ADDENDUM WATER QUALITY ANALYSES

BENEFIT OF EXISTING AND EXPANDED ENVIRONMENTAL SENSITIVE AREA REGULATIONS ON NUTRIENT AND SEDIMENT YIELDS

CLAYTON BYPASS

JOHNSTON AND WAKE COUNTY,
NORTH CAROLINA
(R-2552)

PREPARED FOR:

THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
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EXECUTIVE SUMMARY

Watershed analyses were performed on behalf of the N.C. Department of Transportation (NCDOT) for two sub-watersheds within the vicinity of the proposed Clayton Bypass (Bypass) (R-2552). An evaluation of Current Condition and two separate evaluations for each of two future scenarios were performed to consider the potential enhanced benefit of expanding the existing designated Environmental Sensitive Area (ESA) boundaries and associated riparian buffer protection to include nearly the complete limits of the two modeled sub-watersheds. The analyses conducted as part of this study include comparative modeling of current and future yields for total nitrogen (TN), total phosphorus (TP), and sediment (both overland and in-stream transport) within the two sub-watersheds. Throughout this document, the term "yield" is intended to reflect the amount of a substance that is successfully transported out of the sub-watershed, while the term "loading" refers to the amount of a substance that is exported directly from a given land use area into adjacent streams or micro-watersheds (cells). The purpose of the study is to estimate the percentage difference in nutrient and sediment yields between the "existing buffer protection" and "expanded buffer protection" evaluations for each land use scenario. This study is intended to supplement previous modeling results performed for the Bypass that focused on the effect of land use transitions on pollutant yields within a larger Study Area that included these two sub-watersheds. For this study, these sub-watershed areas were selected and provided by NCDOT, and are reportedly based upon coordination from NCDOT and the U.S. Fish and Wildlife Service (USFWS). These analyses were completed using the Soil and Water Assessment Tool (SWAT) model developed by the U.S. Department of Agriculture (USDA).

Two riparian buffer evaluations were performed for this study. SWAT was run using Evaluation A (existing ESA buffers) and Evaluation B (expanded ESA buffers) to compare the removal benefits of each buffer network. Evaluation A consisted of complete 50-foot buffer coverage (when identified as being extant in Current Condition) along intermittent and perennial streams throughout each modeled sub-watershed, with 100-foot buffers on perennial streams within existing ESA-designated areas. Evaluation B consisted of complete 50-foot buffer coverage (when identified as being extant in Current Condition) along intermittent streams, and 100-foot buffers on perennial streams throughout the area proposed for ESA expansion.

Results indicate that larger buffers do have a direct benefit of reducing overland pollutants. For the upper Swift Creek sub-watershed, the larger buffers modeled in Evaluation B are successful at preventing any of the 7- to 12-percent increase in pollutant loadings predicted with existing riparian buffer protection strategies. For the lower Little Creek sub-watershed, the larger buffers modeled in Evaluation B further reduced all pollutant loadings, such that when combined with the land use-transition away from agriculture, a reduction ranging from 13- to 37-percent below Current Condition yields has been predicted. These results suggest that additional protection of riparian buffers may have a positive effect on the preservation of rare, unique, and federally protected aquatic resources.

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1.0 INTRODUCTION

EcoScience Corporation (ESC) has been retained by the N.C. Department of Transportation (NCDOT) to perform additional watershed-based change analyses for nutrient and sediment yields within the vicinity of the proposed Clayton Bypass (Bypass) in Johnston County, North Carolina (Figure 1, Appendix A). Throughout this document, the term "yield" is intended to reflect the amount of a substance that is successfully transported out of the sub-watershed, while the term "loading" refers to the amount of a substance that is exported directly from a land use area into adjacent streams or micro-watersheds (cells). These additional analyses are expected to append the results reported by ESC (2004). The watershed modeling performed for this study involves two separate, smaller sub-watershed areas that were originally considered as part of a larger, 92.5-square mile region that was studied and discussed in ESC (2004). These two sub-watersheds, which include portions of the upper Swift Creek watershed centered on Swift Creek between Lake Benson and NC 42, and the lower Little Creek watershed centered on Little Creek between the proposed Bypass and the confluence of Little Creek and Swift Creek, will be hereafter referred to as the upper Swift Creek and lower Little Creek sub-watersheds, respectively (Figure 1, Appendix A). Streams within the vicinity of the Bypass contain populations of dwarf wedge mussel (*Alasmidonta heterodon),* an aquatic species listed as federally Endangered, and several other aquatic species identified as Federal Species of Concern (FSC). The dwarf wedge mussel is a rare species that receives consideration under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*), and may be threatened by water quality degradation. The purpose of this supplemental study is to identify the potential benefit of expanding the existing designated Environmental Sensitive Area (ESA) boundaries to include nearly all of the two modeled sub-watersheds (Figure 2, Appendix A). Expanding the existing ESA would involve the regulation of 100-foot buffers on all perennial streams within most of the modeled sub-watersheds. Currently, the existing ESA protection only covers portions of each sub-watershed. In addition, this report provides regulatory agencies and local municipalities supporting documentation to compare the benefits of these additional Best Management Practices (BMPs) to the benefits derived from other possible mitigation strategies. This report provides a watershed-scale evaluation of potential water quality benefits from increased protection associated with widened riparian buffers along streams within each modeled sub-watershed.

Results of these nutrient and sediment analyses were used to quantify percentage increases between identical land-use scenarios. The same land use scenarios were originally modeled by ESC (2004). The modeling effort considered two new riparian buffer evaluations: Evaluation A and Evaluation B. Evaluation A considered 100-foot riparian buffers on perennial streams within existing ESA protected areas, as well as 50-foot riparian buffer protection on all other streams in non-ESA protected areas. Evaluation B considered 100-foot buffer ESA protection on all perennial streams outward to the nearly the complete limits of both sub-watersheds. Riparian buffer protection of 50 feet, according to the Neuse River Riparian Area Rules, has been modeled on all intermittent streams. Analyses of Current Condition (Year 2003) and two future scenarios were conducted to provide a baseline for comparison. Scenario 1 land use considered projected growth without the Bypass, and Scenario 2 considered all growth observed in Scenario 1, as well as projected growth associated with the Bypass and development induced by the project. Each modeled scenario used similar assumptions and data inputs to make buffer evaluations the focus of comparison. All future scenarios were modeled with consideration for constraints resulting from current and anticipated BMPs such as Neuse River riparian buffers and stormwater ponds resulting from Phase I and II Stormwater Controls.

All modeling for these analyses was performed with the Soil and Water Assessment Tool model (SWAT). Additionally, stream bed and bank erosion were considered in these analyses, although more realistic results have previously been obtained using the Center for Computational Hydraulic Engineering 1-Dimensional stream hydrodynamics model (CCHE1D). CCHE1D was not used in this effort, because only buffer presence or absence, not buffer width, affects the results of the model.

2.0 METHODS

This study was heavily dependent on the accurate portrayal of available data from a number of sources utilized for quantitative analyses. Methods and sources of utilized data are described in three primary categories: Study Area Definition, Land Use, and Model Description.

2.1 Study Area Definition

The upper Swift Creek and the lower Little Creek sub-watersheds have been defined by natural catchment boundaries that occur within areas that NCDOT estimates as having a high likelihood of benefit to surviving aquatic species populations, if enhanced buffer protection is afforded to these areas. These sub-watershed areas were selected and provided to ESC from NCDOT, and were reportedly based upon coordination between NCDOT and the U.S. Fish and Wildlife Service (USFWS) (personal communication, LeiLani Paugh, August 2, 2004). The existing ESA boundaries were available digitally from NCDOT, and incorporated into a Geographical Information Systems (GIS) database.

The upper Swift Creek sub-watershed consists of a 24.6 square mile area (Figure 1, Appendix A). Swift Creek is oriented on a northwest/southeast axis. The southern boundary of the sub-watershed includes the upper limits of multiple, smaller catchments for unnamed tributaries that drain north to Swift Creek. The upper limit of the sub-watershed along Swift Creek is delineated by the Lake Benson dam to the northwest. Other boundaries of the sub-watershed are defined by the upper limits of the Mahler's Creek catchment to the north, the eastern drainage divide for an unnamed tributary to Swift Creek (between Mahler's and White Oak Creeks) to the east, and a point just upstream of the confluence of Swift and White Oak Creeks to the southeast. The sub-watershed incorporates the complete limits of the 14-digit hydrologic unit 03020201110030. Additionally, portions of major roads such as I-40, US 70, NC 50, and NC 42 occur within the sub-watershed providing the major infrastructure for commutes as well as opportunities for additional development.

The lower Little Creek sub-watershed consists of a 5.2 square mile area (Figure 1, Appendix A). Little Creek is oriented on a north/south axis. The northern boundary for the modeled sub-watershed is delineated by the proposed crossing of the Bypass across the Little Creek catchment. The lower limit of the sub-watershed along Little Creek is located at the confluence of Little and Swift Creeks. The other boundaries of the sub-watershed are defined to the east and to the west by the drainage divides between Little Creek and adjacent catchments for unnamed tributaries to Swift Creek. The sub-watershed incorporates approximately 29-percent of the 14-digit hydrologic unit 03020201110050. No major roads currently occur within the modeled sub-watershed. Construction of the proposed Bypass will provide major access for commutes and opportunities for development within the sub-watershed.

2.2 Land Use

Twelve land-use categories are utilized by the SWAT model. The 12 categories are defined by the amount of impervious area and vegetation cover within a tax parcel unit (Table 1). All land-use information was digitized and provided to ESC by URS Corporation (2004) in ArcView 3.x shapefile format. A set of new, revised land-use files were provided by URS Corporation for this study, which corrected some discrepancies associated with land use within the Swift Creek Mitigation Site and land-use data used in ESC (2004). Within the sub-routines of SWAT, variables, including cover type, percent impervious surface, and runoff curve numbers, were assigned to each land use and applied to the parcels within that category. All scenarios of land use are provided in Figures 3A and 3B (Appendix A).

Table 1. Corresponding land-use categories used in AnnAGNPS and SWAT. Only SWAT was used in these supplemental analyses, but land use data were taken from pre-existing land use data (URS 2004), which were sorted into AnnAGNPS categories. Study Area land use was categorized using tax parcels as land-use units.

AnnAGNPS Land-use Category	SWAT Land-use Category
COMM: Business, Commercial, 85% impervious	**UCOM**: Commercial
CROPLAND: Fallow, Row Crops, Small Grain	**SOYB**: Soybean
HOUSE20: Housing, 1-acre lots, 20% impervious	**URLD**: Residential, Low Density
HOUSE25: Housing, 0.5-acre lots, 25% impervious	**URML**: Residential, Med/Low Density
HOUSE30: Housing, 0.3-acre lots, 30% impervious	**URML**: Residential, Med/Low Density
HOUSE38: Housing, 0.25-acre lots, 38% impervious	**URMD**: Residential, Medium Density
HOUSE65: Housing, 0.125-acre lots, 65% impervious	**URHD**: Residential, High Density
INDUST: Business, Industrial, 72% Impervious	**UIDU**: Industrial
PASTURE: Pasture, Grassland, or Range	**PAST**: Pasture
WATER: Lakes, Ponds, Reservoirs	Ponds have been inserted as a separate feature, not a land-use category
WOODG*: Woods-Grass Combination	**FRSE**: Forest-Evergreen
WOODS: Woodland or Forest	**FRST**: Forest-Mixed

* WoodG denotes areas where large trees preside over a maintained understory, like a municipal park or school where canopy sized trees shade maintained lawns.

2.2.1 Land-use Controls

For Current Condition, the presence of an existing riparian buffer network was identified through manual interpretation of the SWAT-generated stream network overlain on aerial photography from Wake and Johnston Counties (dated 1999 and 2001, respectively). Each stream reach was evaluated for 1) no buffer, 2) a 50-foot buffer, or 3) a 100-foot buffer. A forested area that was wider than 100 feet was considered as having only a 100-foot buffer. In such cases, these larger areas of wooded land were considered by SWAT as a forested land use, which provided even more reductions that 100-foot buffers. For Scenarios 1 and 2, both structural and non-structural BMPs (storm water ponds and riparian buffers) were constructed or preserved as appropriate within SWAT. Riparian buffers were preserved adjacent to streams when buffers were identified in Current Condition and identified for development in Scenario 1 or 2. Storm water ponds have been applied to land use in future scenarios for all new development of 1.0 acre or more as required by Phase II storm water regulations (EPA 1999, DWQ 2001). To identify intermittent stream reaches for receipt of riparian buffers, the stream network generated by SWAT was used to find the specific drainages predicted to produce an intermittent stream flow. SWAT derived the stream network by interpolation of a digitally created, three-dimensional terrain surface using GIS (see ESC 2004).

2.3 Model Description

SWAT is a continuous simulation, surface run-off, pollutant loading and yields, computer model created by the U.S. Department of Agriculture (USDA) (Arnold and Allen 1992a; Srinivasan and Arnold 1994). SWAT is capable of predicting the influence of land cover and land uses on (sediment, water, and chemical yields) from ungauged stream basins. SWAT also contains integrated sub-routines to predict stream channel erosion and stream transported sediment. The model subdivides the landscape into discrete micro-watersheds (cells), that are assigned parameters (such as slope, soil, land use, etc) that are used by the model to predict pollutant loading and run-off from each cell. Additionally, SWAT is capable of modeling the water quality protection benefits of BMPs such as riparian buffers and sediment ponds. SWAT is capable of predicting run-off, sediment loading and yield, and nutrient loadings and yields for total nitrogen (TN) and total phosphorus (TP) (Arnold and Allen 1992a; Srinivasan and Arnold 1994). The mathematical processes utilized within SWAT include weather generation, run-off volumes from precipitation, erosion, and sediment delivery. A more comprehensive discussion of the SWAT model was provided in ESC (2004), and can also be found in other published scientific resources (Arnold and Allen 1992, Arnold *et al*, 1992, Arnold *et al.* 1998, Srinivasan *et al.* 1994, Srinivasan 1995, Neitsch *et al.* 2002).

Two riparian buffer evaluations were performed for this study. SWAT was run using Evaluation A (existing ESA buffers) and Evaluation B (expanded ESA buffers) to compare the pollutant removal benefits of expanded buffers. Evaluation A consisted of complete 50-foot buffer coverage (when identified as being extant in Current Condition) along intermittent and perennial streams throughout each modeled sub-watershed, with 100-foot buffers on perennial streams within existing ESA designated areas (Figure 2, Appendix A). Evaluation B consisted of complete 50-foot buffer coverage (when identified as being extant in Current Condition) along intermittent streams, and 100-foot buffers on perennial streams throughout the modeled sub-watershed.

While both overland and stream-generated sediment yields are reported in this study, it should be noted that the sediment reduction benefit of the expanded buffers has been compared only for overland sediment yields. For this study, SWAT was not calibrated to fully predict all of the benefits of riparian buffers, thus, did not successfully predict trends between different buffer *widths* for stream-generated sediment loads. Identifying trends in-stream erosion is confounded by the fact SWAT reduced overland sediment loads by passing them through the modeled riparian buffers, but has not reduced overland water runoff volume or velocity. This created a condition called "hungry water." A given volume of water, with a given velocity, that flows across the landscape and into the stream bed is expected to pick up a set concentration of sediment as it enters a stream. In these modeled evaluations, the overland sediment load has been reduced through the use of riparian buffers. The in-stream sediment concentrations are lower, thus the water within a stream is "hungry" for more sediment. A stream then over-erodes the channel substrate and banks until the sediment concentration within the stream was stable. This situation has occurred within SWAT because the riparian buffers were applied as filter strips, which are not capable of slowing water velocities. Thus, stream-bank erosion is more prevalent than expected for real conditions, as it is anticipated that the riparian buffers would attenuate the volume and velocity of surface flow prior to water entering the channel. To employ the standard method of slowing water velocities through riparian buffers in SWAT, the riparian buffers would need to be a larger percentage of the total land use within each cell, and be assigned unique Soil Conservation Service (SCS) curve numbers and erosion parameters. This would not be a practicable effort due to the relatively large sizes of the modeled sub-watersheds. This current artifact of the model could be neutralized through calibration, but only with more field data, the involvement of other models, and a larger timeframe, which were all considered impracticable since the overland numbers can be used to aid in decision making for this study.

3.0 RESULTS AND DISCUSSION

Yields of TN, TP, and total sediment (TS) (referred to cumulatively as "pollutants") vary with differing land-use patterns and riparian buffer coverage throughout each modeled sub-watershed. The pollutant load responses of modeled cells to individual land use changes have responded similarly to the results reported in ESC (2004), but the different overall land-use changes for the sub-watersheds have resulted in unique pollutant loading trends for these smaller sub-watersheds when compared to the modeled Study Area from the previous study.

Tables 2 and 3 provide the pollutant yields for the upper Swift Creek and the lower Little Creek sub-watersheds, respectively. Table 4 (Appendix B) provides the pollutant yields predicted by ESC (2004). Two separate buffer effectiveness evaluations have been performed for each sub-watershed. In both buffer evaluations, and in both future land-use scenarios, regardless of the Bypass or the modeled sub-watershed, increased coverage by impervious surfaces resulted in

Table 2. Exported annual yields of pollutants from the upper Swift Creek sub-watershed. All numbers are reasonable yields for use in comparitive analyses, but should not be interpreted as an estimate of actual Study Area yields. All mass units are in metric tons. Percent change in pollutant yields are color coded to assist in percent change interpretation. The percent change of each pollutant has a unique color, with TN depicted in red, TP depicted in blue, and overland sediment depicted in purple.

Scenario	TN (Tons)	TP (Tons)	Overland Sediment (Tons)	Stream Sediment (Tons)	TN Change (Tons)	TN Percent Change	TP Change (Tons)	TP Percent Change	Overland Sediment Change (Tons)	Stream Sediment Change (Tons)	Overland Sediment Percent Change	
Existing	7.846	1.3352	3438.17	10901.83	-----	-----	-----	-----	-----	-----	-----	
Future No Bypass A	8.397	1.4258	3309.75	11490.25	0.55	**7.02%**	0.09	**6.79%**	-128.42	588.42	-3.74%	**Over Existing**
Future Bypass A	8.725	1.4931	3035.40	11794.60	0.88	**11.20%**	0.16	**11.83%**	-402.77	892.77	-11.71%	**Over Existing**
Future No Bypass B	7.745	1.3213	3105.44	11514.56	-0.10	**-1.29%**	-0.01	**-1.04%**	-332.73	612.73	-9.68%	**Over Existing**
Future Bypass B	7.524	1.3092	2661.81	11858.19	-0.32	**-4.10%**	-0.03	**-1.95%**	-776.36	956.36	-22.58%	**Over Existing**

*Sediment has been divided into two distinct source categories.

Table 3. Exported annual yields of pollutants from the lower Little Creek sub-watershed. All numbers are reasonable yields for use in comparitive analyses, but should not be interpreted as an estimate of actual sub-watershed yields. All mass units are in metric tons. Percent change in pollutant yields are color coded to assist in percent change interpretation. The percent change of each pollutant has a unique color, with TN depicted in red, TP depicted in blue, and overland sediment depicted in purple.

Scenario	TN (Tons)	TP (Tons)	Overland Sediment (Tons)	Stream Sediment (Tons)	TN Change (Tons)	TN Percent Change	TP Change (Tons)	TP Percent Change	Overland Sediment Change (Tons)	Stream Sediment Change (Tons)	Overland Sediment Percent Change	
Existing	2.20	0.29	1280.28	5760.70	-----	-----	-----	-----	-----	-----	-----	
Future No Bypass A	1.95	0.24	1021.50	5813.50	-0.25	**-11.36%**	-0.05	**-17.24%**	-258.78	52.80	-20.21%	**Over Existing**
Future Bypass A	2.11	0.26	912.54	5787.46	-0.09	**-4.09%**	-0.03	**-10.34%**	-367.74	26.76	-28.72%	**Over Existing**
Future No Bypass B	1.79	0.22	939.78	5834.22	-0.41	**-18.64%**	-0.07	**-24.14%**	-340.50	73.52	-26.60%	**Over Existing**
Future Bypass B	1.90	0.23	803.58	5801.42	-0.30	**-13.64%**	-0.06	**-20.69%**	-476.70	40.72	-37.23%	**Over Existing**

*Sediment has been divided into two distinct source categories.

increases of pollutant yields with one exception. Overland sediment loading is highest for agricultural areas and lowest for urban areas because the impervious surfaces associated with urban areas are not susceptible to erosion. In urban areas, as overland sediment loading was reduced, higher volume and velocity flows resulted in higher stream-generated sediment. While the predicted stream-generated sediment loads are considered to be reasonable when attempting to model impacts of developing land-use changes within a watershed, these loads appear to underestimate the benefit of changes in width of riparian buffer coverage. A continued increase in nutrient yields is expected as urbanization increases over time. One exception is if a cell previously had a large proportion of active agriculture, where fertilizer/herbicide/pesticide management and tilling resulted in high loading rates. In such areas, all pollutant loading decreased after the transition to low-density urban areas. Typically, higher pollutant loading is anticipated as currently undeveloped parcels convert to residential, commercial, and industrial categories. Nutrient export loads from forest and pasture lands are significantly less than export from commercial and industrial parcels (Dodd *et al.* 1992, Hunt and Lucas 2003).

Predicted in-stream sediment rates are higher than overland export rates in this study. In-stream loadings account for 75- to 80-percent of the predicted sediment export from each sub-watershed. This is not unexpected since accelerated stream-bank erosion has been found to be a major cause of non-point source pollution associated with increased sediment supply (Rosgen 2002). Bank collapse, bed erosion, and fluvial entrainment all contribute to stream sediment loads. However, a comparison of modeling scenarios that utilized identical land-use coverage indicates that accelerated stream-bank erosion may be higher than would be realized if the riparian buffer networks were calibrated for attenuating surface water volume and velocity.

3.1 Influence of Land Use

An analysis of Current Condition was necessary to establish baseline parameters for development of future scenarios, as well as the evaluation of buffer effectiveness. Changes in land-use patterns were relevant due to the direct, observed association between land-use categories and nutrient/sediment loading trends. The results of the modeling effort indicate that different pollutant yields occurred between the two modeled sub-watersheds, which are reflective of the different land-use change patterns that were predicted to occur. The proportion of each land use category for all scenarios and both sub-watershed is contained in Tables 5 and 6 (Appendix B)

For the upper Swift Creek sub-watershed, the land use for the Current Condition already was characterized by a relatively high density of urban areas, when compared to the other modeled sub-watershed. The higher density urban land use and lower proportion of rural land use within the sub-watershed led to an expected general increase in pollutant yields with increased development. The implementation of stormwater ponds and riparian buffer protection did noticeably attenuate the increase in pollutant loadings, resulting in lower exported yields.

For the lower Little Creek sub-watershed, the land use for the Current Condition was dominated by agriculture. A decrease in pollutant loading was realized as land-use changed to more low-density urban areas. The benefit of BMPs, as well as the conversion from higher pollutant loading land uses (agriculture) to predominantly low density residential areas without much commercial or other highly impervious areas, resulted in a general decrease in pollutant yields. The decrease in predicted yields may seem counterintuitive, but is in line with previously reported results for rural watersheds (ESC 2002), as well as published scientific literature(Hunt and Lucas 2003, DWQ 1999).

Currently, the lower Little Creek sub-watershed has twice the sediment loading rate per acre than the upper Swift Creek sub-watershed, which is a result of the large amount of active agriculture. In non-buffered areas, the high run-off volumes and large peak flows transported across impervious areas into adjacent, unarmored, natural areas resulted in elevated stream-generated sediment erosion that can contain attached nitrogen and phosphorus.

3.2 Comparison of Buffer Evaluations

Regardless of the modeled sub-watershed or modeled land use, this study indicates that larger buffers have a beneficial effect on reducing overland pollutant loads. It is anticipated that these buffers may also have a stabilizing effect on stream-generated sediment, through attenuation of flow and bank stabilization, but it was not possible to properly calibrate these parameters for this study. For the upper Swift Creek sub-watershed, the larger buffers modeled in Evaluation B are successful at removing the 7- to 12-percent increase in nutrient yields resulting from the same land-use transitions, but with existing riparian buffer protection strategies. For the lower Little Creek sub-watershed, the larger buffers modeled in Evaluation B further reduced all overland pollutant loadings, such that, when combined with the transition to the lower pollutant loading land uses, a reduction ranging from 13- to 37-percent below Current Condition yields is predicted to occur. These results suggest that additional protection of riparian buffers within the modeled sub-watersheds, as well as the entire Study Area from the previous study, may have a positive effect on the preservation of rare, unique, and federally protected aquatic resources.

4.0 SUMMARY

- Supplemental nutrient and sediment analyses were performed for two sub-watersheds proposed to be impacted by the Clayton Bypass (R-2552) in Wake and Johnston Counties, North Carolina. An original study was performed (ESC 2004) which focused on the effect of land-use changes on exported pollutant yields from the modeled area. These new analyses focused on a comparison of pollutant-reduction benefits from different riparian buffer widths, intended to identify the potential benefit of expanding the existing designated ESAs to include the nearly the entire limits of the modeled sub-watersheds. SWAT was used to perform all modeling for this study.
- The upper Swift Creek and the lower Little Creek sub-watersheds have been defined by natural catchment boundaries that occur within areas that have been anticipated by NCDOT as having a high likelihood of continued benefit to surviving aquatic species populations if enhanced protection is afforded to these areas. The upper Swift Creek sub-watershed consists of a 24.6 square mile area, while the lower Little Creek sub-watershed consists of a 5.2 square mile area.
- Predicted future land uses were similar to those reported in the previous study (ESC 2004). Two buffer evaluations, Evaluation A and B, were performed with similar land-use change scenarios in order to isolate pollutant-change trends resulting from expanding the existing protected buffer network associated with designated ESAs (Evaluation A) to a more comprehensive preservation network that extends to the nearly the complete limits of both modeled sub-watersheds (Evaluation B). Use of BMPs, such as Neuse River riparian buffers and storm water detention ponds were considered in both evaluations for future scenarios. Twelve distinct land-use categories were generated and provided by URS Corporation.
- Separate pollutant yield trends were identified for the two modeled sub-watersheds. On a cell-by-cell basis, predicted pollutant loads increase as impervious area increases, unless agriculture land develops into low-density residential development. Agriculture and high-density urban areas (commercial, high density residential, and roads) are responsible for the largest pollutant loads. The upper Swift Creek sub-watershed is predicted to transition from low and medium density residential areas to higher density land-use categories. The lower Little Creek sub-watershed is predicted to transition from rural and agricultural areas to low density residential land uses. Thus, a steady increase of modeled pollutants, although attenuated by BMPs, is observed in the upper Swift Creek sub-watershed while a decrease occurs in the lower Little Creek sub-watershed. These trends, if considered along with the predicted land-use changes, are further supported in scientific literature (Dodd *et al.* 1992, Hunt and Lucas 2003).
- SWAT has demonstrated an ability to predict reasonable estimates of nutrient and sediment export loadings and yields when compared to other published results (Dodd *et al.* 1992, Hunt and Lucas 2003). The expansion of designated ESA areas to include expanded riparian buffer protection for the entire limits of the two modeled sub-watersheds will likely aid the continued survival of rare, unique, and federally protected aquatic species with habitats within the vicinity of the proposed Bypass.

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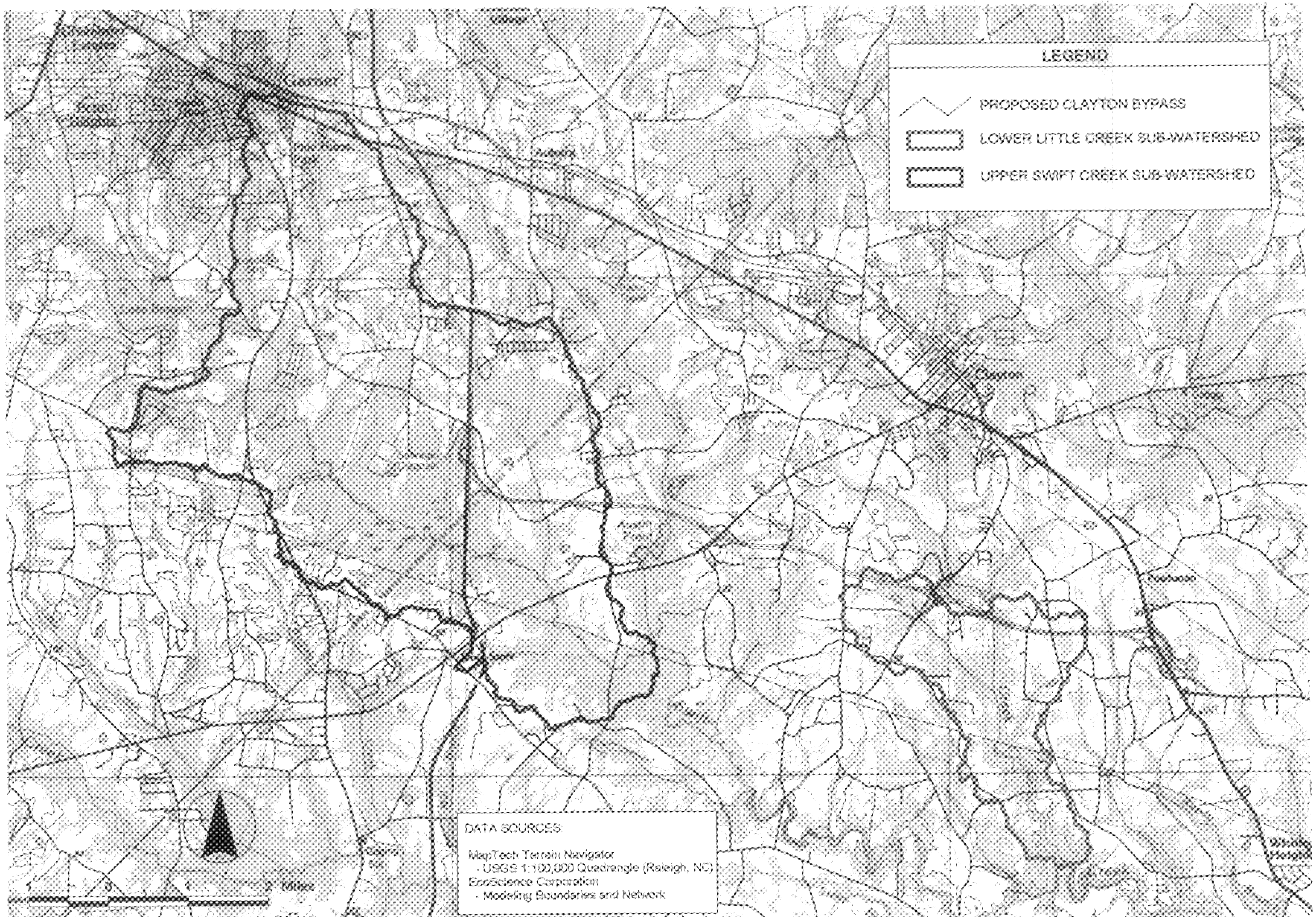
Appendix A
Figures



EcoScience Corporation

CLIENT:

PROJECT:

NUTRIENT AND SEDIMENT ANALYSES

CLAYTON BYPASS (R-2552)

Johnston and Wake Counties, North Carolina

TITLE:

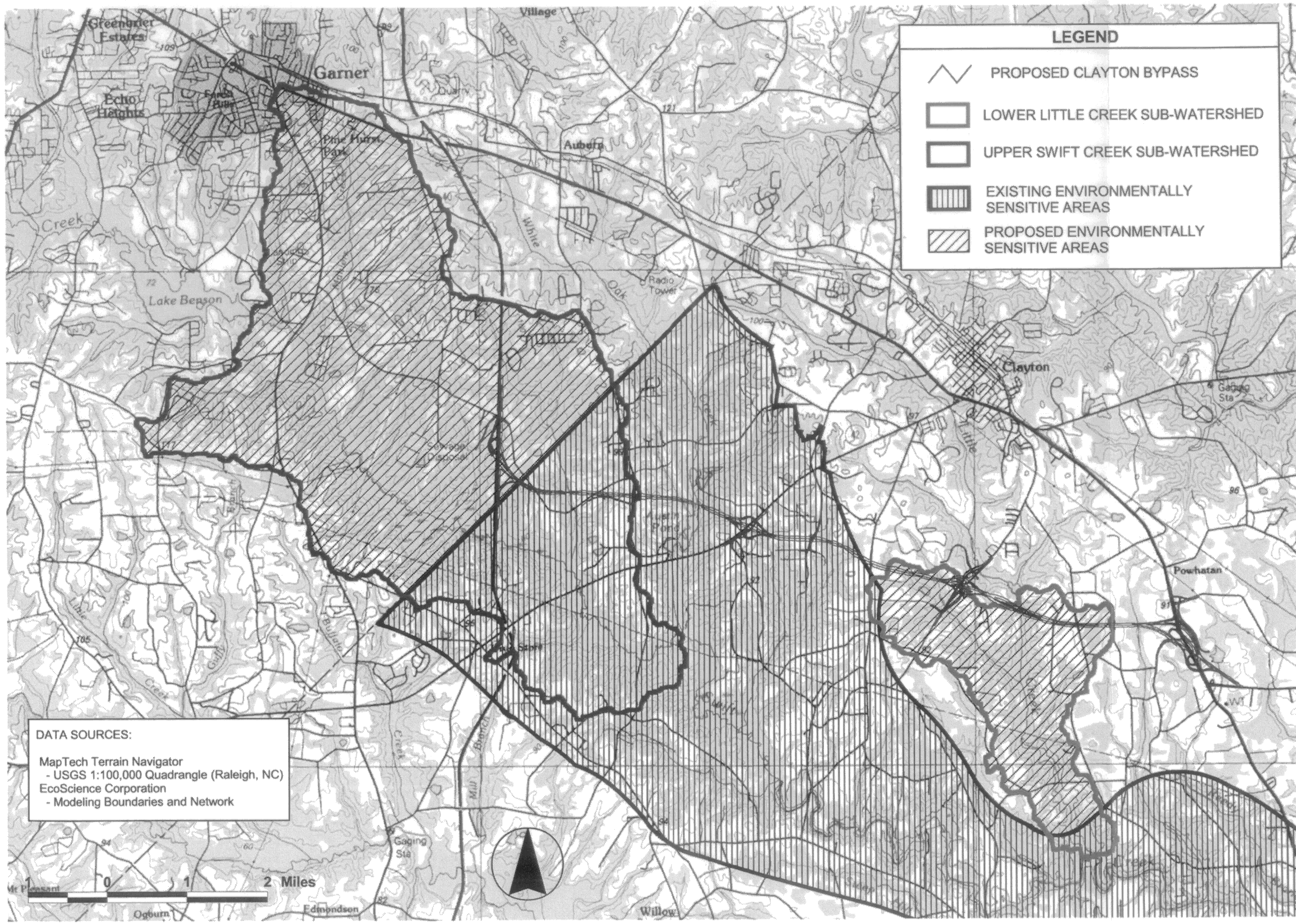
MODELING BOUNDARIES

Dwn By:	Ckd By:
MAF	BA
Date:	Scale:
SEPT 2004	AS SHOWN

ESC Project No.: 02-113.40

FIGURE

1



EcoScience Corporation

CLIENT:

PROJECT:

NUTRIENT AND SEDIMENT ANALYSES

CLAYTON BYPASS (R-2552)

Johnston and Wake Counties, North Carolina

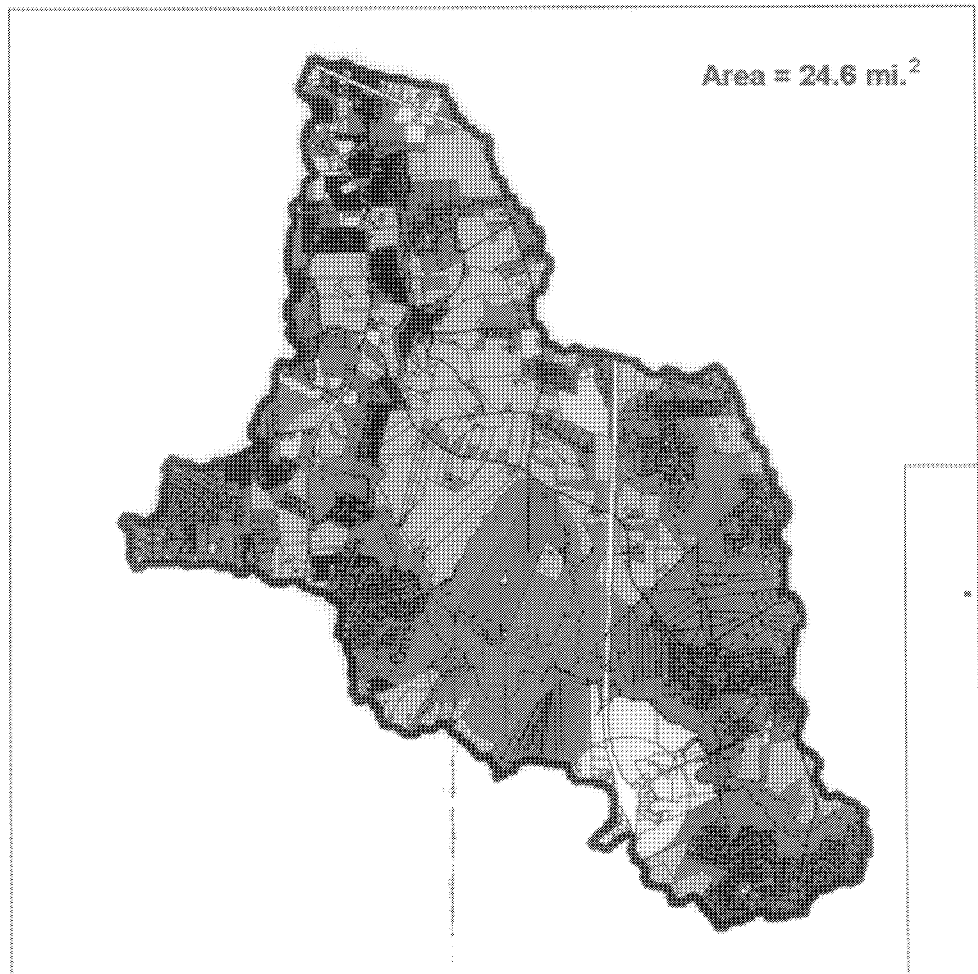
TITLE:

ESA EXISTING AND PROPOSED

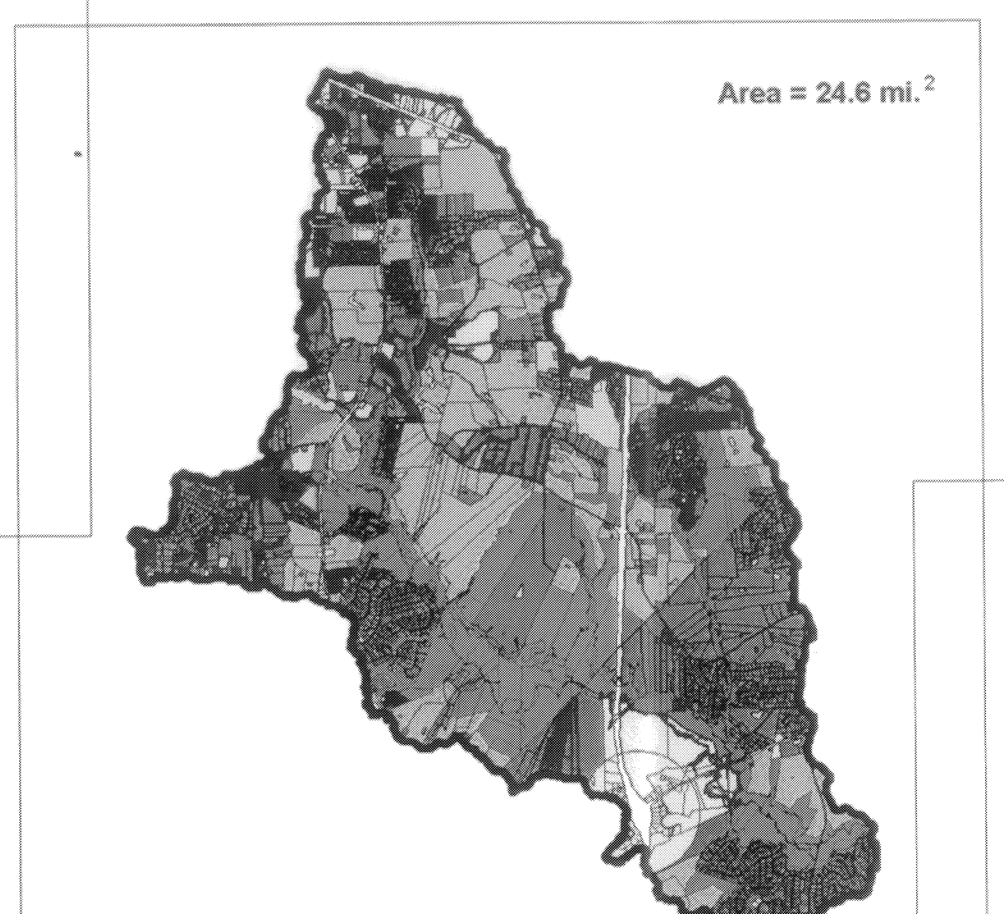
Dwn By:	Ckd By:
MAF	BA
Date:	Scale:
SEPT 2004	AS SHOWN
ESC Project No.:	
02-113.40	

FIGURE

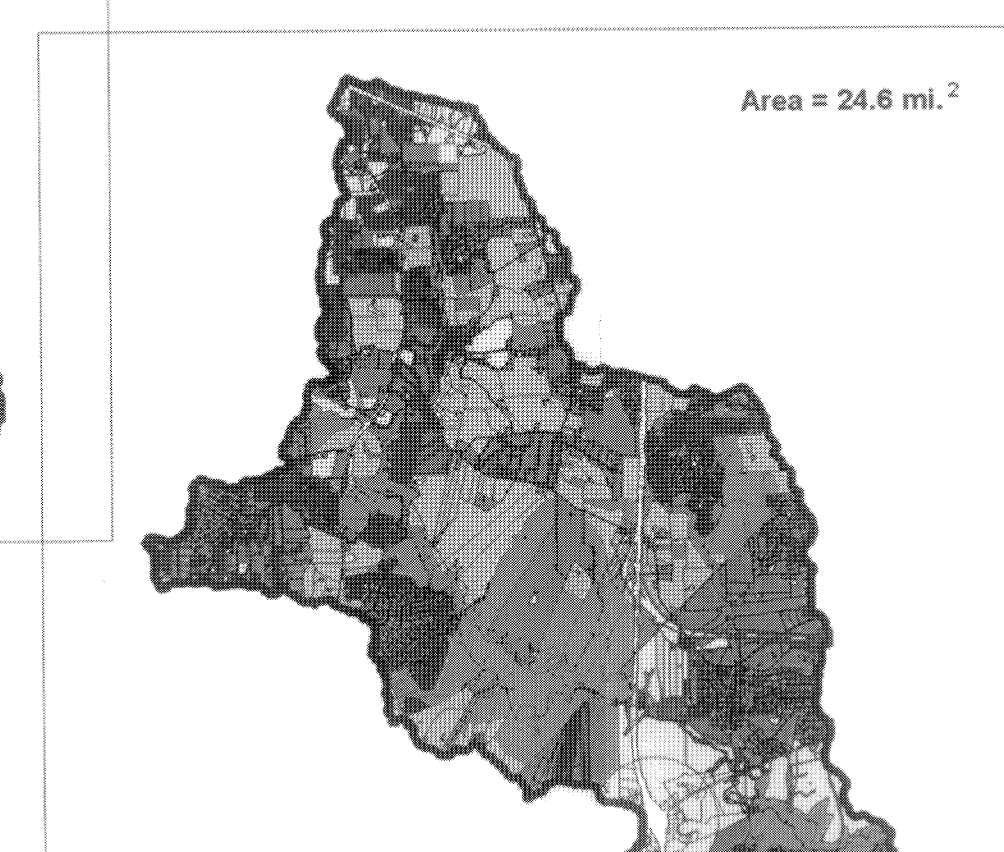
2



Current Condition



Year 2025 - No Bypass



Year 2025 - With Bypass

UPPER SWIFT CREEK SUB-WATERSHED

LAND USE CATEGORY

- COMMERCIAL
- CROPLAND
- HOUSE20
- HOUSE25
- HOUSE30
- HOUSE38
- HOUSE65
- INDUSTRIAL
- PASTURE
- ROAD
- WATER
- WOODG
- WOODS

Upper Swift Creek Sub-Watershed

EcoScience Corporation

CLIENT:

PROJECT:

NUTRIENT AND SEDIMENT ANALYSES

CLAYTON BYPASS (R-2552)

Johnston and Wake Counties, North Carolina

TITLE:

LAND USE FOR THREE MODELED SCENARIOS

Dwn By: MAF	Ckd By: BA
Date: SEPT 2004	Scale: AS SHOWN
ESC Project No.: 02-113.40	

FIGURE

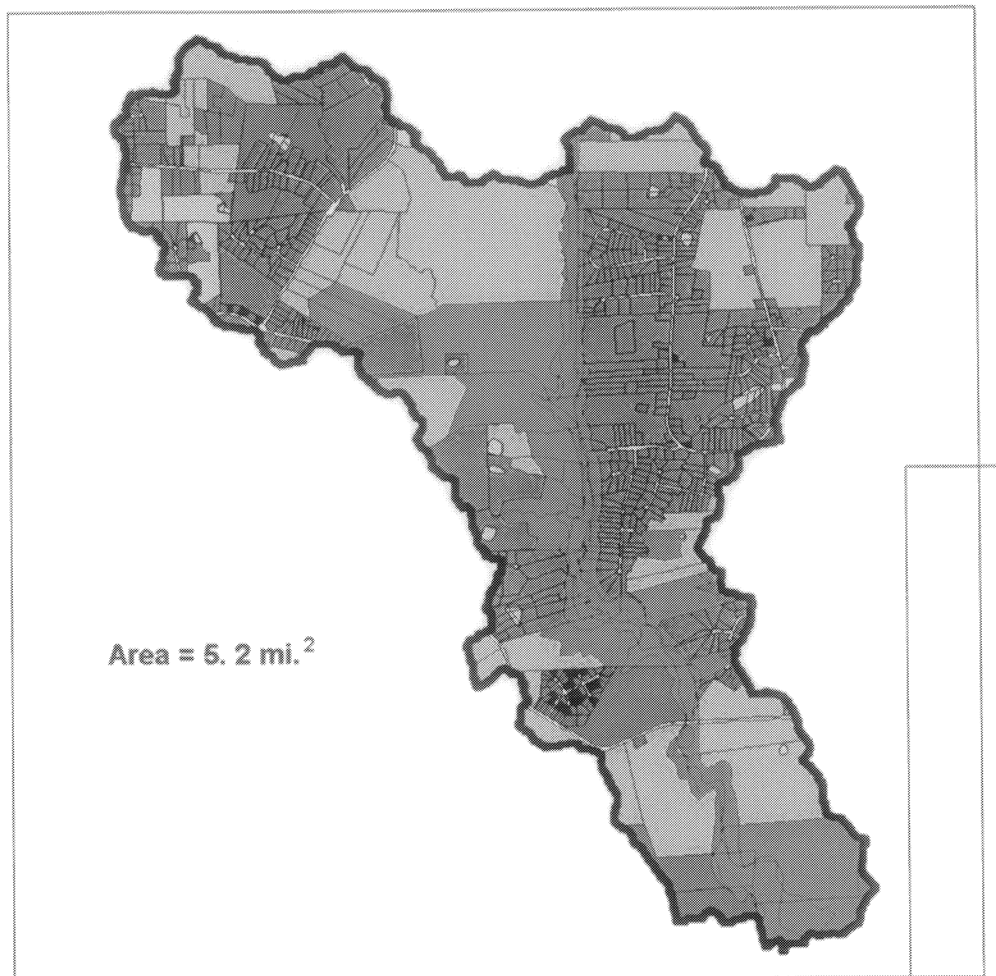
3A

Lower Little Creek Sub-Watershed

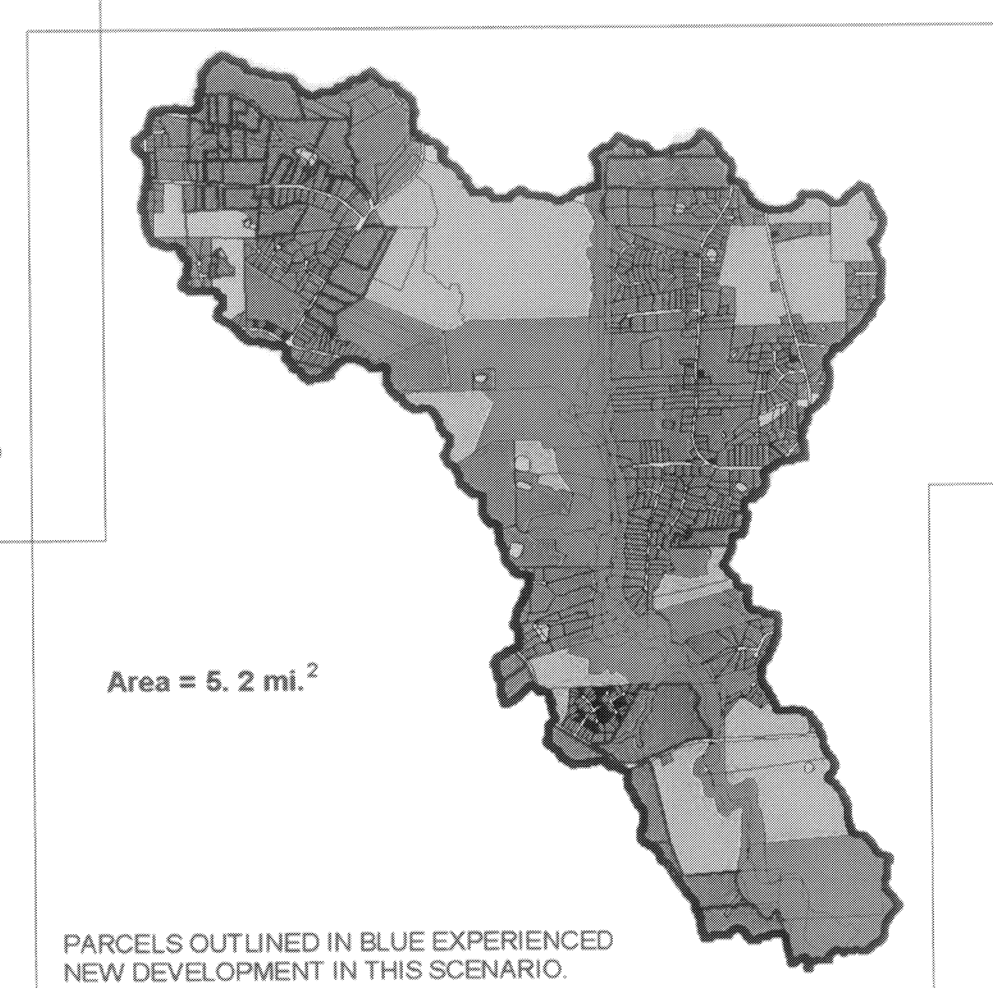
LOWER LITTLE CREEK SUB-WATERSHED

LAND USE CATEGORY

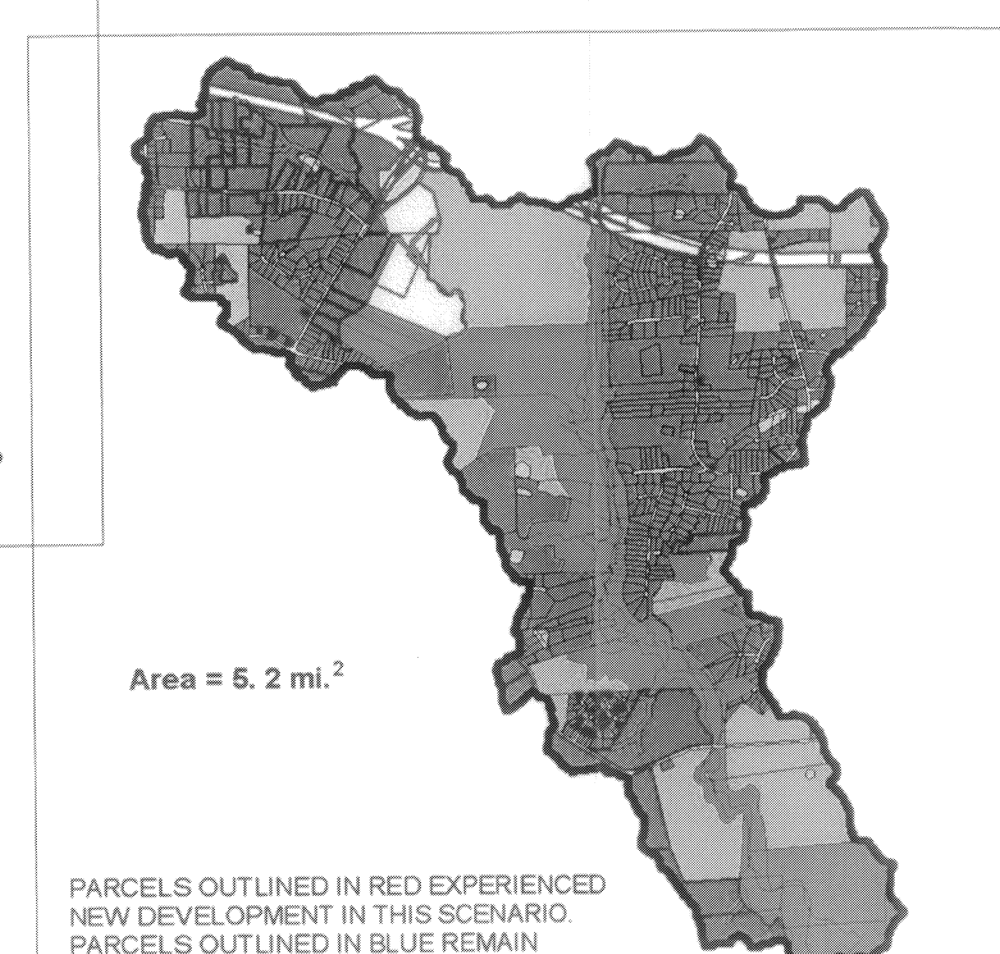
- COMMERCIAL
- CROPLAND
- HOUSE20
- HOUSE25
- HOUSE30
- HOUSE38
- HOUSE65
- INDUSTRIAL
- PASTURE
- ROAD
- WATER
- WOODG
- WOODS



Current Condition



Year 2025 - No Bypass



Year 2025 - With Bypass

EcoScience Corporation

CLIENT: North Carolina Department of Transportation

PROJECT:

NUTRIENT AND SEDIMENT ANALYSES

CLAYTON BYPASS (R-2552)

Johnston and Wake Counties, North Carolina

TITLE:

LAND USE FOR THREE MODELED SCENARIOS

Dwn By:	Ckd By:
MAF	BA
Date: SEPT 2004	Scale: AS SHOWN
ESC Project No.: 02-113.40	

FIGURE

3B

Appendix B
Supplemental Tables and Information

Table 4. Exported annual yields of pollutants from the Study Area. All numbers are reasonable yields for use in comparitive analyses, but should not be interpreted as an estimate of actual Study Area yields. All mass units are in metric tons. Percent change in pollutant yields are color coded to assist in percent change interpretation. The percent change of each pollutant has a unique color, with TN depicted in red, TP depicted in blue, overland sediment depicted in purple, and stream sediment depicted in green.

Scenario	TN (Tons)	TP (Tons)	Overland Sediment (Tons)	Stream Sediment (Tons)	TN Change (Tons)	TN Percent Change	TP Change (Tons)	TP Percent Change	Overland Sediment Change (Tons)	Stream Sediment Change (Tons)	Overland Sediment Percent Change	Stream Sediment Percent Change	
Existing	67.40	116.60	15279.90	22921.00	-----	-----	-----	-----	-----	-----	-----	-----	
Future No Bypass	88.20	122.40	20149.30	30225.60	20.80	**30.86%**	5.80	**4.97%**	4869.40	7304.60	31.87%		**Over Existing**
Future Bypass	92.80	122.60	20551.50	30828.90	25.40	**37.69%**	6.00	**5.15%**	5271.60	7907.90	34.50%		**Over Existing**

*Sediment has been divided into two distinct source categories.

Table 5. Landuse compositon of the upper Swift Creek sub-watershed.

Landuse	Existing (%)	Future No Bypass (%)	Future Bypass (%)
Commercial	5.55	6.93	9.76
Cropland	26.10	23.19	20.90
House20	21.33	24.22	23.28
House25	7.07	8.52	7.66
House30	1.57	1.52	2.11
House38	0.33	0.56	0.45
House65	0.52	0.68	1.41
Industrial	0.23	0.34	0.34
Pasture	2.02	2.02	0.99
Road	5.35	5.38	6.22
Water	0.00	0.00	0.00
WoodG	4.72	3.33	4.31
WoodS	25.21	23.58	22.31

Table 6. Landuse compositon of the lower Little Creek sub-watershed.

Landuse	Existing (%)	Future No Bypass (%)	Future Bypass (%)
Commercial	0.07	0.07	2.34
Cropland	30.85	23.39	20.12
House20	29.57	42.24	40.07
House25	6.24	6.27	6.22
House30	0.45	0.45	0.49
House38	1.79	1.79	1.76
House65	0.04	0.04	0.04
Industrial	0.00	0.00	0.00
Pasture	0.18	0.18	0.54
Road	2.56	2.56	5.13
Water	0.66	0.66	0.65
WoodG	6.24	0.00	0.00
WoodS	21.35	22.35	22.64