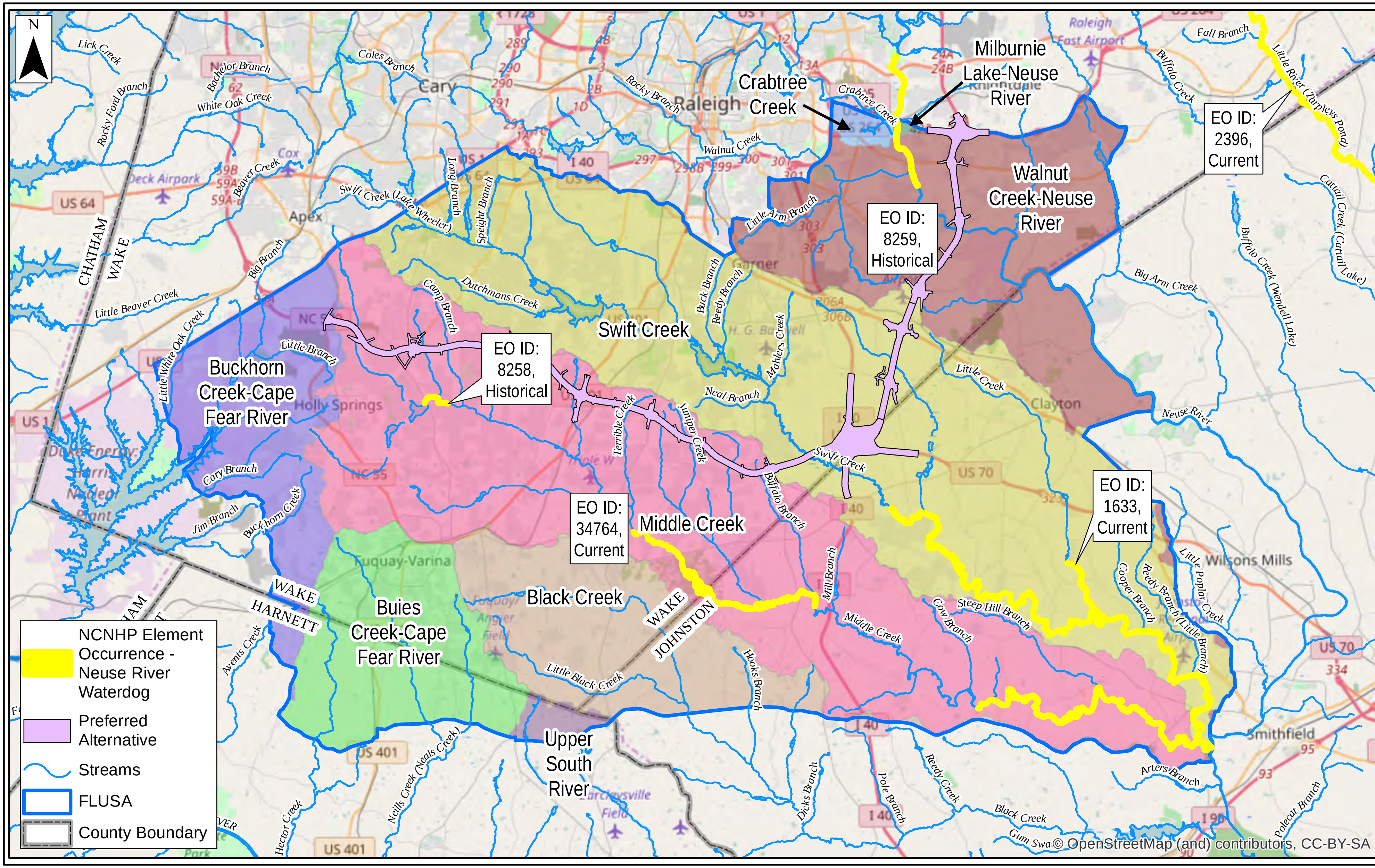
Scale: 0 1 2 Miles

Job No.: 16-318

Drawn By: NMS

Checked By: KMS

Figure 2-4



Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

North Carolina Natural Heritage Program
Element Occurrence: Neuse River Waterdog
Wake, Johnston, & Harnett Counties, North Carolina

Date: June 2017

Scale: 0 1 2 Miles

Job No.: 16-318

Drawn By: NMS

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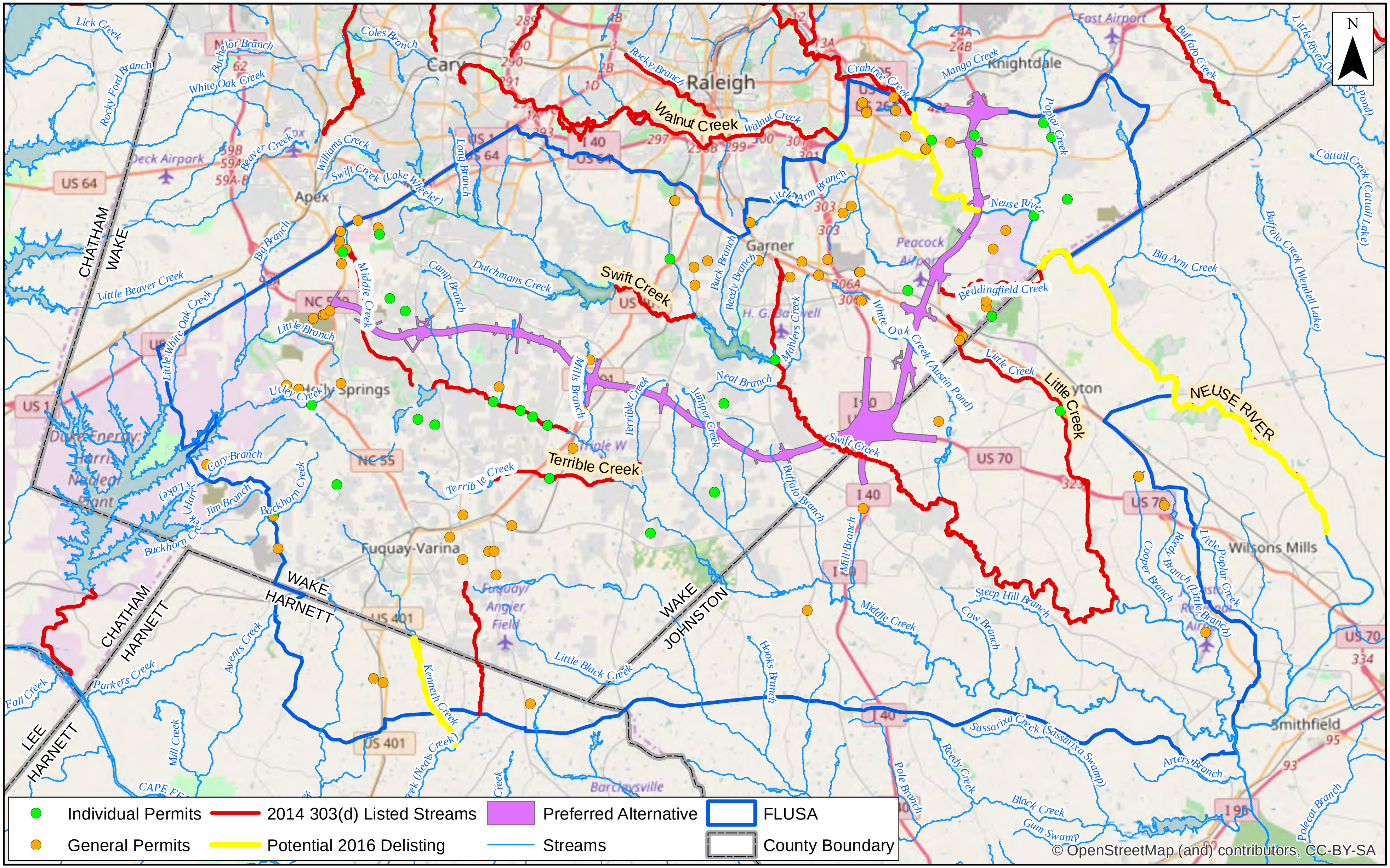
Figure 2-5



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Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

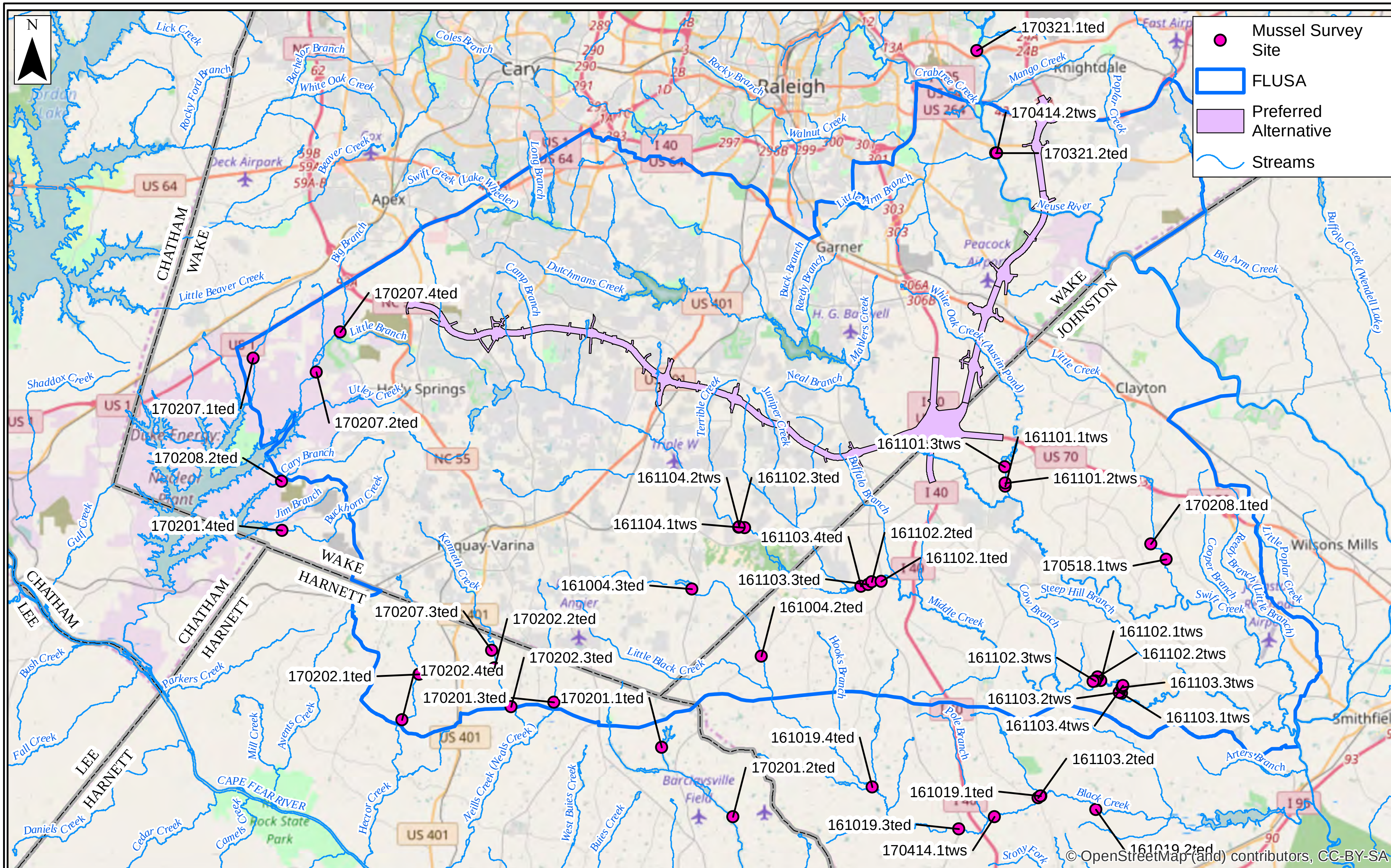
303(d) Listed Streams & National Pollutant Discharge Elimination System Discharges

Wake, Johnston, & Harnett Counties, North Carolina

Date:	June 2017
Scale:	0 1 2 Miles
Job No.:	16-318
Drawn By: NMS	Checked By: KMS

Figure

3



Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway
Southeast Extension

Mussel Survey Locations

Wake, Johnston, & Harnett Counties, North Carolina

Date: June 2017

Scale: 0 1 2 Miles

Job No.: 16-318

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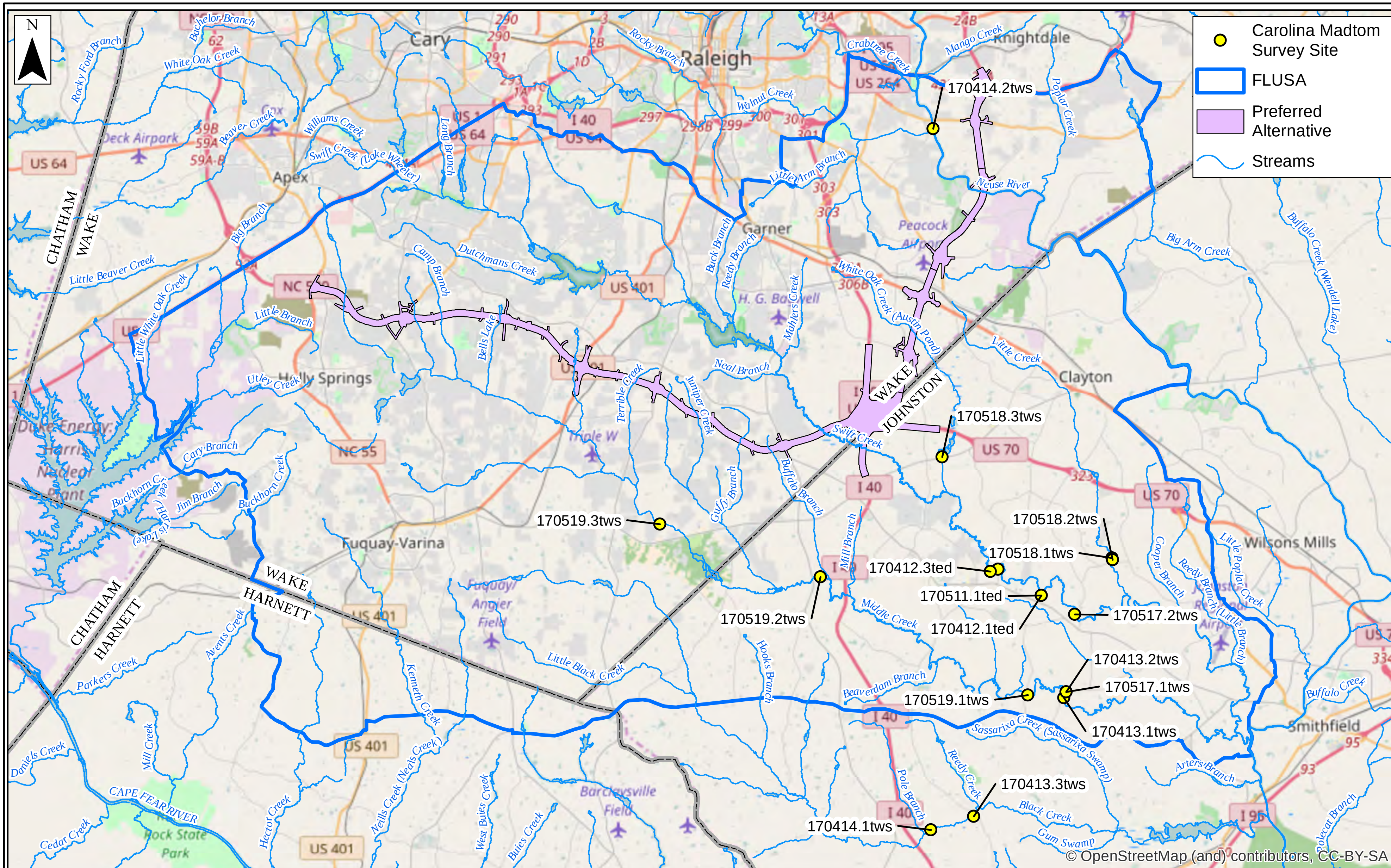
Figure 4



Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

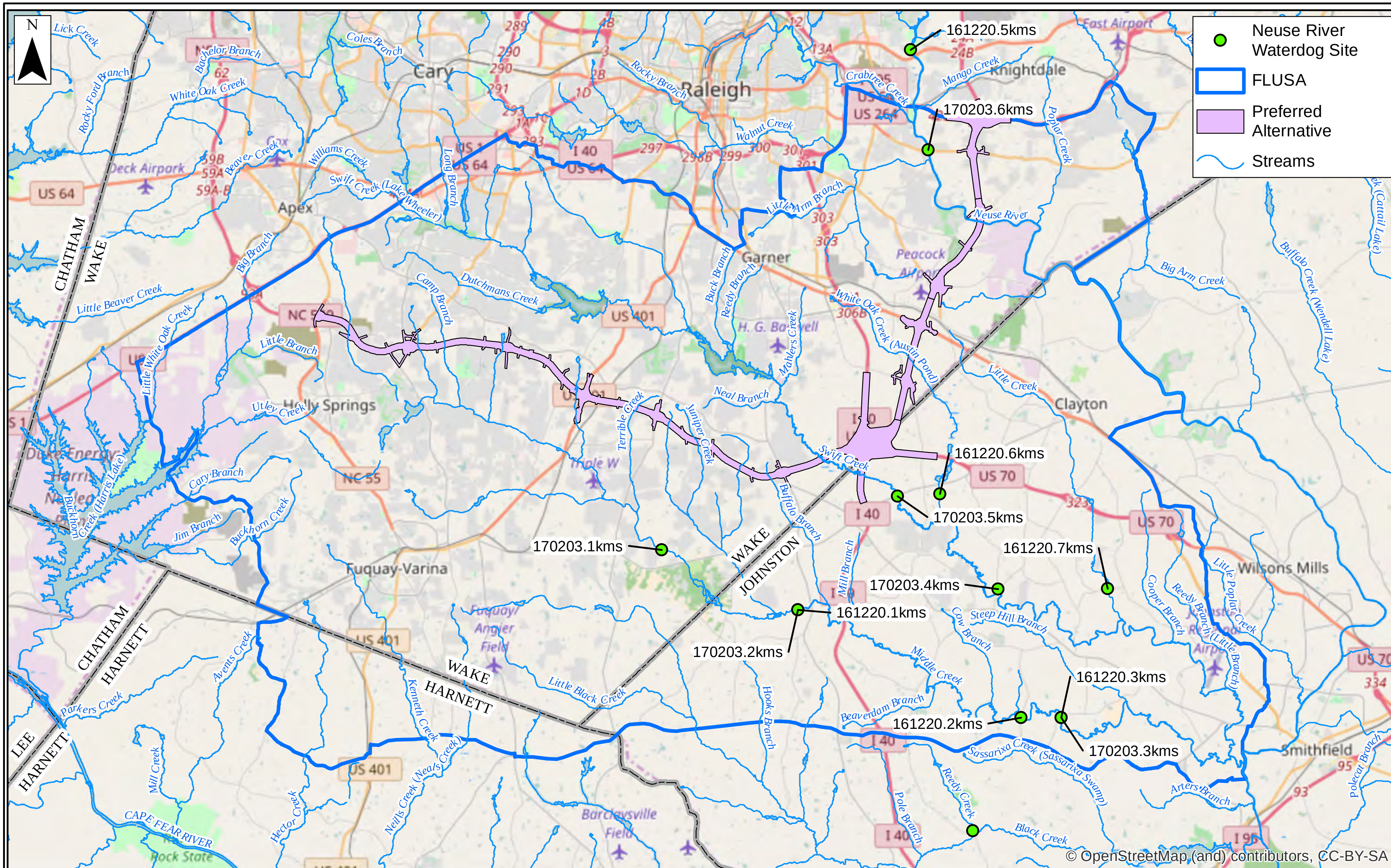
Carolina Madtom Survey Locations

Wake, Johnston, & Harnett Counties, North Carolina

Date:	June 2017
Scale:	0 1 2 Miles
Job No.:	16-318
Drawn By: NMS	Checked By: KMS

Figure

5



Prepared For:

Aquatic Species Survey Report
Complete 540 Triangle Expressway Southeast Extension

Neuse River Waterdog Survey Locations

Wake, Johnston, & Harnett Counties, North Carolina

Date:	June 2017
Scale:	0 1 2 Miles
Job No.:	16-318
Drawn By: NMS	Checked By: KMS

Figure

6