APPENDIX A

Factors Not Considered in Fiscal Analysis Cost Estimates For the Existing Development Rule

The cost estimates in the Fiscal Analysis for the Existing Development Rule are fundamentally flawed, resulting in a severe underestimate of the total cost of complying with the Jordan Lake Rules. The major errors that bias the costs on the low side are discussed below.

1. Construction costs were based on BMP costs for new development. Research by Wossink and Hunt (funded through the NC Water Resources Research Institute in part by the City of Durham and other members of the Urban Water Consortium) collected construction cost information for BMPs in North Carolina and the surrounding area. These costs were for BMPs at new land development sites where site designers have maximum flexibility to incorporate stormwater treatment early in preliminary site layout based on existing topography and proposed grading, and conflicting existing utilities, if any. Site designers can balance cut-and-fill grading such that any excavation required for the stormwater BMP is balanced by fill material used elsewhere on the site so that no excavated soil need be hauled offsite. By contrast retrofitting of existing development typically involves conflicts with utilities and existing structures, and BMPs must be fit into available space making design more complex, layouts are not efficient, and much more material must be excavated because existing topography has not been used effectively to minimize grading. Excavation costs are higher and much more material must be hauled offsite.

   After development of the Fiscal Analysis, the Center for Watershed Protection published the Urban Stormwater Retrofit Practices (CWP, August 2007.) The CWP manual compares costs for new development reported by Wossink and Hunt to a database of construction costs for retrofits. The CWP manual reports that based on comparative costs for retrofits and new development, a multiplier of 1.5X should be used for typical bioretention retrofits (page E-8), 2.3X for wet ponds (p. E-6), and 7X for stormwater wetlands (page E-6.) Structural sand filters are typically used only on constrained sites in new development and CWP therefore suggests the new development costs are also appropriate for retrofits.
2. Area requirements for retrofits included only the surface area of the pool plus 15% added to account for “slopes, etc.” The cost equations provided by the Ada Wossink and Bill Hunt, and A. Moran and B. Hunt references listed in FA Appendix B, notes 1 and 3, p.B-1), provide the area of only the permanent wet pool area. The 15% increase accounts only for the slopes that are wetted when the stormwater wetland or pond is treating a storm event. Such an allowance is based on optimal configuration, and does not account for site constraints. More importantly, BMPs need to be maintained in order to continue working as designed, and area requirements should provide for an access path on flat ground from which trucks and construction equipment can access the BMP to remove sediment and to maintain dams. Furthermore, ingress must be provided from a public right-of-way or easement in order to access the BMP for inspection and maintenance. Additional area may need to be provided for new drainage easements associated with any new inlet or outlet pipes, any dam structures, and associated level spreaders or velocity dissipaters.

3. Land cost developed from data provided by the City of Durham inexplicably finds the average cost to be $78,000 per acre, whereas land values in Durham range from an average of $92,000 for low density residential at the low end up to $374,000 per acre for high density residential property. The City's estimated land costs do not include either US Army Corps of Engineers' land or NC university property, for which no value was assigned in the parcel database. It is erroneous to assume that land for which no tax value is assigned has a value of zero. Furthermore, neither Corps land nor state property would be available to the City to implement the rule. It may also be that the NCDWQ estimate may have included road rights-of-way (ROW) - for which no tax value is assigned - incorrectly assuming the value of the land to be zero. It is doubtful that room exists in existing ROW to accommodate retrofits, and even where such room currently exists, there are opportunity costs associated with devoting that area to retrofits as opposed to sidewalks, bikeway, light rail, or other uses. These parcels that did not have a tax value assigned could have been addressed as opportunity costs. However, in the Existing Development Rule portion of the Fiscal Analysis, opportunity costs were assumed to be zero in Table 5.2. Thus, the Fiscal Analysis does not accurately account for the cost of land, either as direct costs or as opportunity costs.
4. Planning costs, primarily surveying and engineering design, were assumed to be 25% which too low to account for the greater engineering complexity required to address site constraints and regulatory issues involved in retrofitting.
5. Current estimates are that stormwater treatment retrofits have a life expectancy of 20 years or less. For the 30-"full" year implementation period in the Fiscal Analysis, required reconstruction costs have not been included.
6. The amount of developed land in the watershed is greater than indicated in the watershed model; not only did this result in unit loading rates (pounds per acre per year) being higher than reported elsewhere, it also results in the area of land actually needing retrofits to be under reported.

APPENDIX B

Estimated Cost of Retrofitting Existing Development In the City of Durham to Achieve 35% Reduction

Alternative Number	Assumed mix of BMPs	Land area required, acres	# of BMPs	Capital costs	20 year total costs, incl. O&M	Unit costs, $/pound N
1	Wetlands (92%)*	1,504	1,570	$340,800,000	$349,600,000	$247
2	Wetlands (83%) +Buffers & level spreaders (13%)*	1,513	1,830	$325,500,000	$333,600,000	$235
3	Wetlands (75%) +Bioretention (18%)*	1,513	11,003	$401,700,000	$431,500,000	$305
4	Wetlands (67%) +Bioretention (26%)*	1,519	14,980	$428,500,000	$467,300,000	$330
5	Bioretention (50%) + wetlands*	1,541	27,370	$506,500,000	$572,500,000	$404
6	Bioretention w/ some wetlands downstream*	1,569	38,962	$588,300,000	$680,500,000	$480

* The percentage shown in parentheses indicates the load reduction accomplished by the BMP, rather than the area treated. The percentages do shown do not sum to 100% because a small amount of bioretention, buffers & swales was included in each of the cost models assuming that in certain situations one of these would ideally address site-specific topography or land use issues.

Costs shown above are based on a spreadsheet cost model developed by the City of Durham's Stormwater Services Division. The six scenarios above represent various mixes of different BMPs that were adjusted to achieve a 35% overall reduction in loading from the City of Durham. The spreadsheet accounts for area required by each type of BMP and the range of drainage areas treated by each type of BMP. In all scenarios, it was necessary to assume a certain portion of existing development has two BMPs in series in order to obtain sufficient load reductions, and the spreadsheet calculates load to the second BMP based on reductions in the first BMP.

Loads and land costs in the spreadsheet model are based on the existing land use of parcels within the City of Durham that drain to Jordan Lake from Durham County's GIS parcel database. Land costs are based on assessed tax value and recent sale price, where reported, in the parcel database.

Construction costs for BMPs are based on the cost equations for new development BMPs in "The Economics of Structural Stormwater BMPs in North Carolina," Ada Wossink and Bill Hunt, published by the NC Water Resources Research Institute, UNC-WRRI-2003-344, May 2003. Retrofit multipliers were used to account for the higher costs of retrofitting reported in CWP, 2007. Design and engineering costs were also based on 35% and 40% of construction cost as reported in CWP, 2007 for retrofits, with the higher rate used to account for environmental permitting.

APPENDIX C

Estimated Cost per Household for In the City of Durham For the Existing Development Rule

Unless the legislature provides significant funding, we should assume that costs will be borne by people living in the Jordan Lake watershed. Most communities have impairment in other watersheds. For example, the City of Durham faces upcoming requirements to reduce nitrogen loading to Falls Lake. Requirements to address Falls Lake will be at least as stringent as those for Jordan Lake.

The table below expresses the City of Durham costs for complying with the Existing Development Rule on a per person and a per household basis for people and households in the Jordan Lake watershed. The cost per household is a way of showing the impact on families that the Existing Development rule will have. We are extremely concerned about the affordability of the existing development rule and the impact on low-income families.

It should be noted that these costs do not assume removal of existing occupied structures, relocation of utilities, or any of a number of other worst-case scenarios. We note that the language in the Existing Development Rule does not preclude the City from having to undertake such extreme measures.

Alternative Number	Assumed mix of BMPs	20 year total costs, incl. O&M	Cost per Person	Cost per Household
1	Wetlands (92%)*	$349,600,000	$3,023	$7,074
2	Wetlands (83%) +Buffers & level spreaders (13%)*	$333,600,000	$2,885	$6,751
3	Wetlands (75%) +Bioretention (18%)*	$431,500,000	$3,731	$8,732
4	Wetlands (67%) +Bioretention (26%)*	$467,300,000	$4,041	$9,456
5	Bioretention (50%) + wetlands*	$572,500,000	$4,951	$11,585
6	Bioretention w/ some wetlands downstream*	$680,500,000	$5,885	$13,770

* Small amount of buffers & swales included, assumed best fit to certain topography & land use

The above costs are based on the 20-year life-cycle costs from Appendix A, and the estimated population in that part of the City of Durham that drains to Falls Lake. A GIS analysis conducted by the Durham City-County Planning Department determined that the City had a population of 101,464 in the Jordan Lake watershed in April, 2000. This was updated to August 2007 using dwelling units added in the City within the watershed, together with 2.38 persons per household and occupancy rates to estimate that the population had grown by 14,174. Total current City of Durham population in the Jordan Lake watershed is estimated to be 115,638.

APPENDIX D

Neuse River TMDL
(Selected Pages)

Total Maximum Daily Load for Total Nitrogen to the Neuse River Estuary, North Carolina

March 1999

Neuse River Basin

Prepared by:
NC Department of Environment and Natural Resources
Division of Water Quality
Water Quality Section
Post Office Box 29535
Raleigh, NC 27626-0535
(919) 733-5083

TABLE OF CONTENTS

percentage. The model was linked into a GIS system, and the results are displayed in Figure 13. This method estimates that approximately 2.34 million pounds per year of total nitrogen that originates from point sources arrives at New Bern.

Allowable Point Source Load

Thus, the point source total nitrogen allocation at New Bern is 1.64 million pounds per year, a 30% reduction from the estimated 1995 delivered load to the estuary.

Nonpoint Sources

Baseline NPS Loading

Since point sources contribute approximately 2.34 million pounds of total nitrogen per year, nonpoint sources were calculated by difference to contribute the remainder of the baseline load or 7.31 million pounds per year (9.65 – 2.34 million pounds per year).

In order to partition the baseline nonpoint source load into the various categories such as agriculture, forestry, and urban areas, the export coefficient method was used to estimate the amount of nitrogen that enters surface waters from the various landuses/landcovers. Numerous studies have been conducted to determine the amount of nitrogen that leaves a watershed and enters surface waters on an annual basis. The export coefficient approach can be used to describe the amount of nutrients leaving a given land use type. The export coefficient itself is derived from an examination of actual field measurements taken over a period of time and is usually a single number expressed as mass/area/time.

The export coefficients developed by Research Triangle Institute (Dodd and McMahon, 1992) were used as a basis for determining export. The export coefficient for atmospheric deposition was updated using data available from the National Atmospheric Deposition Program (NCEMC, 1997a). Table 3 contains the nitrogen export coefficients.

Table 3: Export Coefficients Used in TN Loading Calculations in Neuse River Basin

Land Use	Export Coefficient (lb/acre-year)
Urban	8.06
Cultivated	13.56
Managed Herbaceous	4.37
Forest	1.72
Open Water (direct atmospheric depostion)	8.75

The 1993-95 infrared satellite imagery data was used to estimate acreages of various land use within the basin. Since the land cover did not have municipal area interpreted, DWQ surveyed municipalities in the basin with populations greater than 5000 to determine an estimate of average land use within municipal areas. Total nitrogen load was estimated using these export coefficients for cultivated land, managed herbaceous land, forests, urban land, and direct atmospheric deposition on open water. The following estimates of nitrogen load resulted:

Table 4: Estimated TN Load by Land Cover for Neuse River Basin

Land Use	Acres in Trent	TN in Trent (lb/yr)	Acres above New Bern	TN above New Bern (lb/yr)	TN in Basin (lb/yr)	Percent Load from Land Use
Urban	1,635	13,178	192,407	1,550,800	1,563,979	8%
Cultivated	75,437	1,022,926	850,279	11,529,783	12,552,709	67%
Mngd Herb	6,425	28,077	137,158	599,380	627,458	3%
Forest	200,073	344,126	1,932,297	3,323,551	3,667,676	20%
Open Water	1,076	9,415	36,810	322,088	331,503	2%

The direct deposition to the estuary was also estimated. There are 28,950 impaired acres in the estuary below New Bern. Using the same export coefficient of 8.75 lb/acre-year results in an estimated load of 0.25 million pounds directly deposited on the estuary below New Bern.

The managed herbaceous land use was then partitioned into agricultural and urban land uses based on Department of Agriculture Survey results. The survey indicated that approximately 25% of turf grass is in non-agricultural use such as golf courses, lawns and commercial lands and the remaining 75% was in agricultural land. Based on these numbers, the managed herbaceous land use was split into urban and forested land, and a general agricultural class was created.

The final step in calculating the baseline nonpoint source loads was to estimate the total nitrogen loading that is actually transported to the estuary for each land use type. Export coefficients are a measure of the nitrogen load leaving a given land use type. Some of this nitrogen is lost as it travels to a nearby stream and eventually to the estuary. DWQ assumed that the nitrogen load to the estuary for each land use was proportionate to the loads estimated at the edge of field. The atmospheric deposition directly to the estuary below New Bern was added to the load estimated to be directly deposited on open water above New Bern (i.e. 100% of this load was assumed to be transported to the estuary). Table 5 shows the final baseline total nitrogen loads by category for the Neuse River Basin:

Table 5: Baseline TN Loads by Land Use Category

Land Use	Baseline TN Load (million lb/yr)
Urban	0.65
Agriculture	4.90
Forest	1.38
Open Water (Atmospheric Deposition)	0.38
Total Baseline NPS Load	7.31

Allowable NPS Loads

DWQ initially set 30% reduction targets from the baseline calculation for each nonpoint source category. Commentors indicated that reductions could not be made from forested land. Therefore, the nitrogen from this land use was considered as background in the final allocation. The 30% reduction that would be needed from forested land was allocated among agriculture and urban land in proportion to their respective land areas within the basin. The allocation targets for each nonpoint source category are included in Table 6.

Table 6: Allocation Targets by Land Use Category

Land Use	TN Allocation (lb/yr)
Agriculture	3,090,000
Urban	390,000
Open Water (Atmospheric Deposition)	260,000
Forest (Background)	1,380,000
Total	5,120,000

(Note: The numbers in the above table differ from those that would be calculated from the table reported in the 1997 Report of Proceedings for three reasons. First, based on comments from EPA, the Trent River nonpoint source loads were included in the calculations. Second, based on comments from EPA, atmospheric deposition below New Bern was accounted for. Third, the point source numbers were checked by obtaining the lab sheets from each facility with permitted flows of 0.5 MGD or greater. The numbers for the smaller dischargers were also quality assured with hard copies of the discharge monitoring reports to ensure the numbers were entered correctly into the computer compliance system. Thus, the allocation to point sources has changed slightly since the 1997 Report of Proceedings was drafted, and this affected the nonpoint source allocations slightly).

It should also be noted that this TMDL accounts for only the nitrogen entering the estuary via freshwater. Because nitrogen is soluble, it is transported through groundwater. At this time, the amount of nitrogen entering the Neuse River from groundwater sources is unknown and cannot be quantified. Groundwater is accounted for in the nonpoint source allocation, since the baseline load at Fort Barnwell and Pollocksville (Trent watershed) includes all sources, even those that cannot be quantified for allocation purposes with current data. Some of the control measures to reduce nitrogen loading in the basin such as buffers, do reduce the nitrogen load from groundwater.

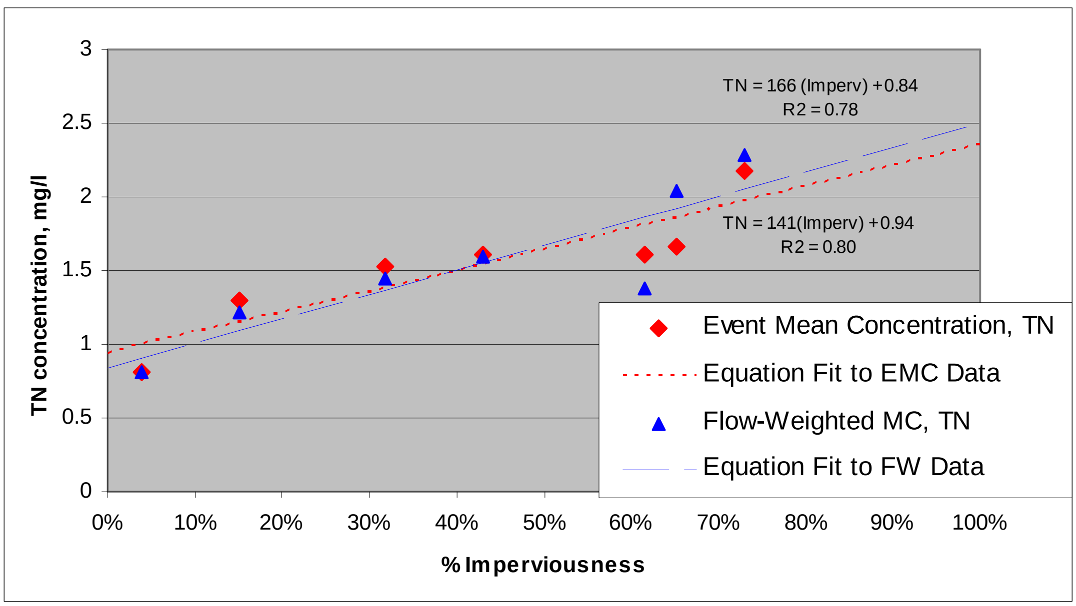
APPENDIX E

Concentration of Nitrogen in Stormwater

The concentration of nitrogen in urban stormwater runoff is well below 3.0 mg/L to before treatment.

Event Mean Concentrations (EMCs) reported for various land uses in Durham ranges from 0.8 mg/L for open space to 2.2 mg/L for commercial (Source: Table B-1b, "City of Durham Stormwater Management Program for the Neuse River Nutrient Sensitive Water Strategy," January 24, 2001). To be conservative, the City used 2.6 mg/L for impervious surfaces.

Figure B-1b
Variation of Total Nitrogen in Stormwater Runoff With Imperviousness



Median concentrations reported in a national database range from 1.33 mg/L total nitrogen for open space to 2.2 mg/L total nitrogen for commercial, with a slightly higher concentration - 2.3 mg/L - reported for freeways (Source: National Stormwater Quality Database (NASQD version 1.1), February 16, 2004.)

The Neuse and the Tar-Pam nitrogen calculations are based on nitrogen concentration ranging from 1.42 for managed pervious to 2.6 mg/L for transportation impervious surfaces. The concentrations are shown on the Tar-Pam calculation worksheet:

Piedmont of the Tar-Pamlico River Basin:

Includes Oxford, Henderson, Rocky Mount and Tarboro as well as Franklin, Nash and Edgecome Counties

BMP Removal Calculation Worksheet (Automated)

Project Name: ____________________
Date: ____________________
By: ____________________ Checked By: ____________________

Directions:

> It may be advantageous to split the development into separate catchments to be handled by separate BMPs. The tables below allow the development to be split into as many as three catchments, and can be copied for greater than three. NOTE: Unless runoff flowing onto the development from offsite is routed separately around or through the site, the offsite catchment area draining in must be included in the acreage values of the appropriate land use(s) and treated.

> **Above each table:** Enter the catchment acreage in the top green blank. Based on a comparison of the post-development TN and TP export coefficients you calculated above to the rule requirements of 4.0 lb/ac/yr TN and 0.4 lb/ac/yr TP, select BMP(s) from the list for treating the catchment runoff. Enter the chosen BMP(s) nutrient removal rates in the green blanks. If more than one BMP is to be used in series, the combined removal rates will be calculated automatically in the blue blanks.

> **Catchment Tables:** Enter the acres of each type of land cover in the green boxes. The spreadsheet will calculate all of the light blue boxes. NOTE: Compare the Total Catchment Acreage for the Development (final table) to the value you established in the pre-BMP worksheet tables, and also to the site plans, for consistency. All of these values need to be the same

BMP Nutrient Removal Rates

	TN	TP	Design Standard
Wet Detention Pond	**25**	**40**	**NC BMP Manual**
Stormwater Wetland	**40**	**35**	**NC BMP Manual**
Sand Filter	**35**	**45**	**NC BMP Manual**
Bioretention	**35**	**45**	**NC BMP Manual**
Grass Swale	**20**	**20**	**NC BMP Manual**
Vegetated Filter Strip w/ Level Spreader	**20**	**35**	**NC BMP Manual**
Dry Detention	**10**	**10**	**NC BMP Manual**

Catchment 1:

Total acreage of catchment 1 =		ac			
First BMP's TN removal rate =		%	First BMP's TP removal rate =		%
Second BMP's TN removal rate =		%	Second BMP's TP removal rate =		%
Third BMP's TN removal rate =		%	Third BMP's TP removal rate =		%
TOTAL TN REMOVAL RATE =	0	%	TOTAL TP REMOVAL RATE =	0	%

(1) Type of Land Cover	(2) Catchment Acreage	(3) S.M. Formula (0.46 + 8.3I)	(4) Average EMC of TN (mg/L)	(5) Column (2) * (3) * (4)	(6) Average EMC of TP (mg/L)	(7) Column (2) * (3) * (6)
Transportation impervious			**2.60**		**0.19**	
Roof impervious			**1.95**		**0.11**	
Managed pervious			**1.42**		**0.28**	
Wooded pervious			**0.94**		**0.14**	
Area taken up by BMP			**1.95**		**0.11**	
Fraction Impervious (I) =			**Pre-BMP TN Load (lb/yr) =**		**Pre-BMP TP Load (lb/yr) =**	
Total Area of Development =			**Pre-BMP TN Export (lb/ac/yr) =**		**Pre-BMP TP Export (lb/ac/yr) =**	
			Post-BMP TN Load (lb/yr) =		**Post-BMP TP Load (lb/yr) =**	
			Post-BMP TN Export (lb/ac/yr) =		**Post-BMP TP Export (lb/ac/yr) =**	

APPENDIX F

EVIDENCE OF DECLINING NUTRIENT LOADS, Part 1

The following pages are excerpted from United States Geological Survey Scientific Investigations Report 2005–5271, “Suspended Sediment and Nutrients in the Upper Cape Fear River Basin, North Carolina, 2002–04, with an Analysis of Temporal Changes, 1976–2004,” authored by Timothy B. Spruill, Phillip S. Jen, and Ryan B. Rasmussen.

The report indicates that phosphorous loads and nitrogen loads have been declining in the Haw River at Bynum. A pdf file of this report is available online at http://pubs.water.usgs.gov/sir2005-5271/

Suspended Sediment and Nutrients in the Upper Cape Fear River Basin, North Carolina, 2002–04, with an Analysis of Temporal Changes, 1976–2004

By Timothy B. Spruill, Phillip S. Jen, and Ryan B. Rasmussen

Prepared in cooperation with the Upper Cape Fear River Basin Association

Scientific Investigations Report 2005–5271

U.S. Department of the Interior
U.S. Geological Survey

Suspended Sediment and Nutrients in the Upper Cape Fear River Basin, North Carolina, 2002–04, with an Analysis of Temporal Changes, 1976–2004

By Timothy B. Spruill, Phillip S. Jen, and Ryan B. Rasmussen

Abstract

An investigation of suspended sediment and nutrients was conducted in the Haw River near Bynum and in the Deep River at Moncure, North Carolina, to characterize water quality based on data collected weekly or biweekly between August 2002 and August 2004. Samples were collected five times per year for selected major ions and trace elements to help in characterizing the water quality at these sampling sites. Sediment and nutrient data collected from 1976 to 2004 also were analyzed to evaluate whether loads and concentrations changed significantly over this period.

The water chemistry in the Haw and Deep Rivers is of mixed ionic composition, although the water chemistry in the Haw River is more variable. Water types in both rivers generally shifted from calcium and bicarbonate in the winter and spring months and during high flows to sodium and chloride during low flows in the summer. Sediment and nutrient loads were estimated for calendar years 2002 and 2003 using the nutrient and suspended-sediment concentration data collected between 2002 and 2004 for calibration of regression load models. Sediment and nutrient loads generally were greater in 2003, an unusually wet year, than in 2002. Annual constituent yields generally were higher in the Deep River with the exception of dissolved nitrate and nitrite. Phosphorus loads and concentrations were significantly higher in the Deep River as a result of substantial continuous-discharge sources of phosphorus, particularly near High Point, North Carolina. More stringent wastewater-treatment requirements in the Haw River primarily are responsible for much lower phosphorus concentrations and loads compared with those in the Deep River. Seasonal loads were evaluated at both sites for the period September 2002 through August 2004. Primary transport of nutrients and sediment occurred during spring 2003 and winter 2004.

Historical flow and water-quality data previously collected at both sites by the U.S. Geological Survey and the North Carolina Division of Water Quality were used to evaluate historical changes through time and to compare information from the two datasets. Historical water-quality changes between 1976 and 2004 were greatest in the Haw River near Bynum, which had a statistically significant (p is less than 0.05) decrease in sediment, total nitrogen, and total phosphorus concentrations and loads. Decreases in cultivated land, improved land-management practices, and improved wastewater-treatment processes since the 1980s are primary reasons for the observed improvement in water quality in the Haw River.

Because sampling was limited for nutrients (16 samples) and sediment (25 samples) in the Deep River, changes in concentrations between the early 1980s and 2002–04 were not statistically detectable (p is greater than 0.05) for suspended sediment, total nitrogen, or total phosphorus. Data from the North Carolina Division of Water Quality also indicated no change between 1992 and 2004. Calculated sediment loads, however, using the load-streamflow regression models calibrated for two separate periods, 1976–83 and 2002–04, indicate that sediment loads may be lower for 2002–04 compared with those in the early 1980s. Nutrient concentrations have remained relatively unchanged since the 1980s.

Introduction

The Upper Cape Fear River Basin Association (UCFRBA) in North Carolina established a 44-station water-quality sampling network in 2000 to support analyses of water quality in the Haw and Deep River basins and to serve as a basis for providing recommendations to local, State, and Federal authorities regarding maintenance and improvement of water quality and water resources in the upper Cape Fear River basin. The monitoring network was established under an agreement with the North Carolina Division of Water Quality (NCDWQ) and supersedes the NCDWQ in-stream monitoring requirements for point-source discharge facilities that participate in the UCFRBA monitoring program.

per acre compared with about 14,000 pounds per acre from cropland in the United States (Pimentel and others, 1995). Even though population and urbanization increased in the basin (North Carolina Division of Water Quality, 2000, 2005a), these factors are overshadowed by the dramatic decrease in agricultural land use in the basin that occurred during the 1980s and by improvements in crop-management practices since the 1980s. These findings are in agreement with those of Richter and others (1995), who determined that sediment transport in the Yadkin River basin in the North Carolina Piedmont decreased by about 30 percent from the 1950s to the 1990s, primarily because of an approximate 50-percent decrease in cropland during the period and improvements in crop-management practices since the early 1990s, even though residential and urban areas increased by 80 percent.

Total Phosphorus in the Haw River near Bynum

Total phosphorus data are available for the Haw River near Bynum from the USGS for three periods—monthly between 1981 and 1986, quarterly between 1992 and 1995, and monthly or biweekly from August 2002 through August 2004. Monthly phosphorus data for the Haw River also are available from the NCDWQ for January 1980 through 2004. Both total phosphorus concentrations and loads decreased in the Haw River between 1980 and 2004. Total phosphorus concentrations decreased significantly between the periods 1976–85 and 2002–04 ($p < 0.001$) from a median of 0.34 mg/L to a median of 0.13 mg/L, according to USGS data and corroborated by NCDWQ data (fig. 11). Using load data computed by LOADEST, the decrease in phosphorus loads

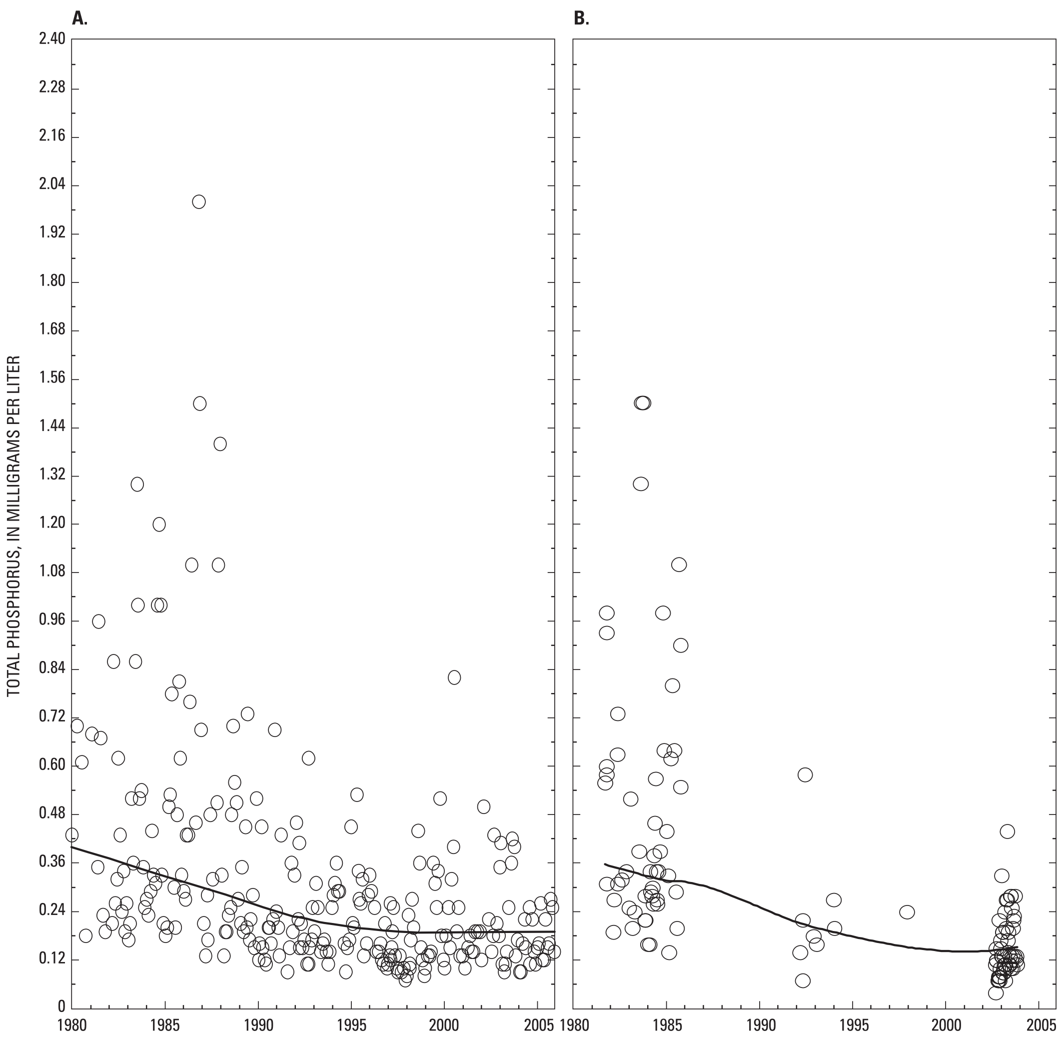


Figure 11. Total phosphorus data from (A) the North Carolina Division of Water Quality and (B) the U.S. Geological Survey for the Haw River near Bynum, North Carolina, 1980–2004, and trends indicated by LOWESS smooth lines.

between 1981–85 and 2002–04 was similar to the decrease in sediment—more than 50 percent for annual loads (table 10). The total phosphorus loads reported by Childress and Treece (1996) are between the 1981–85 and 2002–04 model calculations. The lower phosphorus loads observed during 2002–04 compared with those in the 1980s are consistent with data from other studies, both nationally and locally.

Table 10. Annual phosphorus loads for calendar year 1976–2003 streamflows in the Haw River near Bynum, North Carolina, for two calibration periods, 1981–85 (shaded) and 2002–04 (shaded).

[Annual water-year loads from Childress and Treece (1996) are given for comparison]

Calendar year	Phosphorus load, in tons, 1981–85	Phosphorus load, in tons, 2002–04	Phosphorus load, in tons, from Childress and Treece (1996)
1976	324	106	
1977	334	112	
1978	699	335	
1979	798	359	
1980	373	145	
1981	334	122	
1982	682	290	
1983	575	235	
1984	740	332	
1985	558	214	
1986	209	68	
1987	501	260	
1988	264	85	
1989	740	305	480
1990	620	238	490
1991	460	189	490
1992	453	167	310
1993	552	251	530
1994	393	163	360
1995	631	265	
1996	760	338	
1997	434	175	
1998	553	280	
1999	460	165	
2000	409	141	
2001	246	98	
2002 E	464	162	
2003 E	1,054	485	

[E] Calendar year loads for 2002 and 2003 were estimated based on the calibration period September 2002 through August 2004.

Dissolved phosphorus concentrations decreased nationwide in many streams in response to a ban on phosphorus in detergents in 1988 (Smith and others, 1993). This decrease also was noted by Childress and Treece (1996) for streams draining into Jordan Lake, including the Haw River near Bynum. Data from both the USGS and NCDWQ indicate a significant decrease in total phosphorus concentrations in the basin since 1980, primarily because of decreased point-source discharges. The median orthophosphate concentration (the dissolved portion of total phosphorus) decreased from 0.2 mg/L during 1981–85 to about 0.06 mg/L during 2002–04, accounting for more than 50 percent of the observed decrease in total phosphorus. A comparison of 1981–85 instantaneous total phosphorus loads (median of 0.86 ton per day) with 2002–04 data (median of 0.46 ton per day) also indicated a significantly lower load ($p < 0.01$) during the later period (fig. 12).

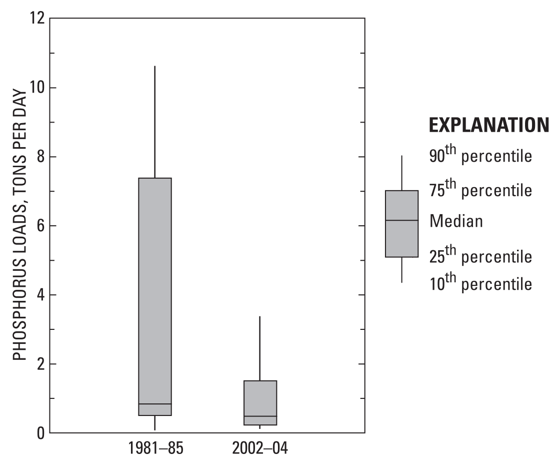


Figure 12. Instantaneous phosphorus loads for 1981–85 and 2002–04 at the Haw River near Bynum, North Carolina.

Total Nitrogen in the Haw River near Bynum

Most total nitrogen data from the USGS for the Haw River near Bynum are available for three periods—monthly between 1981 and 1985, quarterly or less frequently between 1992 and 1998, and monthly or biweekly from August 2002 through August 2004. Monthly total nitrogen data also are available from the NCDWQ for January 1980 through 2004. As with suspended sediment and total phosphorus, concentrations of total nitrogen from USGS data were significantly lower ($p < 0.001$) using a Mann-Whitney (Conover, 1980) test for differences during the later sampling period (median of 2.2 mg/L compared with a median of 1.4 mg/L). Concentrations of dissolved Kjeldahl nitrogen (organic nitrogen plus ammonia) decreased by half from a median concentration of 1.25 to 0.61 mg/L ($p < 0.05$) between 1981–85 and 2002–04, and accounted for much of the observed decrease in total

APPENDIX G

EVIDENCE OF DECLINING NUTRIENT LOADS, Part 2

The following pages are a memorandum by the NC Division of Water Quality, "Trend Analysis of Nutrient and TSS Concentrations in the CFRB," authored by Narayan Rajbhandari, dated October 15, 2004.

The report focuses on nutrient loads in the Cape Fear River Basin 9CFRB). The report incorrectly identifies New Hope Creek as being in Greensboro. In fact, USGS gaging station USGS 02097314 NEW HOPE CREEK NEAR BLANDS, NC is located in Durham at Stagecoach Road, (NC State Road 1107). Information on this gaging station can be found online at http://nc.water.usgs.gov/.

The memorandum indicates that in New Hope Creek, the decline in nitrogen concentration from 1990 to 2004 was statistically significant, despite development occurring in three municipalities (Durham, Chapel Hill, Carrboro) and two counties (Durham and Orange).

NC Division of Water Quality
Planning Branch
Modeling and TMDL Unit

MEMORANDUM

To: Michelle Woolfolk

From: Narayan Rajbhandari

CC: Boyd DeVane
Cam McNutt

Date: October 15, 2004
Subject: Trend Analysis of Nutrient and TSS Concentrations in the CFRB

Introduction:
This Memo contains the results of trend analysis in the Upper and Middle Cape Fear River Basins. As you requested, the following constraints were paced on the analysis:

1. No more than five and no fewer than two stations should be included.

2. Time series of water quality and discharge should be available for a minimum of 7 to 10 co-incident years. (This is in order to include the theoretical length of the El Nino-La Nina climatic cycle.)

3. The analysis should include trends for the following parameters: total nitrogen (TN), defined as the sum of total Kjeldahl nitrogen and nitrate-nitrogen, total phosphorus (TP), and total suspended solids (TSS).

4. Monitoring stations and trends should represent both urban and rural land uses in small watersheds. Avoid mainstream stations in the Haw, Deep, and Cape Fear Rivers.

Site Selection:
Seven water bodies in the UCFRB were considered for this study (Table 1). However, based on availability of flow data, only three water bodies could be selected: East Fork Deep River, New Hope Creek, and Rockfish Creek. The former two water bodies are located near High Point and Greensboro (Guildford County) respectively; and therefore represent urban watershed. The subsequent water body represents rural to urban changing watershed and is located near Raeford (Hoke County).

Data Management:
Detection of trends in stream water quality is more difficult when concentrations are related to stream flow and seasonality, when concentrations are not normally distributed, and when concentrations contain missing values (Gilbert, 1987 and Hirsch et al., 1982). In this study, the flow-adjusted concentration was, therefore, estimated based on regression of concentration on some function of discharge to overcome the flow relatedness. The flow-adjusted concentration was then tested for a trend by using the Seasonal Kendall test to overcome seasonality and non-normality.

Table 1. Upper and Middle Cape Fear River Basin stations considered for trend analysis.

Land use / Water Body	Ambient Station	USGS Station	Remarks
I. Urban			
East Fork Deep River	B4240000	02099000	Flow data from 1994/04/01 through 1997/09/30 are not available.
North Buffalo Creek	B0540000	02095500	Flow data are not available prior to 1998/07/31.
South Buffalo Creek	B0660000	02095000	Flow data are not available prior to 1998/07/31.
New Hope Creek	B3040000	02097314	Flow data are available since 1990.
II. Rural to Urban			
Rockfish Creek	B7700000	02104279	Flow data are not available prior to 1998/01/15.
III. Rural			
Little Troublesome Creek	B0160000	_	No flow data
Bear Creek	B5480000	_	No flow data

The Seasonal Kendall technique usually predicts significant and unambiguous trends for concentrations longer than 10 years (Aroner, 2000). However, among the three selected water bodies, the East Fork Deep River and Rockfish Creek did not have more than ten years of flow data (Table 1). Flow measurements were discontinued from 1994/04/01 through 1997/09/30 was discontinued in East Fork Deep River and flow measurement began on 1998/01/15 in Rockfish Creek (Table 1). A regression method was, therefore, used to estimate the missing flow values in the two water bodies as follows:

The USGS gauge stations 02099500 at the Deep River near Randleman and 02104220 at the Rockfish Creek at US 401 were selected to estimate missing flows at the ambient stations B4240000 (USGS 02099000) in the East Fork Deep River near High Point and

B7700000 (USGS 02104279) in the Rockfish Creek at SR1432 respectively. The selected USGS stations had similar physical and biological watershed conditions and had continuous flow measurement from1990 through 2004.

The measured flows at 02099000 in the East Fork Deep River were regressed with the flows at 02099500 in the Deep River to obtain following regression equation 1.

Flow @ USGS 099000 = 1.468 + 0.144 * Flow @ USGS 02099500 -------- (1)
R-Square = 0.56
Similarly, the measured flows at 02104220 in the Rockfish Creek were regressed with the flows at 021042790 to obtain following regression equation 2.

Flow @ USGS 21042790 = 5.774 + 1.795 * Flow @ USGS 21042200 --------- (2)
R-Square = 0.82.

Above equations 1 and 2 were then used to estimate the missing flow values for the East Fork Deep River and Rockfish Creek. Following methods were then utilized to evaluate trend in nutrient and TSS concentrations for January1990 through March 2004.

Methods:
The Water Quality / Hydrology Graphics / Analysis System (WQHYDRO) model was used to evaluate trends in TN, TP and TSS concentrations in the East Fork Deep River, New Hope Creek, and Rockfish Creek. The model is a multi-faceted computer program, which is capable of computing flow-adjusted concentration and Seasonal Kendall test (Aroner, 2000).

The WQHYDRO model removes the concentration variation related to stream flow with flow-adjusted data by using a robust smoothing technique called Locally Weighted Scatterpot Smooth (LOWESS). The technique describes the relationship between concentration (Y) and flow (X) without assuming linearity or normality. The resulting residuals are considered flow-adjusted concentrations.

The WQHYDRO model computes the Seasonal Kendall test both for serial correlation data (autocorrelation) and non-serial correlation data. Serial correlation can be understood as follows: a measurement at one time period reflects the concentration at a previous time period; or in other words the observations within or between water samples are dependent of one another.

A fundamental assumption of statistical procedures is that observations within or between samples are independent of one another. For that reason, any statistical test on serially correlated data would disclose wrong information. Many water quality time series exhibits serial correlation. Appropriate adjustment during analysis must be made to deal with this. Therefore, the data were checked for log-1 auto-correlation in this study. If significant, an autocorrelation corrected version of the Seasonal Kendall test was used.

The WQHYDRO model has an automatic provision for removing the serial correlation problem using an autocorrelation-corrected version of the Seasonal Kendall test. The technique is known as Seasonal Kendal with Correction (SKWC). For the non-serial correlation data, the model uses Seasonal Kendal without Correction (SKWOC) technique. Utilizing the automatic provision, the Seasonal Kendall test was applied to test a null hypothesis that there was no trend in TN, TP, and TSS concentrations in the East Fork Deep River, New Hope Creek, and Rockfish Creek. An alternative hypothesis is that there was a trend. Upward trend (positive slope) indicates degradation of water quality, whereas downward trend (negative slope) indicates improvement of water quality. The hypothesis was tested at 95% confidence level.

Results:

1. East Fork Deep River

Box plots of nutrient and TSS concentrations for each month are given in Figures 1.1 to 1.3. The solid line inside the box represents median concentration value. The box plots indicates that average TN and TP concentrations peaked at 0.8 mg/L and 0.09 mg/L in February and dropped down to 0.5 mg/L and 0.04 mg/L in October respectively. Similarly, TSS concentration peaked to 21 mg/L in June and dropped down to 5 mg/L in October. The ranges between the peaked and lowered values were considerably wide, suggesting seasonality associated with nutrient and TSS concentrations in the East Fork Deep River. The ranges further suggest that late winter was the most likely period for TN and TP to be elevated, and early summer was the most likely period for TSS to be elevated.

LOWESS plots for TN, TP, and TSS against flow are presented in Figures 1.4 to 1.6. The residuals of the LOWESS smooths were tested using the Seasonal Kendall test. The SKWC for lag-1 serial correlation was used to test the null hypothesis. The graphical representations of trends are presented in Figures 1.7 to1.9. The results indicate that there was significant negative trend in flow-adjusted TP concentration in the river at 95% confident level. There were no significant trends in flow-adjusted TN and TSS concentrations.

Trend slope represents median rate of change in flow-adjusted concentrations in the East Fork Deep River and serves as an approximation to actual temporal variations after natural variability has been removed. The significant downward slope of TP suggests that the decrease in TP concentration per year was 0.0033 mg/L on average during the study period, January 1990 through March 2004.

2. New Hope Creek:
Distribution of nutrient and TSS concentrations showed presence of seasonality in the New Hope Creek (Figures 2.1 to 2.3). Average TN concentrations gradually increased from 1.15 mg/L in January to 6.8 mg/L in September. TP concentrations gradually peaked from 0.12 mg/L in January to 0.43 mg/L in July. Similarly, TSS concentration peaked from 6 mg/L from February to 59.5 mg/L in June. The results indicate that summer period was the critical period when TN, TP, and TSS concentrations reached to a high value in the creek.

LOWESS plots for TN, TP, and TSS against flow are presented in Figures 2.4 to 2.6. The residuals of the LOWESS smooths were tested using the Seasonal Kendall test. The SKWC for lag-1 serial correlation was used to examine significance of trend slope in the New Hope Creek during the study period, January1990 through March 2004. The test indicates that the downward trend in flow-adjusted TN concentration was significant at 95% confidence level (Figure 2.7). On average, TN concentration decreased by 0.17 mg/L each year in the New Hope Creek.

The downward trends in flow-adjusted TP and TSS concentrations were not significant at 95% confident level (Figure 2.8 and 2.9).

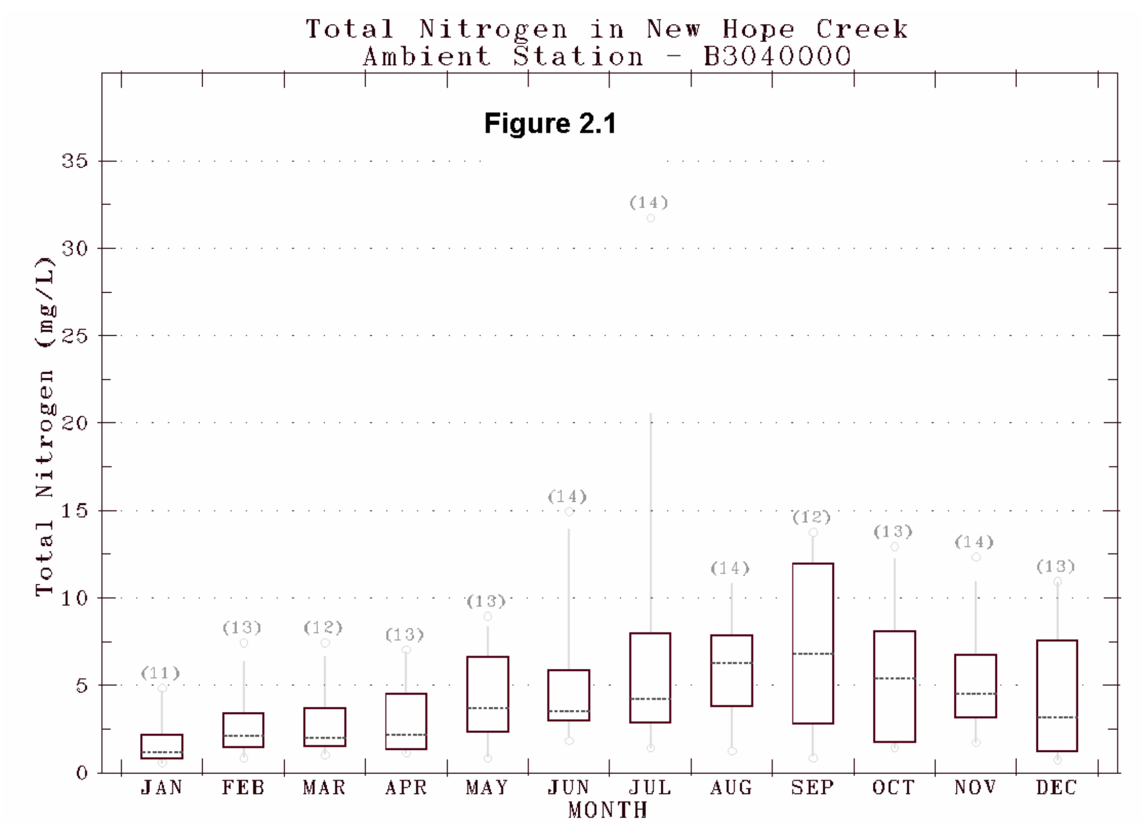
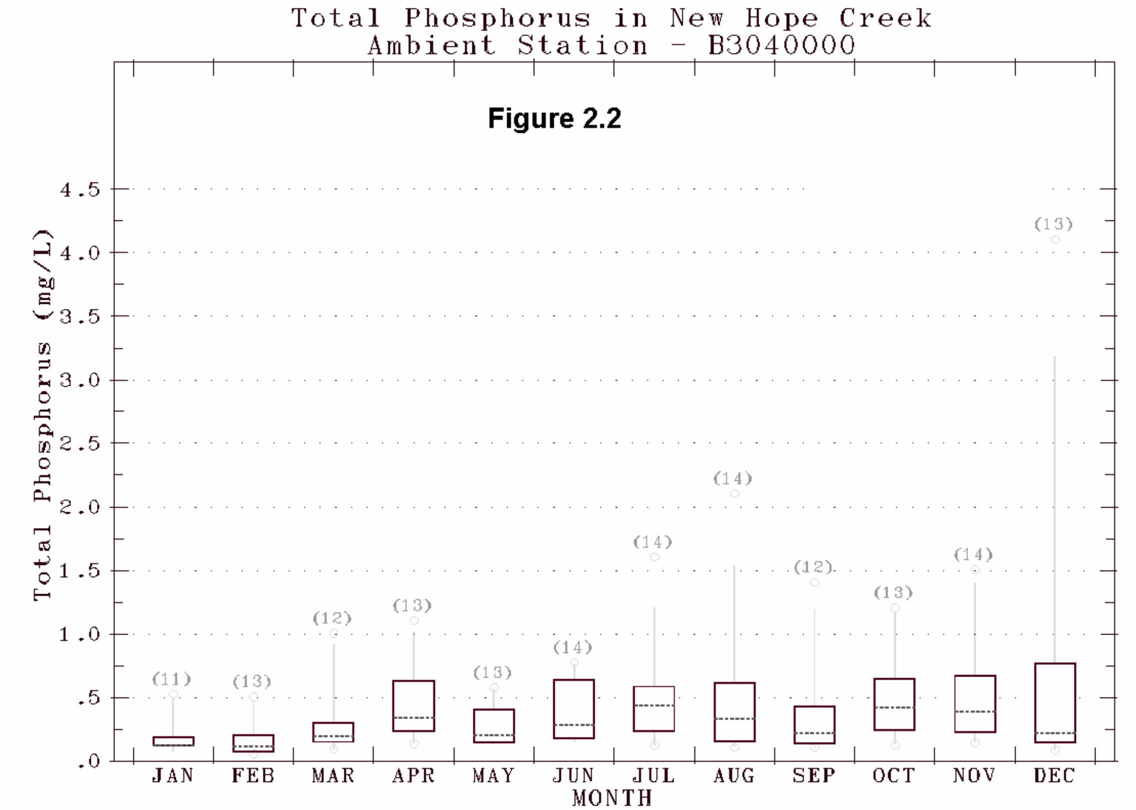
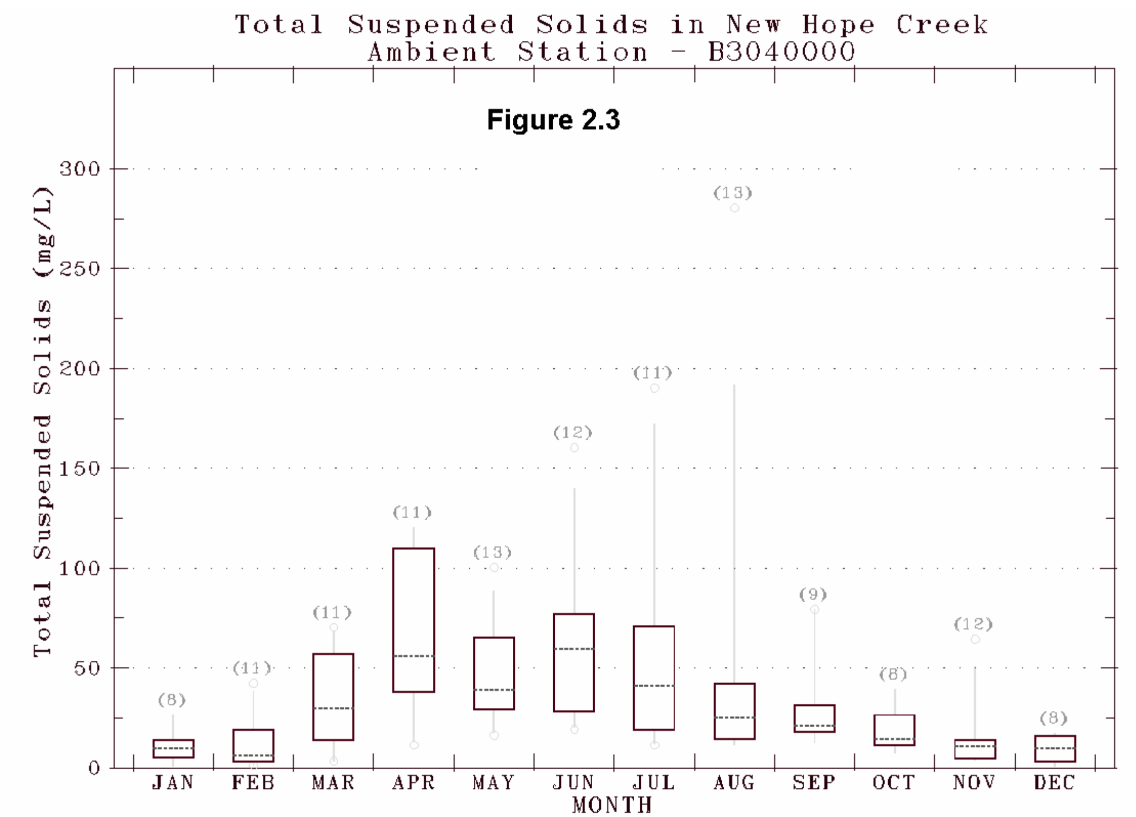
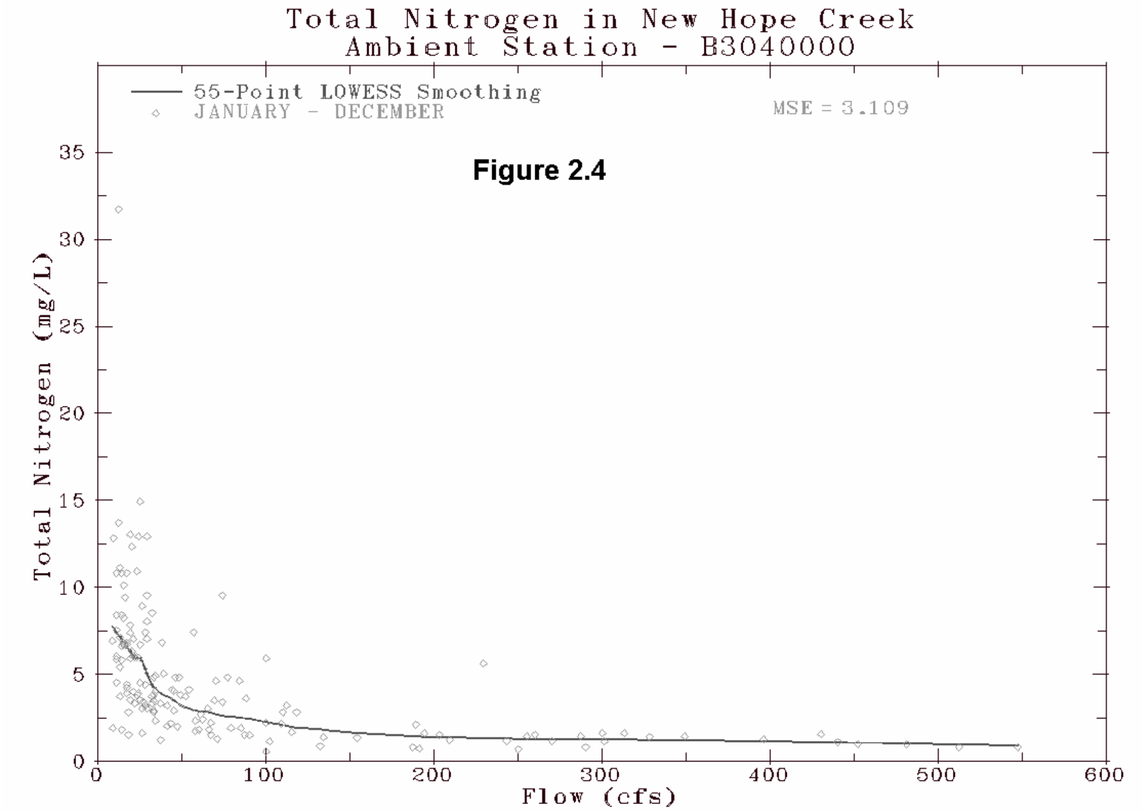
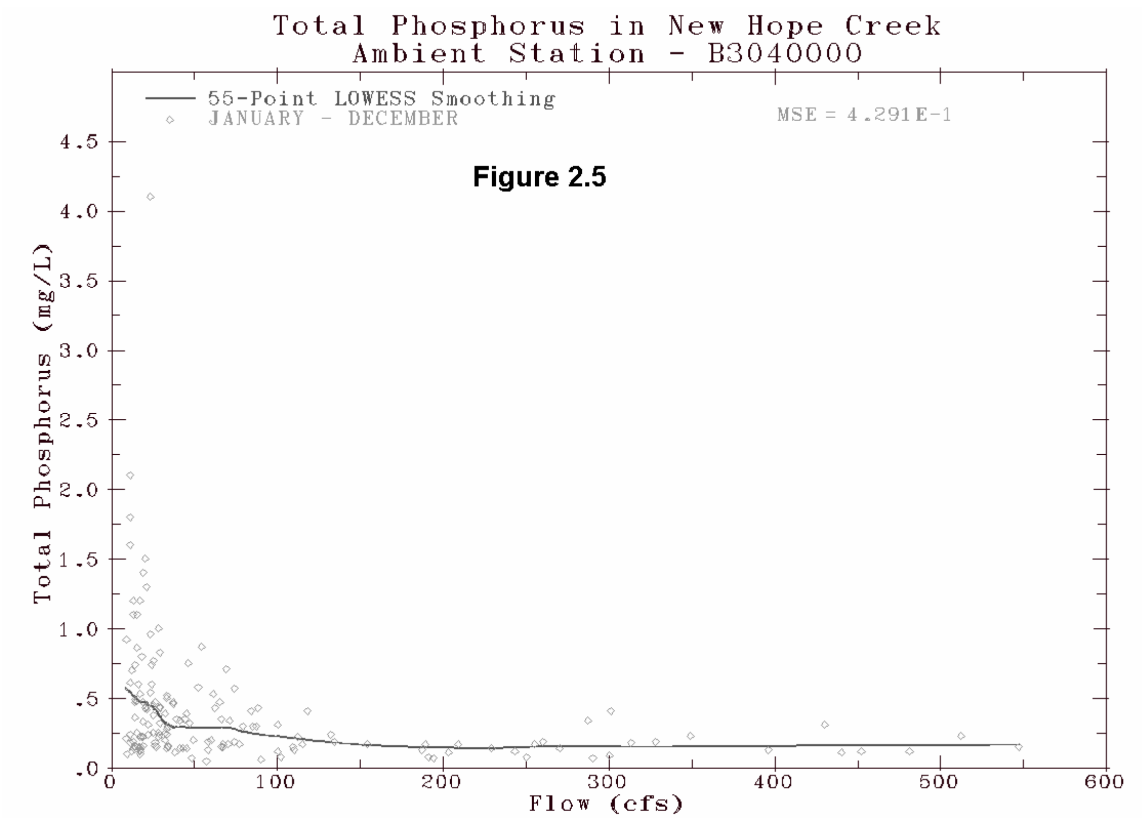


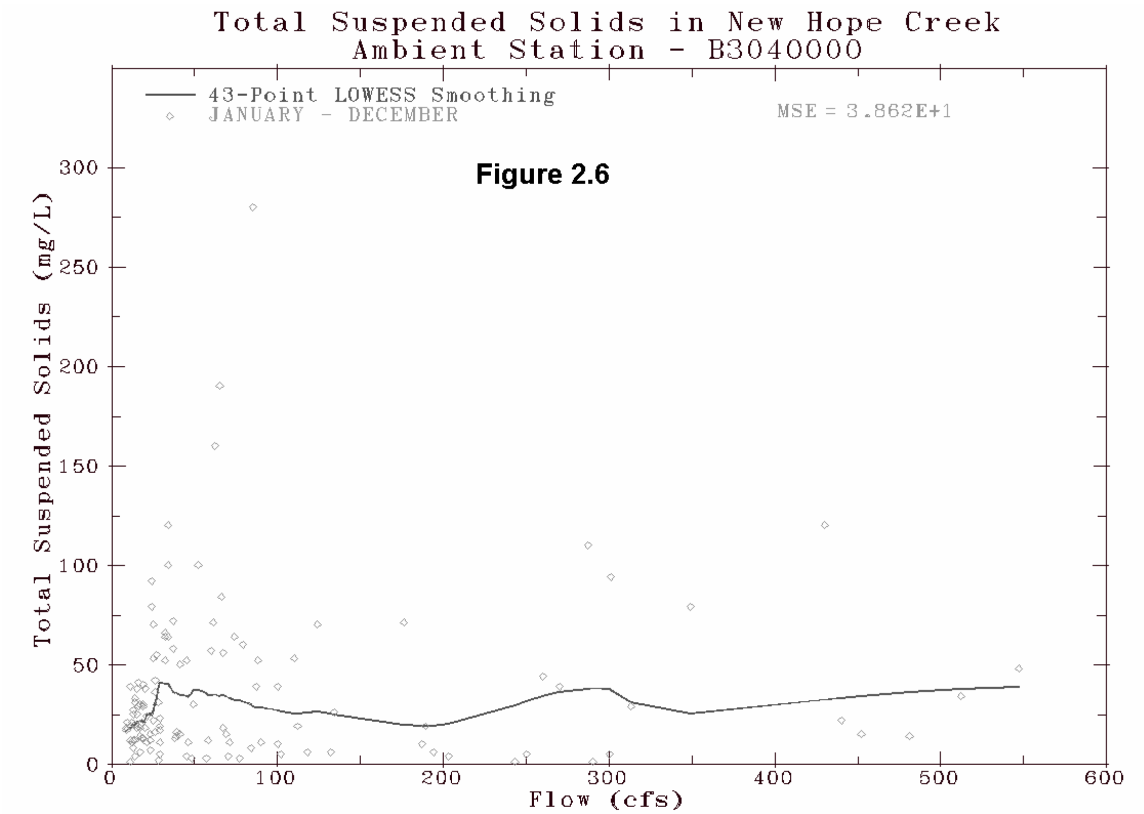
Figure 2.1

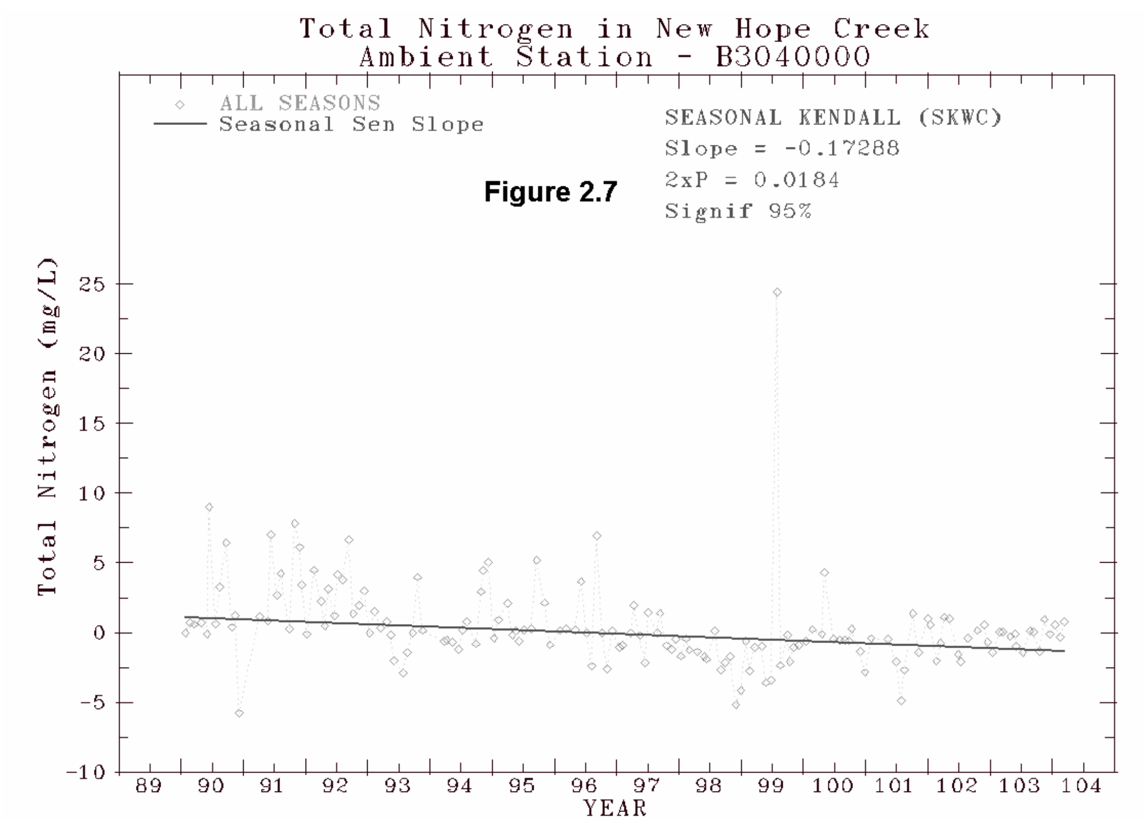

Total Phosphorus in New Hope Creek
Ambient Station - B3040000
Figure 2.2
Total Phosphorus (mg/L)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
(11)
(13)
(12)
(13)
(13)
(14)
(14)
(14)
(12)
(13)
(14)
(13)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH


Total Suspended Solids in New Hope Creek
Ambient Station - B3040000
Figure 2.3
Total Suspended Solids (mg/L)
300
250
200
150
100
50
0
(8)
(11)
(11)
(11)
(13)
(12)
(11)
(13)
(9)
(8)
(12)
(8)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH


Total Nitrogen in New Hope Creek
Ambient Station - B3040000
55-Point LOWESS Smoothing
JANUARY - DECEMBER
MSE = 3.109
Figure 2.4
Total Nitrogen (mg/L)
Flow (cfs)
0
5
10
15
20
25
30
35
100
200
300
400
500
600


Total Phosphorus in New Hope Creek
Ambient Station - B3040000
55-Point LOWESS Smoothing
JANUARY - DECEMBER
MSE = 4.291E-1
Figure 2.5
Total Phosphorus (mg/L)
Flow (cfs)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
100
200
300
400
500
600


Total Suspended Solids in New Hope Creek
Ambient Station - B3040000
43-Point LOWESS Smoothing
JANUARY - DECEMBER
MSE = 3.862E+1
Figure 2.6
Total Suspended Solids (mg/L)
Flow (cfs)


Total Nitrogen in New Hope Creek
Ambient Station - B3040000
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWC)
Slope = -0.17288
2xP = 0.0184
Signif 95%
Figure 2.7
Total Nitrogen (mg/L)
YEAR

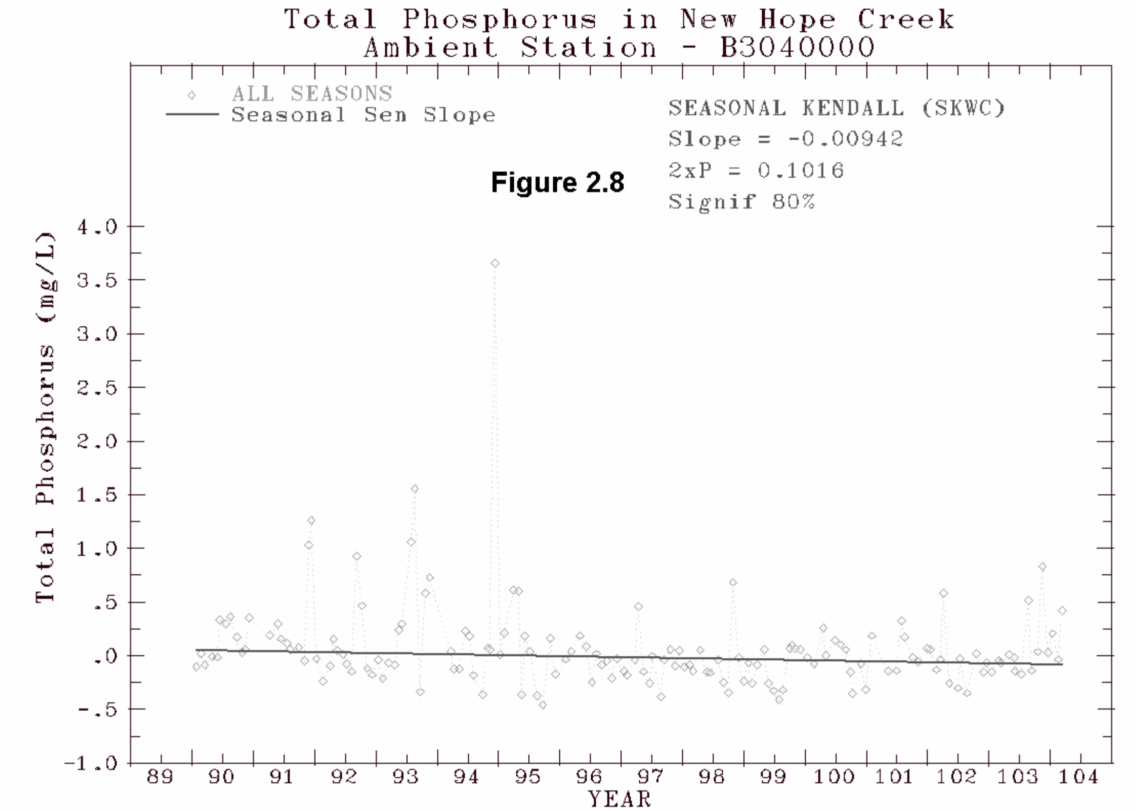


Figure 2.8

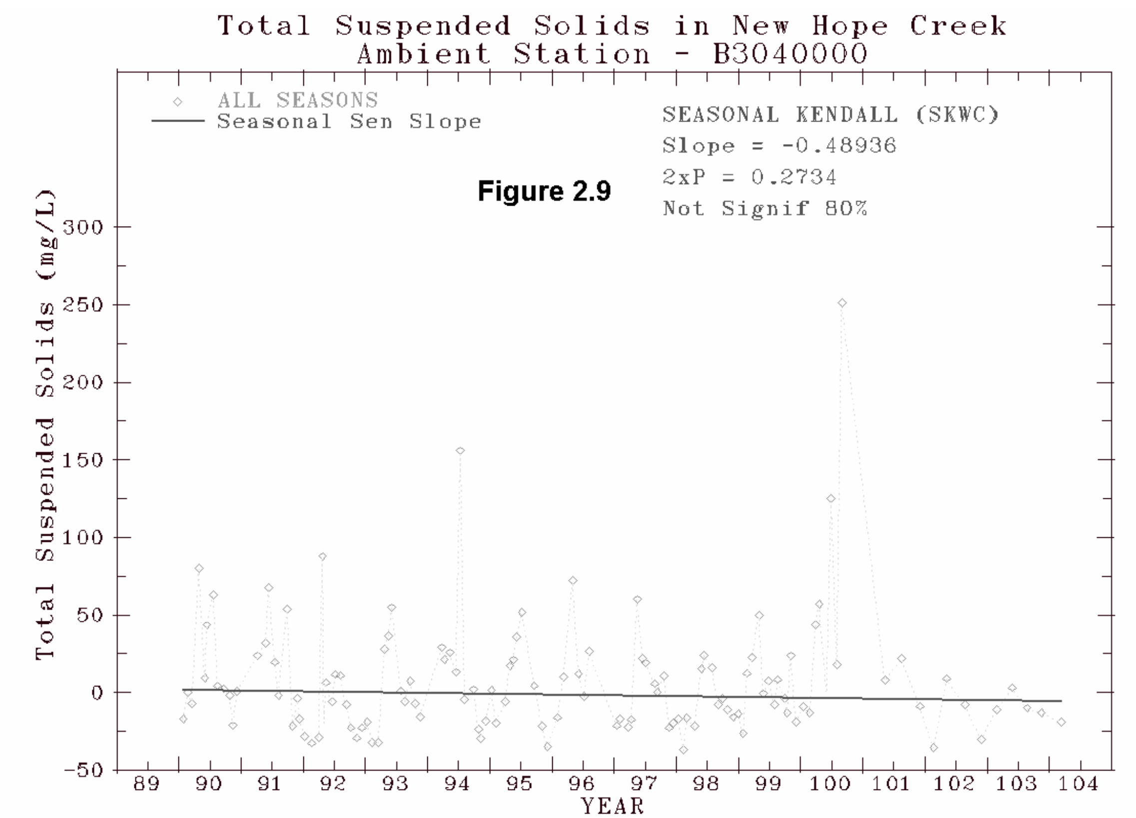


Figure 2.9

Conclusion:
Trend analysis in TN, TP, and TSS concentrations was performed for the East Fork Deep River, New Hope Creek and Rockfish Creek to examine the relative contribution of urban and rural to urban land uses in the upper and middle Cape Fear River Basins.

The analysis could not be performed for a rural watershed due to insufficient and/or absent of flow measurements. In addition, the USGS discharge stations in rural parts of the upper and middle Cape Fear River Basins were sparsely distributed, thereby making difficult to find suitable locations for trend analysis. Therefore, in near future, flow measurement should be carried on at the potential existing ambient stations for at least ten years in order to understand the relative contribution of rural land in the UCFRB.

The WQHYDRO model was used to test a null hypothesis that no trend in nutrient and TSS concentrations exits in the water bodies at 95% confidence level. The results are summarized in Table 2 below. A significant downward flow-adjusted TP concentration was noticed in the East Fork Deep River, whereas a significant downward flow-adjusted TN concentration was noticed in the New Hope Creek. On the contrary, no significant trend in nutrient and TSS concentrations was noticed in the Rockfish Creek at 95% confident level.

Table2. Result of Seasonal Kendall Tend Analysis Using Flow -Adjusted Nutrients and TSS in the upper and middle Cape Fear River Basins.

Water Bodies / Parameters	Seasonal Sen Trend Slope (mg/L)	P Values	Significant Trend at 95%
1. East Fork Deep River (Urban Landuse)			
TN	0.0009	0.93	NO
TP	-0.0033	0.01	YES
TSS	0.00650	0.89	NO
2. New Hope Creek (Urban Landuse)			
TN	-0.1729	0.02	YES
TP	-0.0094	0.10	NO
TSS	-0.4894	0.27	NO
3. Rockfish Creek (Rural to Urban Landuse)			
TN	0.0141	0.14	NO
TP	0.0039	0.17	NO
TSS	0.1633	0.08	NO

References:

Aroner, Eric R. January 2000. Water Quality / Hydrology Graphics / Analysis System. User's Manual. WQHYDRO Consulting, Portland, OR 97218.

Gilbert, Richard O. Gilbert. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, NY.

Hirsch, Robert M, James R. Slack, and Richard A. Smith. February 1982. Techniques of Trend Analysis for Monthly Water Quality Data. Water Resources Research, Vol. 18. No. 1. pp 107-121.