MEMORANDUM

Date: November 16, 2006

To: Chuck Hill, Chairman, Technical Advisory Committee

From: Ed Holland, Chairman, Information Management Subcommittee

Subject: UCFRBA 2000-2004 Water Quality Trends Analysis

The Information Management Subcommittee of the Upper Cape Fear River Basin Association (UCFRBA) is pleased to release the *UCFRBA 2000-2004 Water Quality Trends Analysis*. This report reviews five years of water quality data collected from 2000 through 2004. Our analysis did not reveal any unexpected trends or findings.

The first three years of the five-year study period included the worst drought of record for the Upper Cape Fear region, followed by one of the wettest years on record. The identification of statistically meaningful water quality trends within such a limited time frame characterized by extreme hydrologic conditions was especially challenging. Most of the temporal differences in pollutant concentrations noted in this report most likely reflect differences in streamflow conditions, rather than changes (improvement or degradation) in the sources of those constituents.

A principal function of the UCFRBA is to manage and support a network of ambient water quality monitoring stations as required by the NPDES permits of individual members. An additional objective is to share with other entities and the general public the scientific and technical information that the UCFRBA program compiles regarding point and non-point pollution sources. The *Trends Analysis* report attempted to meet this objective, but we note that the geographic configuration of monitoring locations does not enable us to distinguish the water quality impacts of point source wastewater discharges from the more general nonpoint stormwater contributions of the urban areas in which those wastewater discharges are located. This uncertainty is reflected by the phrase "downstream [or upstream] from urban areas and wastewater treatment plants," which is used throughout the report.

As noted above, our analysis did not reveal any unexpected findings. Approximately one-third of the fecal coliform bacteria samples exceeded 400 cfu/100mL. (North Carolina's water quality standard of 200 colony forming units (cfu) for fecal coliform, which is based on the geometric mean value of a minimum of five samples collected within 30 days, could not be applied to these data because of the program's once-per-month sampling frequency). These exceedences occurred more frequently during periods of higher streamflow in urban areas, likely indicating a nonpoint source. Approximately 50 percent of the manganese samples, which were collected only in water supply watersheds, exceeded the regulatory standard, and only 6 percent of all samples exceeded the turbidity standard. Data indicate that the overall quality of water leaving the Haw

River Subbasin is better than the quality of the water leaving the Deep River Subbasin. Total nitrogen and total phosphorus concentrations leaving the Haw River Subbasin were the lowest of the three subbasins in the Upper Cape Fear study area, and likely reflected the trapping effects of the B. Everett Jordan Reservoir.

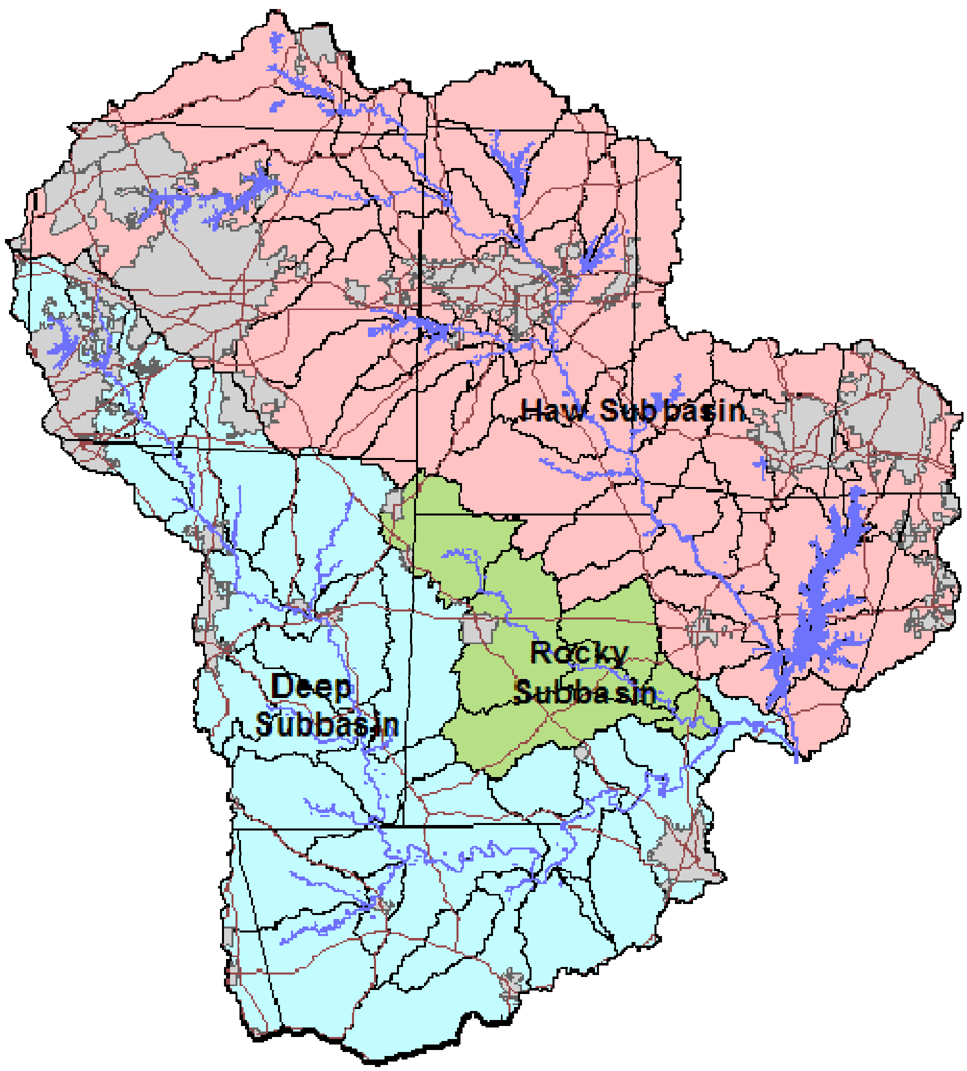
The Information Management Subcommittee recommends that a similar analysis of spatial and temporal trends be conducted after five years of additional data have been compiled; i.e., in 2010, when the UCFRBA will have collected a total of ten years of water quality data.

We believe that this report represents a useful step in documenting long-term conditions of the Upper Cape Fear study area.

Ed Holland, Chairman
Information Management Subcommittee

Upper Cape Fear River Basin Association

2000-2004 Water Quality Trends Analysis



November 2006

Executive Summary

This report reviews five years of Upper Cape Fear River Basin Association water quality data collected from 2000 through 2004. The first three years of this period included one of the worst droughts on record in North Carolina, especially during 2001 and 2002, followed in 2003 by one of the wettest years of record. The identification of statistically meaningful water quality trends within a relatively short time frame characterized by such extreme hydrologic conditions is especially challenging. As such, most of the temporal differences in pollutant concentrations noted in this report are likely due to differences in streamflow conditions and do not necessarily represent changes (i.e., improvement or degradation) in the sources of the parameters under consideration.

Data in this report indicate only a few exceedences of water quality standards, except for fecal coliform bacteria, manganese, and chlorophyll *a*, each of which had a greater than 10 percent exceedence frequency. Chlorophyll *a* was only measured behind several low-head dams on the Deep River, and sampling was discontinued in 2005.

The fecal coliform bacteria standard could not be appropriately applied to these data due to the program's monthly sampling frequency (North Carolina's water quality standard of 200 colony forming units (cfu) for fecal coliform is based on the geometric mean value of a minimum of five samples collected within 30 days). Approximately one-third of the fecal coliform bacteria samples exceeded 400 cfu/100mL. These exceedences occurred more frequently during higher flows in urban areas, likely indicating a nonpoint source. For manganese, which is sampled only in water supply watersheds, approximately 50 percent of the samples exceeded the standard. Exceedence frequencies were highest in the Upper New Hope Arm region of the Haw River Subbasin.

Only 6 percent of the samples exceeded the turbidity standard overall, with only the Upper New Hope Arm and Asheboro regions having more than a 10 percent exceedence frequency.

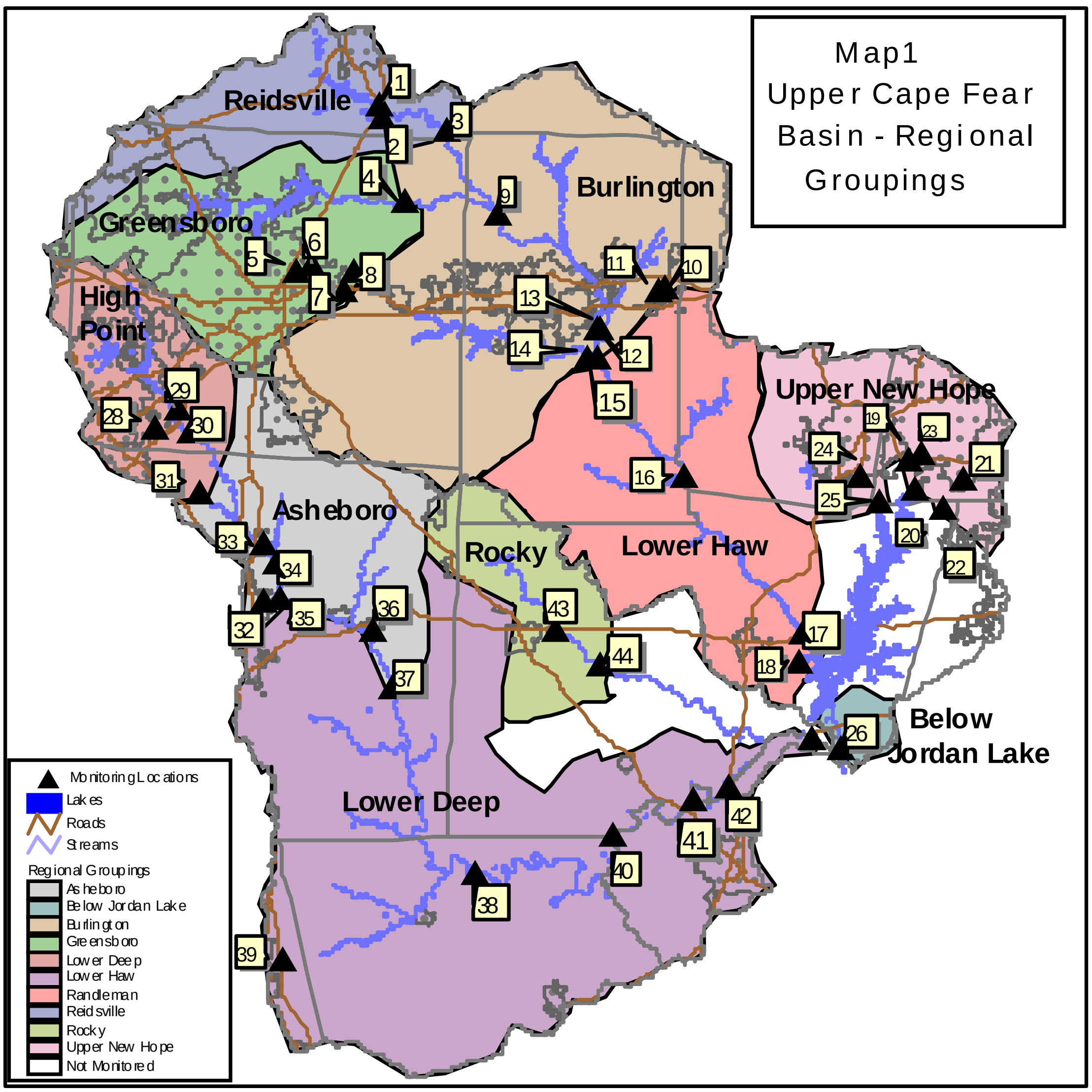
The minimum dissolved oxygen standard was exceeded more than 10 percent of the time only during low-flow periods, with the Reidsville region having the highest frequency of exceedences. Overall, dissolved oxygen concentrations appeared to increase during the study period, perhaps indicating improved water quality.

Data from this study indicate that the overall quality of water leaving the Haw River Subbasin is better than the quality of the water leaving the Deep River Subbasin. This difference was also noted in the recent USGS study, *Suspended Sediment and Nutrients in the Upper Cape Fear River Basin, North Carolina, 2002–04, with an Analysis of Temporal Changes, 1976–2004*. Total nitrogen and total phosphorus concentrations leaving the Haw River Subbasin were the lowest of the three subbasins in the Upper Cape Fear study area, and likely reflected the trapping effects of the B. Everett Jordan Reservoir.

Table of Contents

Background

The Upper Cape Fear River Basin (UCFRB) includes more than 10 counties, 30 municipalities, and nearly 150 permitted wastewater dischargers. The permitted discharges total more than 140 million gallons per day. Twenty-one local governments and private companies established the Upper Cape Fear River Basin Association (UCFRBA) in February of 2000 under a joint agreement with the North Carolina Division of Water Quality that superseded previously separate in-stream water quality monitoring requirements for individual wastewater dischargers. The UCFRBA has collected water quality samples at 44 stream sites since 2000 (see Map 1). This report provides graphic summaries of the first five years of water quality data and attempts to identify spatial and temporal comparisons.



Objectives and Methodology

The Information Management Subcommittee of the UCFRBA Technical Advisory Committee outlined the following approach for organizing and analyzing water quality data in order to identify any water quality trends within the study area. Location numbers noted below are those assigned by the UCFRBA.

1. Entire Upper Cape Fear River basin

2. Three main subbasins: Haw, Deep, and Rocky Rivers (Location #s):

   a. Haw (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 46, 47)
   b. Deep (27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 45, 46, 48, 49)
   c. Rocky (43, 44)

3. Ten regional groupings (Location #s):

   a. High Point (28, 29, 30, 31, 48)
   b. Asheboro (32, 33, 34, 35, 36, 37, 45, 49)
   c. Lower Deep (38, 39, 40, 41, 42, 27)
   d. Rocky (43, 44)
   e. Reidsville (1, 2, 3)
   f. Greensboro (5, 6, 7, 8, 4, 46)
   g. Burlington/Graham/Mebane (9, 10, 11, 12, 13, 14, 15)
   h. Lower Haw (16, 17, 18, 47)
   i. Upper New Hope Arm (24, 25, 23, 19, 20, 21, 22)
   j. Below Jordan Lake (26)

4. Streamflow conditions (low, medium, high)

5. Water quality leaving the basin:

   a. Haw River Location (26)
   b. Deep River Location (27)

6. Upstream versus downstream of wastewater treatment plants (Location #s):

   a. Upstream Haw (2, 5, 7, 10, 14, 19, 21, 24)
   b. Upstream Deep/Rocky (28, 29, 32, 33, 36, 41, 43, 48, 49)
   c. Downstream Haw (3, 6, 8, 11, 12, 13, 15, 18, 22, 25, 20)
   d. Downstream Deep/Rocky (30, 34, 35, 37, 39, 42, 44, 45)

7. By calendar year

Parameters Measured

The UCFRBA analyzed for 23 different chemical parameters at 44 sampling locations during the 5-year study period. All sampling locations within each subbasin were monitored on the same day. Sampling protocols did not include any requirements for time-of-day, day-of-month, or high/low streamflow conditions. Table 1 indicates the parameters measured at each site. The program is summarized as follows:

- Field parameters (dissolved oxygen, pH, conductivity and temperature) were measured monthly at all sites and twice a month during the May-September growing season at selected sites.
- Fecal coliform bacteria, total suspended solids, and turbidity were measured monthly at all sites.
- Nutrients (ammonia, total Kjeldahl nitrogen, nitrate/nitrite-nitrogen and total phosphorus) were measured monthly at 41 sites.
- Ten metals (cadmium, copper, chromium, lead, arsenic, zinc, mercury, nickel, aluminum, and iron) were measured monthly at 32 sites. In addition, manganese was measured at 11 locations upstream of local water supply intakes.
- Chlorophyll *a* was measured at 3 sites.

(Samples were collected routinely from 44 of the 49 locations listed in Table 1. Five incorrect locations were subsequently changed.)

Table 1: Parameters Collected at each Station by Upper Cape Fear Basin Association

ESB STATION NUMBER	UCF Stn	LOCATION	Field Par. #/year	Summer Bi-weekly field par. All'l #/yr	Nutrients #/year	Fecal #/year	Turbidity #/year	TSS #/year	Chl-a #/year	Metals #/year
B0070010	1	Troublesome Crk at US 29 Bus nr Reidsville	12		12	12	12	12		
B0050000	2	Haw Riv at US 29 Business nr Benaja	12	5	12	12	12	12		12
B0170000	3	Haw Riv at SR 2620/2614 High Rock Rd nr Williamsburg	12	5	12	12	12	12		12
B0400000	4	Reedy Fork at SR 2719 High Rock Rd nr Monticello	12		12	12	12	12		
B0480050	5	N Buffalo Crk at N Buffalo Crk WWTP Influent Conduit Pier at Greensboro	12	5	12	12	12	12		12
B0540050	6	N Buffalo Crk at sr 2770 Huffine Mill Rd nr McLeansville	12	5	12	12	12	12		12
B0670000	7	S Buffalo Crk at SR 3000 McConnell Rd nr Greensboro	12	5	12	12	12	12		12
B0750000	8	S Buffalo Crk at SR 2821 Harvest Rd at McLeansville	12	5	12	12	12	12		12
B0850000	9	Haw Riv at SR 1530 Gerringer Mill Rd nr Ossipee	12	5	12	12	12	12		
B1350000	10	Moadams Crk at Corrigdor Rd ups of Discharge nr Mebane	12	5		12	12	12		12
B1380000	11	Moadams Crk at SR 1940 Gibson Rd nr Florence Town	12	5	12	12	12	12		12
B1440000	12	Haw Riv at SR 2158 Swepsonville Rd nr Swepsonville	12	5	12	12	12	12		12
B1200000	13	Haw Riv at NC 54 nr Graham	12	5	12	12	12	12		12
B1940000	14	Big Alamance Crk at NC 87 nr Swepsonville	12	5	12	12	12	12		12
B1960000	15	Big Alamance Crk at SR 2116 Boy Wood Rd at Swepsonsville	12	5	12	12	12	12		12
B2000000	16	Haw Riv at SR 1005 Greensboro-Chapel Hill Rd nr Eli Whitney	12		12	12	12	12		
B2210000	17	Haw Riv at US 64 nr Pittsboro	12		12	12	12	12		
B2450000	18	Roberson Crk at SR 1943 Gum Springs Rd nr Hanks Chapel	12	5	12	12	12	12		
B3020000	19	New Hope Creek at NC54 nr Durham	12	5	12	12	12	12		12+Mn
B3040000	20	New Hope Crk at SR 1107 Stagecoach Rd nr Blands	12	5	12	12	12	12		12+Mn
B3300000	21	Northeast Crk at SR 1102 Sedwick Road nr RTP	12	5	12	12	12	12		12+Mn
B3670000	22	Northeast Crk at SR 1731 O Kelly Church Road nr Durham	12	5	12	12	12	12		12+Mn
B3025000	23	Third Fork Crk at NC 54 nr Durham	12		12	12	12	12		12
B3899180	24	Morgan Crk at Mason Farm WWTP Entrance at Chapel Hill	12	5	12	12	12	12		12+Mn
B3900000	25	Morgan Crk at SR 1726 Old Farrington Rd nr Farrington	12	5	12	12	12	12		12+Mn
B4080000	26	Haw Riv at SR 1011 Old US 1 nr Haywood	12	5	12	12	12	12		12+Mn
B6040300	27	Deep Riv at SR 1011 Old US 1 nr Moncure	12		12	12	12	12		12+Mn
B4380000	28	Richland Crk at SR 1154 Kersey Valley Rd nr Highpoint	12	5	12	12	12	12		12
B4350000	29	Deep Riv at SR 1113 Kivett Dr nr Hayworth Spring	12	5	12	12	12	12		12+Mn
B4440000	30	Deep Riv at SR 1129 Groometown Rd nr High Point	12	5	12	12	12	12		12
B4626000	31	Muddy Crk at SR 1929 Cedar Square Rd nr Glenola	12		12	12	12	12		
B4870000	32	Hasketts Crk at Asheboro WWTP Bridge nr Asheboro	12		12	12	12	12		12
B4770500	33	Deep Riv at Bus 220 Main St at Randleman	12	5	12	12	12	12		
B4800000	34	Deep Riv at SR 2122/2128 Worthville Rd at Worthville	12	5		12	12	12	5	12
B4920000	35	Deep Riv at SR 2261 Old Liberty Rd nr Central Falls	12	5	12	12	12	12	5	12
B5070000	36	Deep Riv at SR 2615 Brooklyn Ave at Ramseur	12	5		12	12	12		
B5100000	37	Deep Riv at SR 2628 Hinshaw Town Rd nr Parks Crossroads	12	5	12	12	12	12		12
B5520000	38	Deep Riv at NC 22 at High Falls	12		12	12	12	12		
B5390800	39	Cotton Crk at SR 1372 Auman Rd culvert	12	5	12	12	12	12		12+Mn
B5575000	40	Deep Riv at NC 42 at Carbonton	12		12	12	12	12	5	
B5685000	41	Deep Riv at Deep River Park Bridge nr Cumnock	12	5		12	12	12		
B5820000	42	Deep Riv at US 15 And 501 nr Sanford	12	5	12	12	12	12		12+Mn
B5950000	43	Rocky Riv at US 64 nr Siler City	12	5	12	12	12	12		12
B5980000	44	Rocky Riv at SR 2170 Rives Chapel Rd nr Siler City	12	5	12	12	12	12		12
Unknown	45	Hasketts Creek below Asheboro WWTP (incorrect site 34)	12	5		12	12	12	5	12
Unknown	46	Reedy Fork At Hwy 87 in Alamance Co. before conflunce w/ Haw River (incorrect site 4)	12		12	12	12	12		
B1980000	47	Haw River at SR 1005 Saxapahaw Rd nr Eli Whitney (incorrect site 16)	12		12	12	12	12		
B4380000	48	Richland Crk at SR1193 Baker Rd nr High Point (incorrect site 28)	12	5	12	12	12	12		12
B4770500	49	Hasketts Creek at US 220 Bus nr North Asheboro (incorrect site 32)	12		12	12	12	12		12

Analytical Methodology

Analytical methods for each parameter are listed in Table 2. Burlington Research and SimaLabs represent essentially the same analytical service provider, as SimaLabs acquired Burlington Research in early 2001. Pace acquired Simalabs' Burlington, North Carolina office in 2004, and the laboratory work moved to the Pace laboratories in Asheville. The UCFRBA hired Meritech to replace Pace in August of 2004. Meritech's laboratory is located in Reidsville, North Carolina.

Table 2: EPA Methods used by Upper Cape Fear Basin Association

	2000	2001	2002	2003	2004
Laboratory Used	Burlington Reseach	SimaLabs	SimaLabs	SimaLabs	Pace/Meritech
Field Parameters:					
Temperature	EPA 170.1	EPA 170.1	EPA 170.1	EPA 170.1	EPA 170.1
Dissolved Oxygen	SM 4500-O-G	SM 4500-O-G	SM 4500-O-G	SM 4500-O-G	SM 4500-O-G
pH	SM 16 423	SM 16 423	SM 16 423	SM 16 423	SM 16 423
Conductivity	EPA 120.1	EPA 120.1	EPA 120.1	EPA 120.1	EPA 120.1
Nutrients:					
Chlorophyll a	ASTM D37318	ASTM D37318	ASTM D37318	ASTM D37318	ASTM D37318 (April-July) SM 10200H (Aug-Sept)
Ammonia	EPA 350.1	EPA 350.1	EPA 350.1	EPA 350.1	EPA 350.1
TKN	EPA 351.1	EPA 351.1	EPA 351.1	EPA 351.1	EPA 351.2 (Jan-July) EPA 351.1 (Aug-Dec)
Nitrate/Nitrite	EPA 300.3 (April-July) August-Dec EPA 353.2	EPA 353.2	EPA 353.2	EPA 353.2	EPA 353.2
Total Phosphorus	EPA 365.4	EPA 365.4	EPA 365.4	EPA 365.4	EPA 365.2 (Jan-July) EPA 200.7 (Aug-Dec)
Metals:					
Cadmium	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Chromium	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Copper	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Nickel	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Lead	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Zinc	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Aluminum	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7
Iron	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7
Manganese	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8 (Jan-July) EPA 200.7 (Aug-Dec)
Arsenic	EPA 206.3	EPA 206.3	EPA 206.3	EPA 206.3	EPA 206.3 (Jan-July) EPA 200.7 (Aug-Dec)
Mercury	EPA 245.1	EPA 245.1	EPA 245.1	EPA 245.1	EPA 206.3 (Jan-July) EPA 245.7 (Aug-Dec)
Other Parameters:					
Fecal Coliform Bacteria	SM 9222D (MF)	SM 9222D (MF)	SM 9222D (MF)	SM 9222D (MF)	SM 9222D (MF)
Total Suspended Solids	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2
Turbidity	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1

Streamflow Data

In order to characterize general streamflow conditions when sampling occurred, each location was associated with an appropriate USGS stream gage. The corresponding streamflow record was subdivided into categories representing “high flow” (upper 25 percent of the range of flow values), “medium flow” (middle 50 percent of the range of flow values), or “low flow” (lower 25 percent of the range of flow values) for the five years of record. Table 3 lists the USGS gage associated with each sampling location and the corresponding high, medium, or low flow regimes assigned to each range.

Table 3: Flow Definitions by Station

Note: Flow in cfs

UCF Stn	LOCATION	Station Information	Flow Gage Used	Low Flow (Lower 25 % flow)	Medium Flow (26-74% flow)	High Flow (Top 25% Flow)
1	Troublesome Crk at US 29 Bus nr Reidsville	major trib, nonpoint input	Reedy Fork @ Gibsonville - 02094500	<=12	13-56	57+
2	Haw Riv at US 29 Business nr Benaja	Upstream Reidsville WWTP	Reedy Fork @ Gibsonville - 02094500	<=12	13-56	57+
3	Haw Riv at SR 2620/2614 High Rock Rd nr Williamsburg	below Reidsville WWTP, DO sag point	Reedy Fork @ Gibsonville - 02094500	<=12	13-56	57+
4	Reedy Fork at SR 2719 High Rock Rd nr Monticello	Model verification data	Reedy Fork @ Gibsonville - 02094500	<=12	13-56	57+
5	N Buffalo Crk at N Buffalo Crk WWTP Influent Conduit Pier at Greensboro	Upstream of N. Buffalo WWTP	NB @ Church 02095271	<=5.7	5.8-14	15+
6	N Buffalo Crk at sr 2770 Huffine Mill Rd nr McLeansville	Downstream N. Buffalo WWTP (prior conf. of N.&S. Buffalo Cks.)	NB @ Greensboro 02095500	<=27	28-54	55+
7	S Buffalo Crk at SR 3000 McConnell Rd nr Greensboro	Upstream TZ Osborne WWTP	SB @ 220 02094770	<=3.4	3.5-14	15+
8	S Buffalo Crk at SR 2821 Harvest Rd at McLeansville	Downstream TZ Osborne WWTP	SB @ nr GSO 02095000	<=7.6	7.7-34	35+
9	Haw Riv at SR 1530 Gerringer Mill Rd nr Ossipee	above Burlington, below Reedy Fk	Haw @ Haw River 02096500	<=149	150-581	582+
10	Moadams Crk at Corrigdor Rd ups of Discharge nr Mebane	Upstream Mebane WWTP	Haw @ Haw River 02096500	<=149	150-581	582+
11	Moadams Crk at SR 1940 Gibson Rd nr Florence Town	Downstream Mebane WWTP	Haw @ Haw River 02096500	<=149	150-581	582+
12	Haw Riv at SR 2158 Swepsonville Rd nr Swepsonville	Dwnstrm Graham WWTP	Haw @ Haw River 02096500	<=149	150-581	582+
13	Haw Riv at NC 54 nr Graham	Between Burlington East & Graham	Haw @ Haw River 02096500	<=149	150-581	582+
14	Big Alamance Crk at NC 87 nr Swepsonville	Upstrm Burlington S. WWTP	Haw @ Haw River 02096500	<=149	150-581	582+
15	Big Alamance Crk at SR 2116 Boy Wood Rd at Swepsonsville	Dnstrm Burlington S. WWTP	Haw @ Haw River 02096500	<=149	150-581	582+
16	Haw Riv at SR 1005 Greensboro-Chapel Hill Rd nr Eli Whitney	below Burlington WWTP & Saxapahaw	Haw @ Haw River 02096500	<=149	150-581	582+
17	Haw Riv at US 64 nr Pittsboro	assess water quality before Jordan Lake	Haw @ Bynum 02096960	<=253	254-1169	1170+
18	Roberson Crk at SR 1943 Gum Springs Rd nr Hanks Chapel	Downstream Pittsboro WWTP	Haw @ Bynum 02096960	<=253	254-1169	1170+
19	New Hope Creek at NC54 nr Durham	Upstrm S. Durham WRF	NH nr Blands 02097314	<=18	19-79	80+
20	New Hope Crk at SR 1107 Stagecoach Rd nr Blands	ambient site	NH nr Blands 02097314	<=18	19-79	80+
21	Northeast Crk at SR 1102 Sedwick Road nr RTP	Upstream Durham Co/RTP WWTP	NE at SR1100 nr Genlee 0209741955	<=7.2	7.3-20	21+
22	Northeast Crk at SR 1731 O Kelly Church Road nr Durham	Downstream Durham Co/RTP WWTP	NE at SR1100 nr Genlee 0209741955	<=7.2	7.3-20	21+
23	Third Fork Crk at NC 54 nr Durham	Drains Durham	NH nr Blands 02097314	<=18	19-79	80+
24	Morgan Crk at Mason Farm WWTP Entrance at Chapel Hill	Upstrm OWASA	Morgan Cknr Chapel Hill 02097517	<=18	19-36	37+
25	Morgan Crk at SR 1726 Old Farrington Rd nr Farrington	below OWASA, DO sag	Morgan Cknr Chapel Hill 02097517	<=18	19-36	37+
26	Haw Riv at SR 1011 Old US 1 nr Haywood	dnstrm Allied, upstrm Neste Resins, gage	Deep @ Moncure 02102000	<=156	157-1089	1090+
27	Deep Riv at SR 1011 Old US 1 nr Moncure	measures Deep R input	Deep @ Moncure 02102000	<=156	157-1089	1090+
28	Richland Crk at SR 1154 Kersey Valley Rd nr Highpoint	above High Point Eastside WWTP, urban, landfill	EF nr HP 02099000	<=5.4	5.5-17	18+
29	Deep Riv at SR 1113 Kivett Dr nr Hayworth Spring	Upstrm of confluence with Richland Creek	EF nr HP 02099000	<=5.4	5.5-17	18+
30	Deep Riv at SR 1129 Groometown Rd nr High Point	Dwnstrm Richland Ck. & HP Eastside,prior to 1st dam	EF nr HP 02099000	<=5.4	5.5-17	18+
31	Muddy Crk at SR 1929 Cedar Square Rd nr Glenola	fecals problem, gage, primary arm of reservoir	EF nr HP 02099000	<=5.4	5.5-17	18+
32	Hasketts Crk at Asheboro WWTP Bridge nr Asheboro	above Asheboro WWTP	Deep @ Ramsuer 02100500	<=67	68-304	305+
33	Deep Riv at Bus 220 Main St at Randleman	above Randleman WWTP, prior to conf. Hasketts Creek	Deep @ Ramsuer 02100500	<=67	68-304	305+
34	Deep Riv at SR 2122/2128 Worthville Rd at Worthville	below Randleman WWTP & Worthville impoundments,above	Deep @ Ramsuer 02100500	<=67	68-304	305+
35	Deep Riv at SR 2261 Old Liberty Rd nr Central Falls	below Asheboro WWTP, below conf. Hasketts Creek	Deep @ Ramsuer 02100500	<=67	68-304	305+
36	Deep Riv at SR 2615 Brooklyn Ave at Ramseur	above Ramseur WWTP	Deep @ Ramsuer 02100500	<=67	68-304	305+
37	Deep Riv at SR 2628 Hinshaw Town Rd nr Parks Crossroads	below Ramseur WWTP	Deep @ Ramsuer 02100500	<=67	68-304	305+
38	Deep Riv at NC 22 at High Falls	slow stretch of river, below Robbins WWTP	Deep @ Ramsuer 02100500	<=67	68-304	305+
39	Cotton Crk at SR 1372 Auman Rd culvert	below Star WWTP	Deep @ Ramsuer 02100500	<=67	68-304	305+
40	Deep Riv at NC 42 at Carbonton	behind Carbonton dam	Deep @ Moncure 02102000	<=156	157-1089	1090+
41	Deep Riv at Deep River Park Bridge nr Cumnock	above Golden Poultry	Deep @ Moncure 02102000	<=156	157-1089	1090+
42	Deep Riv at US 15 And 501 nr Sanford	below Sanford WWTP	Deep @ Moncure 02102000	<=156	157-1089	1090+
43	Rocky Riv at US 64 nr Siler City	below reservoir, above Loves Cr, above Siler City	Rocky @ SR 1300 0210166029	<=.71	.72-4.7	4.8+
44	Rocky Riv at SR 2170 Rives Chapel Rd nr Siler City	below Loves Cr, below Siler City	Rocky @ SR 1300 0210166029	<=.71	.72-4.7	4.8+
45	Hasketts Creek below Asheboro WWTP	incorrect site 34	Deep @ Ramsuer 02100500	<=67	68-304	305+
46	Reedy Fork At Hwy 87 in Alamance Co. before conflunce w/ Haw River	incorrect site 4	Reedy Fork @ Gibsonville - 02094500	<=12	13-56	57+
47	Haw River at SR 1005 Saxapahaw Rd nr Eli Whitney	incorrect site 16	Haw @ Haw River 02096500	<=149	150-581	582+
48	Richland Crk at SR1193 Baker Rd nr High Point	Incorrect site 28	EF nr HP 02099000	<=5.4	5.5-17	18+
49	Hasketts Creek at US 220 Bus nr North Asheboro	Incorrect Site 32	Deep @ Ramsuer 02100500	<=67	68-304	305+

Interpretation of Water Quality Standards

Water quality standards or action levels do not exist for all of the parameters measured during the study. The fecal coliform standard could not be appropriately applied to these data because of the monthly sampling frequency (NCDWQ's 200 cfu/100 mls standard is based on the geometric mean of at least 5 samples collected within a 30-day period). Mercury could not be measured at a level of detection low enough to provide meaningful comparisons to the standard. Water quality standards or action levels were interpreted for the purpose of this report according to the following conventions:

<u>Water quality standards</u>

- Dissolved Oxygen: not less then 5.0 mg/L
- pH: 6-9 std units
- Temperature: < 32 degrees Celsius
- Oxygen Saturation: < 110%
- *Fecal Coliform Bacteria: > 400 cfu/100mL
- Turbidity: < 50 NTU
- Lead: < 25 ug/L
- Manganese: < 200 ug/L (water supply watersheds)
- Cadmium: < 2.0 ug/L
- Arsenic: < 50 ug/L or < 10 ug/L (water supply watersheds)
- Mercury: < .012 ug/L (only measured to .2 ug/L)
- Chromium: < 50 ug/L
- Nickel: < 88 ug/L or < 25ug/L (water supply watershed)
- Chlorophyll *a*: < 40 ug/L

<u>Action Levels only</u>

- Zinc: < 50 ug/L
- Copper: < 7 ug/L
- Iron: < 1000 ug/L

<u>No standards or action levels</u>

- TSS
- Nitrate/Nitrite
- TKN
- Ammonia
- Total Phosphorus
- Total Nitrogen
- Conductivity
- Aluminum

* *Fecal coliform samples were collected monthly, but the NCDWQ water quality standards of 200 cfu/100 mls is based on a geometric mean of at least 5 samples collected within a 30 day period. For the purposes of this report, fecal coliform counts of greater than 400 cfu/100mL in more then 20 percent of the samples from a given location were considered to be an "exceedence."*

Interpretation of Less-Than Values

Data recorded as a "less-than" value were interpreted as one-half of the specified value for the purposes of this report. For example, a value recorded as "< 5 ug/L" would be interpreted as "2.5 ug/L."

Quality Assurance/Quality Control Issues

Metals data from April 2000 to October/November 2001 were invalidated due to QA/QC concerns, and the detection limits of five metals parameters were changed during the 2001-2004 period in agreement with NCDWQ. No statistical analysis of metals data was possible due to these limitations (see also Table 4).

Table 4: Metals With Changing Detection Limits

	Lead	Nickel	Chromium	Cadmium	Arsenic
11/01	10	10	25	2	10
12/01	10	10	25	2	10
1/02	10	10	25	2	10
2/02	10	10	25	2	10
3/02	10	10	25	2	10
4/02	10	10	25	2	10
5/02	10	10	25	2	10
6/02	10	10	25	2	10
7/02	10	10	25	2	10
8/02	10	10	25	2	10
9/02	10	10	25	2	10
10/02	10	10	25	2	10
11/02	10	10	25	2	10
12/02	10	10	25	2	10
1/03	2	5	5	0.5	5
2/03	2	5	5	0.5	5
3/03	2	5	5	0.5	5
4/03	2	5	5	0.5	5
5/03	2	5	5	0.5	5
6/03	2	5	5	0.5	5
7/03	2	5	5	0.5	5
8/03	2	5	5	0.5	5
9/03	2	5	5	0.5	10
10/03	2	5	5	0.5	10
11/03	2	5	5	0.5	10
12/03	2	5	5	0.5	10
1/04	2	5	10	1	5
2/04	2	5	10	0.5	5
3/04	2	5	10	0.5	5
4/04	2	5	10	0.5	5
5/04	2	5	10	0.5	5
6/04	10	5	10	1	5
7/04	10	5	10	1	5
8/04	10	10	5	2	10
9/04	10	10	5	2	10
10/04	10	10	5	2	10
11/04	10	10	5	2	10
12/04	10	10	5	2	10

Note: All metals data reported in ug/L.

Statistics

Statistical analyses were conducted by Dr. Janet MacFall on selected parameters. Significant differences between values are indicated by differences in letters (a, b, c, etc). Tables of the statistical results are presented in the Appendix.

Exceedences of Water Quality Standards

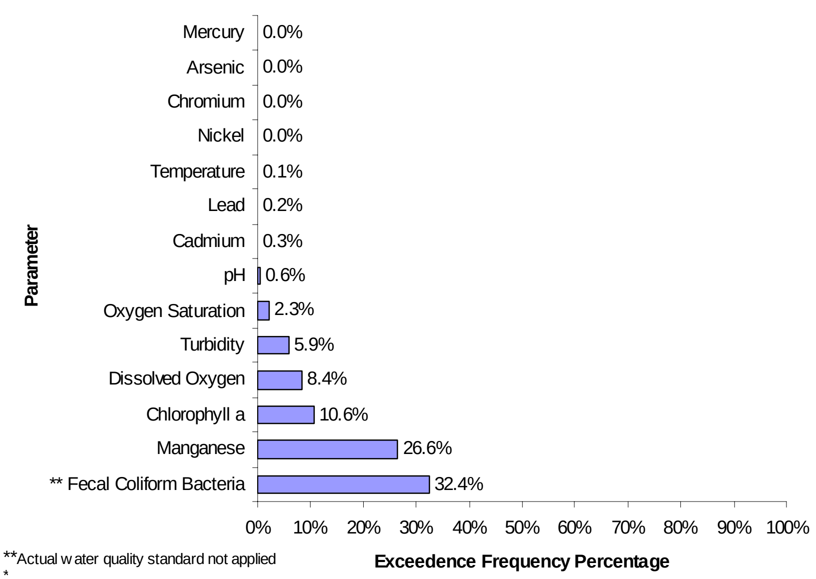
Data acquired during the study period included few water quality standard exceedences. Of the parameters analyzed for which water quality standards or action levels exist, only 7.6 percent of all samples collected exceeded their respective standards or action levels (see Table 5). Among the parameters with water quality standards only, 5.5 percent of the samples exceeded their respective standards. Nearly half of these were represented by fecal coliform samples, whose exceedence levels were qualified by the limitations discussed earlier.

Table 5: Exceedence Frequency Percentage Upper Cape Fear Basin 2000-2004

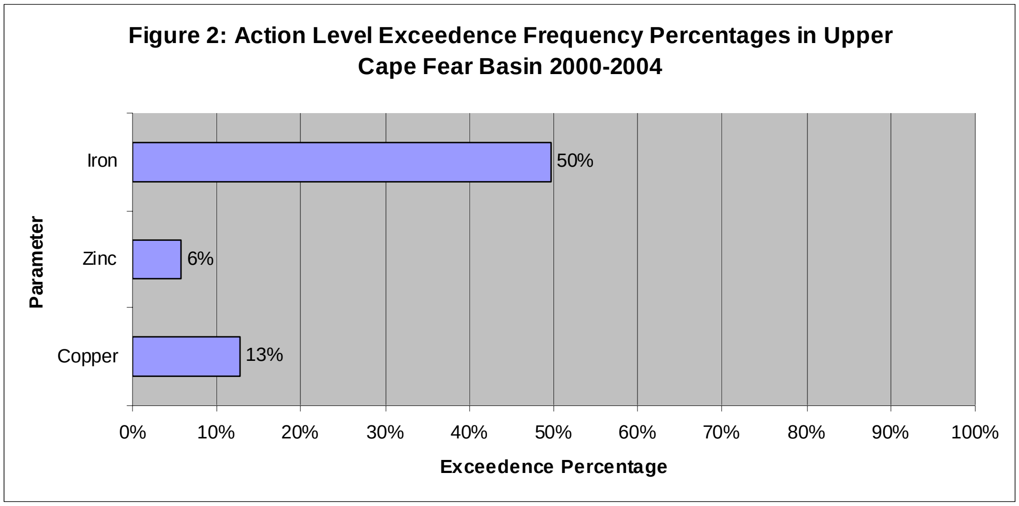
	Total Samples Taken	% Exceeding Criteria
Both WQ Standard and Action Level	30,157	7.6%
WQ Standard only	26,554	5.5%

Fecal coliform bacteria exhibited the highest percentage of exceedences, with almost one-third of the samples exceeding 400 cfu/100mL. Manganese, which was analyzed only in drinking water supply watersheds, exceeded its standard 27 percent of the time. Chlorophyll *a* was collected at three sites behind low-head dams on the Deep River. Ten percent of those samples exceeded the 40 ug/L water quality standard. Chlorophyll *a* sampling was discontinued in August 2004 in agreement with NCDWQ. The remaining parameters exceeded their respective standard less than 10% of the time (see Figure 1).

Figure 1: Water Quality Standard Exceedence Frequency Percentages in Upper Cape Fear Basin 2000-2004

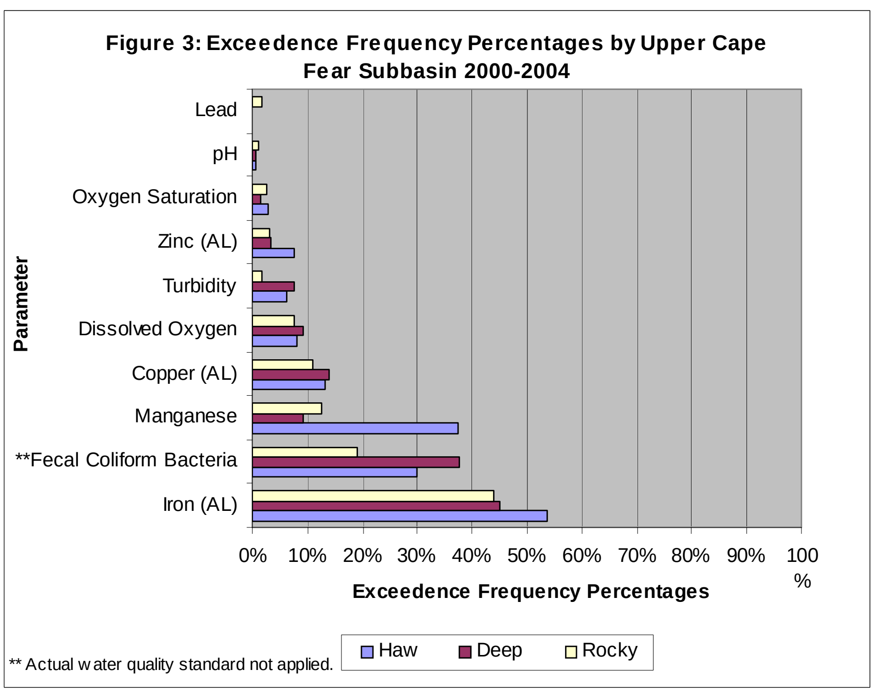


Of the parameters with action levels, iron exhibited the most exceedences (50 percent) as indicated in Figure 2. Abundant concentrations of both iron and manganese occur naturally in soils throughout the Piedmont. Higher stream concentrations are expected, especially during high flow conditions.



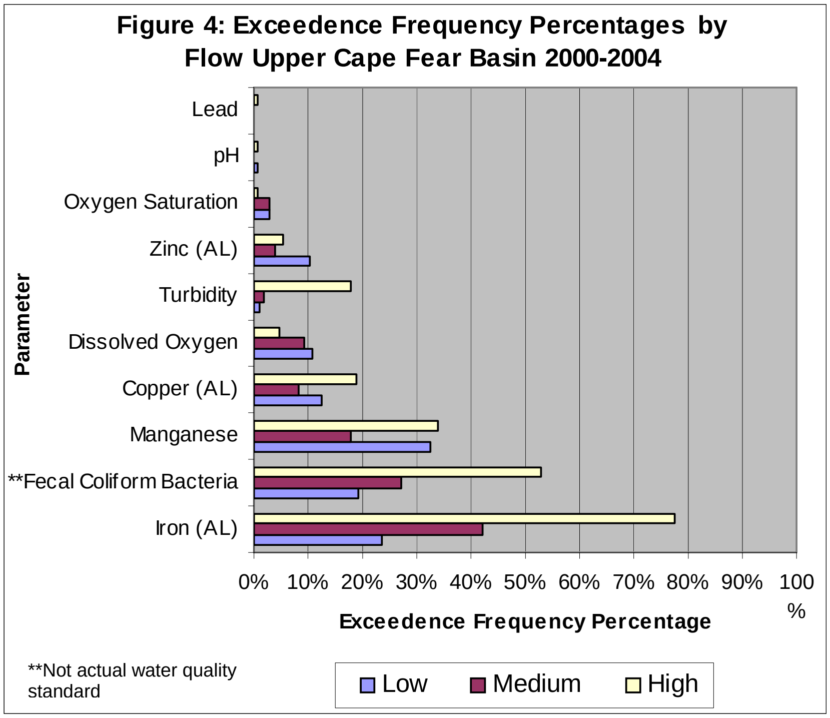
Exceedences by Subbasin, 2000-2004

Figure 3 illustrates the relative numbers of parametric exceedences among the three major subbasins of the Upper Cape Fear River study area. No consistent pattern of spatial differences is apparent.



Exceedences by Flow, 2000-2004

Figure 4 presents exceedence frequency in terms of streamflow conditions. Turbidity, fecal coliform, and iron concentrations exceeded their respective standards most frequently during high-flow conditions, a pattern that is consistent with nonpoint source inputs and streambed resuspension associated with rainfall/runoff events.

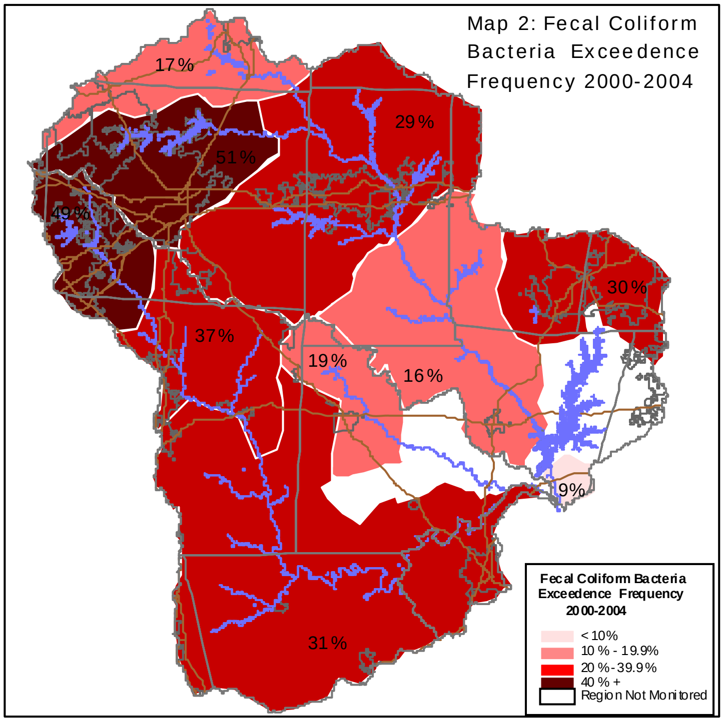


Exceedences by Region, 2000-2004

The following discussion of regional comparisons within the study area focuses only on the four parameters with the highest number of exceedences: fecal coliform bacteria, manganese, dissolved oxygen, and turbidity. As noted earlier, and for the purposes of this report, the fecal coliform "standard" is considered to be more than 20 percent of the samples with values greater than 400 cfu/100mL. Regional groupings of locations were delineated in Map 1.

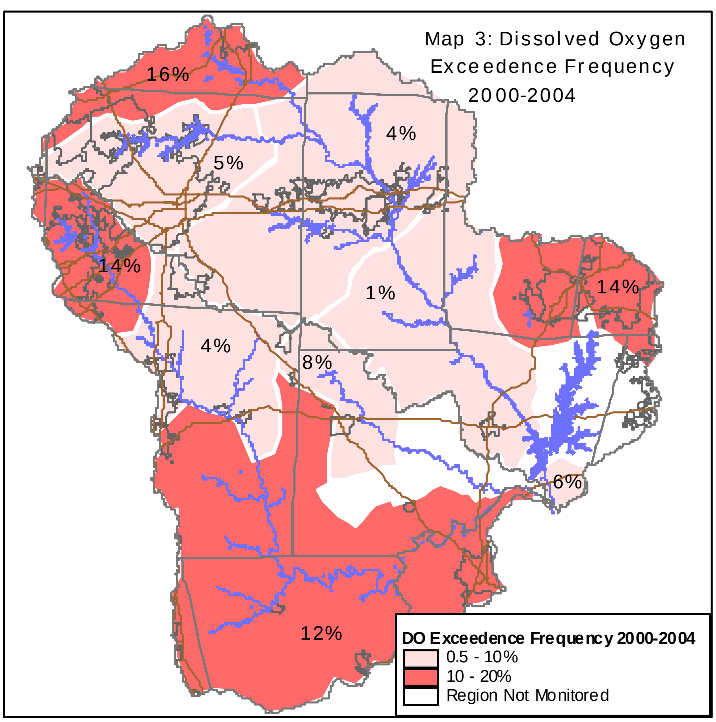
Fecal Coliform Bacteria

The urbanized areas exhibited the highest percentage of samples with more than 400 cfu/100mL. Approximately 50 percent of the samples collected in the Greensboro and High Point regions contained more than 400cfu/100mL (see Map 2). Less then 10 percent of the samples collected below Jordan Lake exceeded 400 cfu/100mL.



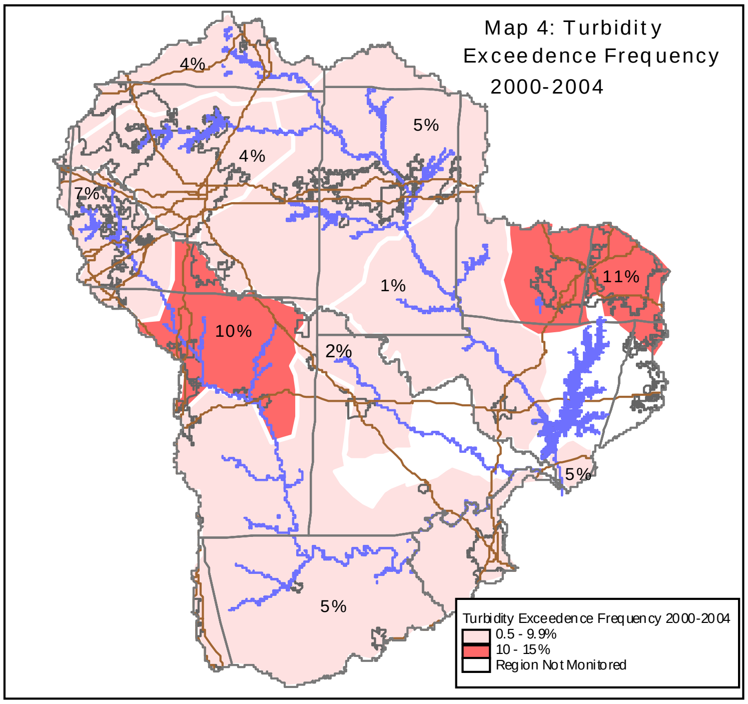
Dissolved Oxygen

The low dissolved oxygen standard was exceeded in more than 10 percent of the samples from four regions during the study period: Reidsville, Upper New Hope, High Point, and Lower Deep. Samples from the Reidsville region exhibited the highest frequency of dissolved oxygen Exceedences at 16% (see Map 3).



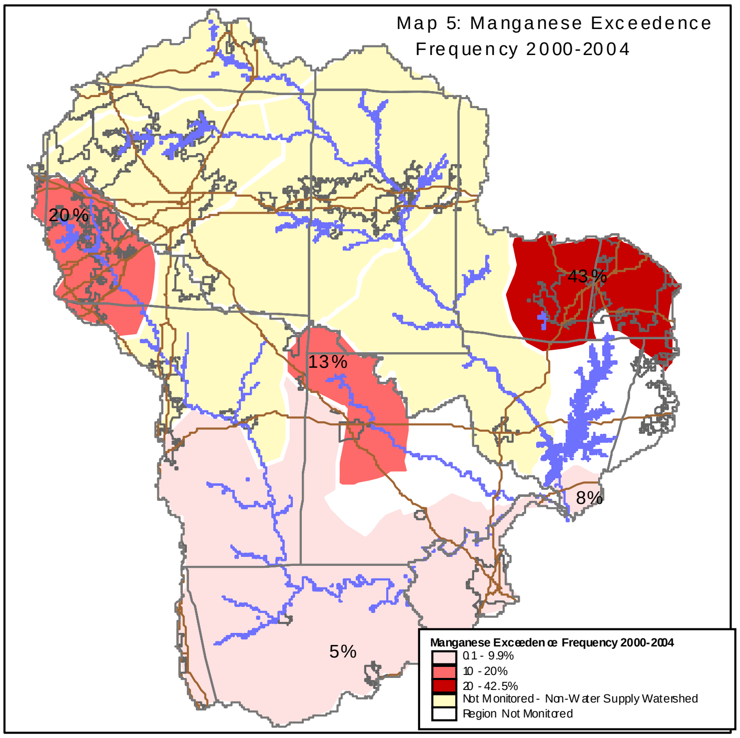
Turbidity

The Asheboro and Upper New Hope regions were the only areas with exceedence frequencies of the turbidity standard of 10 percent or greater (see Map 4).



Manganese

Manganese samples were collected in only five regions, all of which included drinking water supply watersheds: High Point, Lower Deep, Rocky, Below Jordan Lake and Upper New Hope. With 43 percent, the Upper New Hope region had the highest frequency of manganese standard exceedences, which was twice that of any other region (see Map 5). High concentrations of manganese occur naturally in soils throughout the Piedmont, but no explanation is evident for the relative degree of manganese exceedences in water samples from these regions.



<u>Exceedences by Location Relative to Wastewater Treatment Plants/Urban Areas, 2000-2004</u>

Selected sampling sites were grouped according to their location upstream or downstream of wastewater treatment plants (WWTPs). Because most of these locations are also upstream or downstream of major urban areas, the data do not provide a distinction between exceedences associated with the WWTPs *per se* versus exceedences caused by nonpoint runoff from the overall urban area. (The sparse amount of data from the Rocky River Subbasin was combined with the Deep River Subbasin for this analysis.)

No clear patterns are evident in Figures 5 and 6.

Figure 5: Exceedence Frequency Upstream/Downstream WWTP in Haw Subbasin 2000-2004

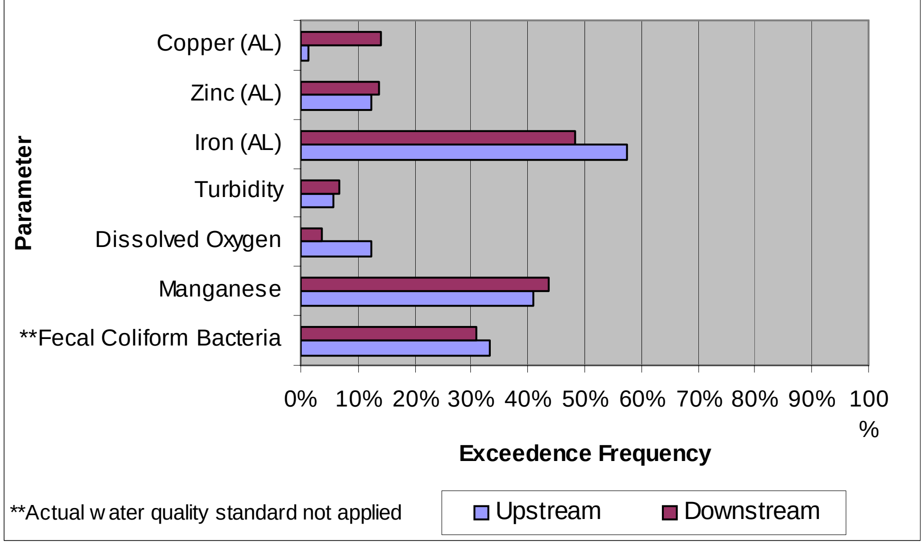
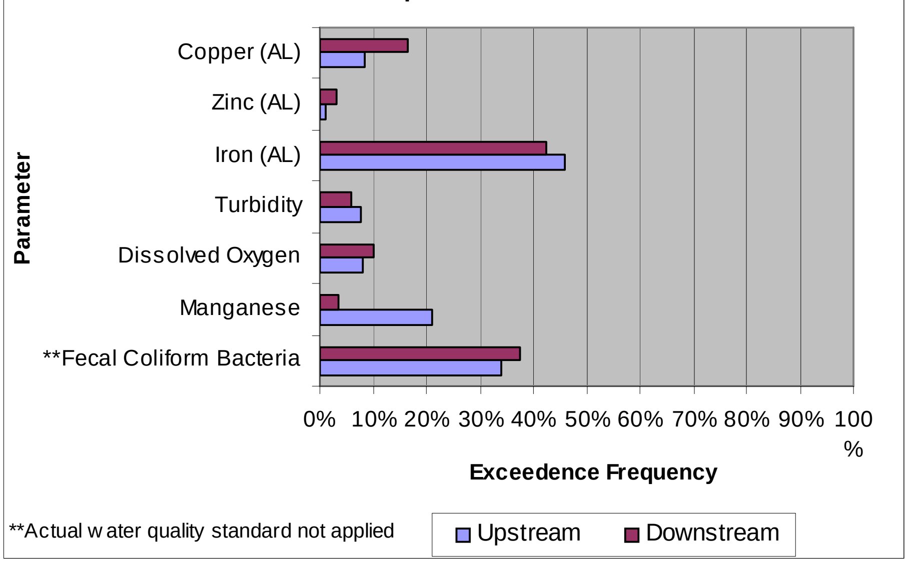


Figure 6: Exceedences Frequency Upstream/Downstream WWTP - Deep Subbasin 2000-2004



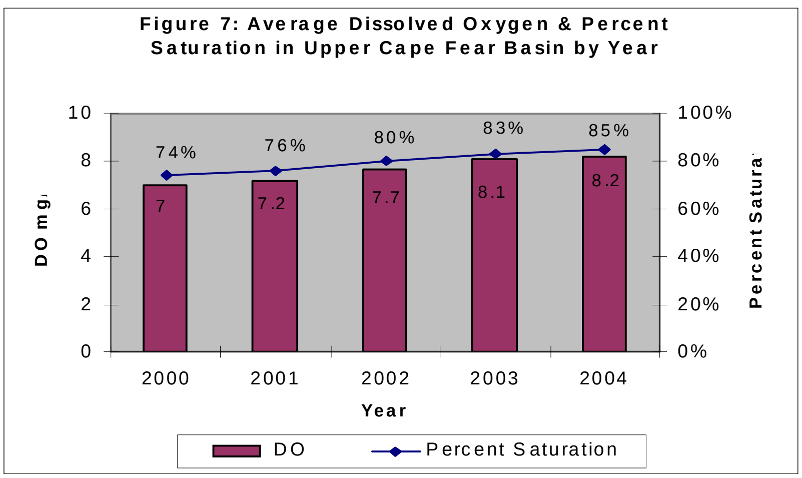
Water Quality Trends

This section examines the mean values of all parameters measured throughout the Upper Cape Fear River Basin during the five-year study period, in order to detect any temporal trends of increasing or decreasing water quality that may be evident.

Dissolved Oxygen

Data indicate an upward trend of dissolved oxygen concentration and saturation in the Upper Cape Fear River Basin during the study period (see Figure 7), but no attempt was made to test the statistical significance of this observation.

Dissolved oxygen saturation values were lower during periods of low streamflow (see Figure 8). No differences were apparent in saturation levels between the three subbasins in total (see Figure 9).



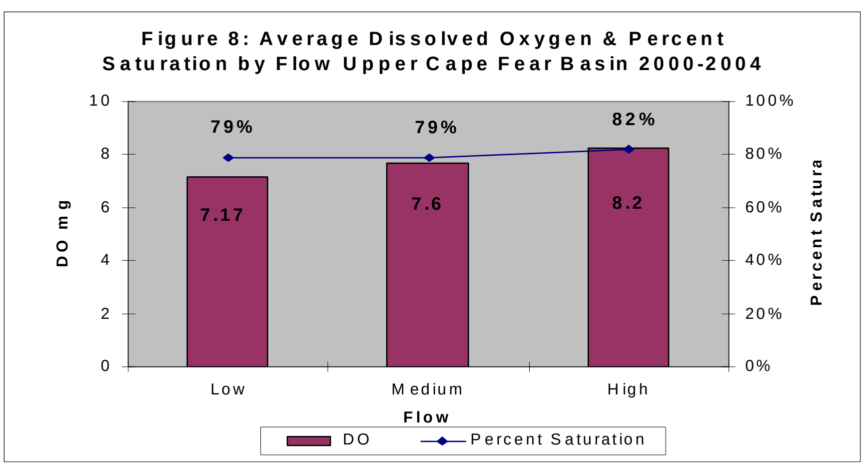
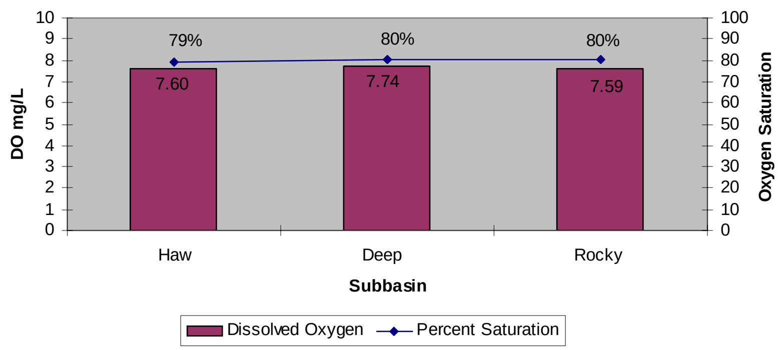
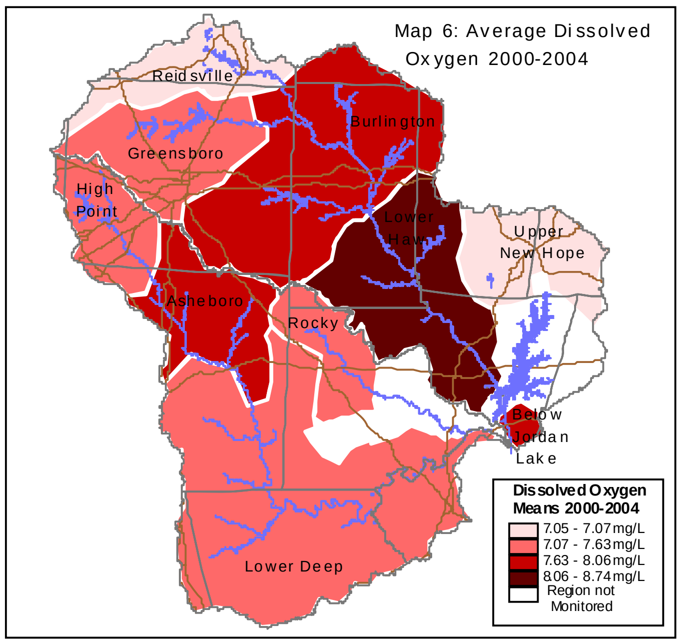


Figure 9: Average Dissolved Oxygen & Percent Saturation by Upper Cape Fear Subbasins 2000-2004



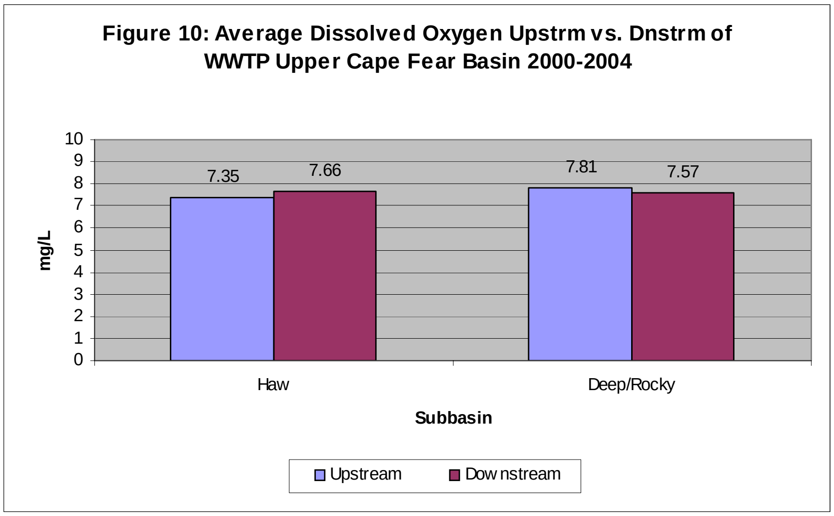
Dissolved oxygen concentrations appeared to be highest in the Lower Haw River region and lowest in the Reidsville region (see Map 6 & Table 6).

Table 6: Dissolved Oxygen Upper Cape Fear Basin 2000-2004		
	Mean	Std Dev
High Point	7.4	2.2
Asheboro	8.1	1.9
Lower Deep	7.6	2.3
Rocky	7.6	2.2
Reidsville	7.1	2.1
Greensboro	7.5	1.9
Burlington	7.9	1.9
Lower Haw	8.7	1.9
Upper New Hope Arm	7.1	2.0
Below Jordan Lake	7.9	2.2



Map 6: Average Dissolved Oxygen 2000-2004

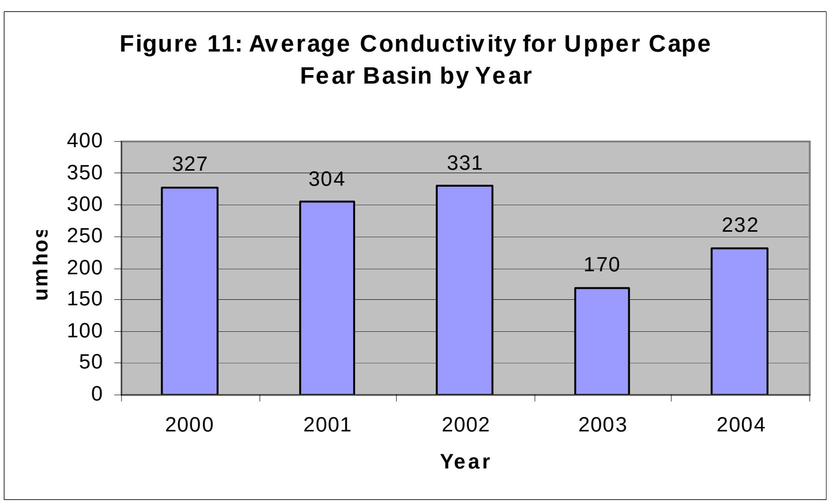
Little difference was evident in dissolved oxygen concentrations upstream or downstream of wastewater plants and urban areas (Figure 10).



Specific Conductivity

Specific conductivity, which is a measure of dissolved ionic compounds, averaged approximately 250 umhos/cm^2 throughout the study area. The apparent trend in decreasing conductivity (see Figure 11) was not tested for statistical significance. Figure 12 indicates the relative dilution of dissolved compounds during periods of higher streamflow.

A comparison of conductivity among the three subbasins is shown in Figure 13. Upstream/downstream differences in conductivity with respect to urban areas and wastewater treatment plants are evident in Figure 14.



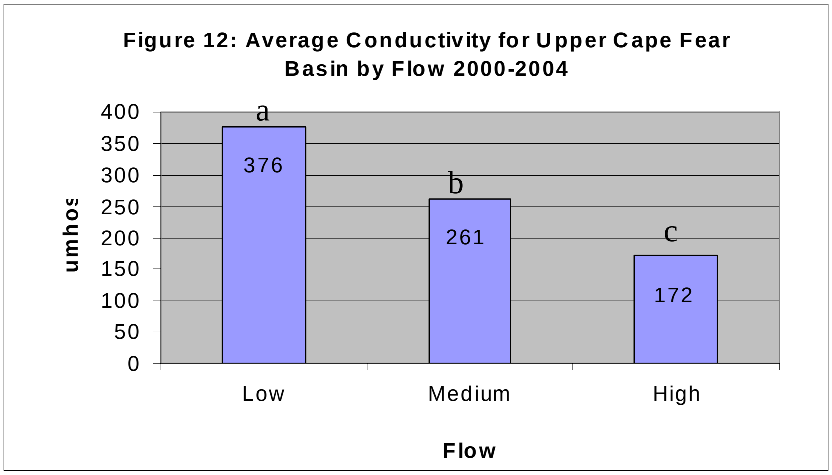


Figure 12: Average Conductivity for Upper Cape Fear Basin by Flow 2000-2004
umhos
400
350
300
250
200
150
100
50
0
a
376
b
261
c
172
Low
Medium
High
Flow

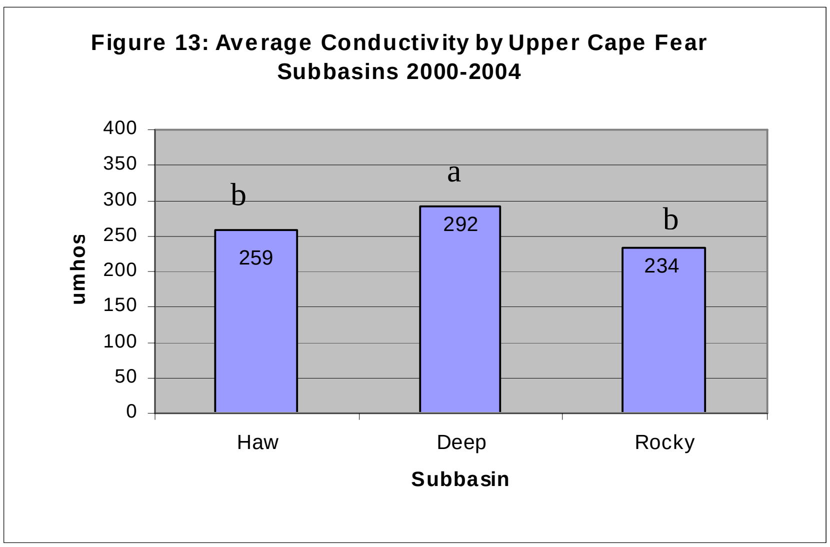


Figure 13: Average Conductivity by Upper Cape Fear Subbasins 2000-2004
umhos
400
350
300
250
200
150
100
50
0
b
259
a
292
b
234
Haw
Deep
Rocky
Subbasin

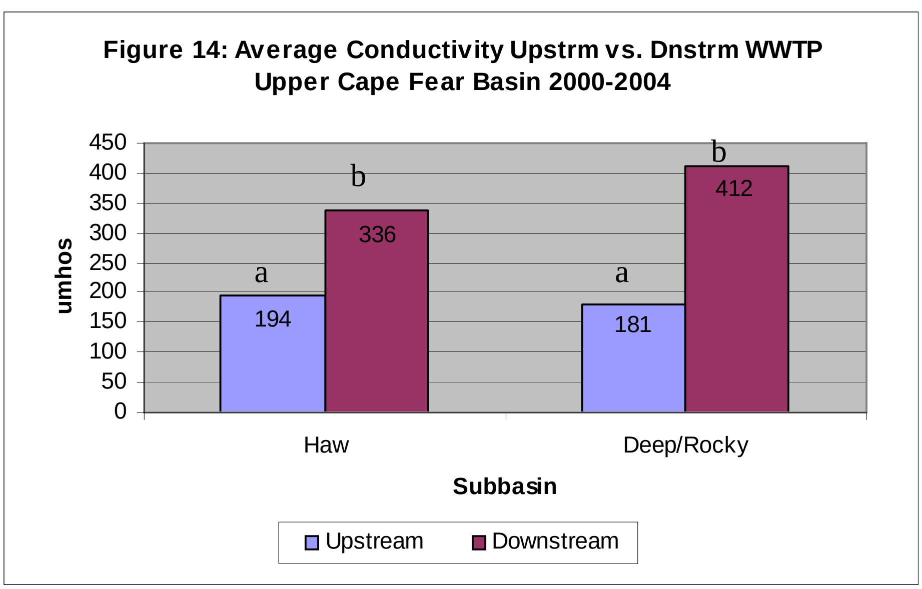


Figure 14: Average Conductivity Upstrm vs. Dnstrm WWTP Upper Cape Fear Basin 2000-2004
umhos
450
400
350
300
250
200
150
100
50
0
a
194
b
336
a
181
b
412
Haw
Deep/Rocky
Subbasin
Upstream
Downstream

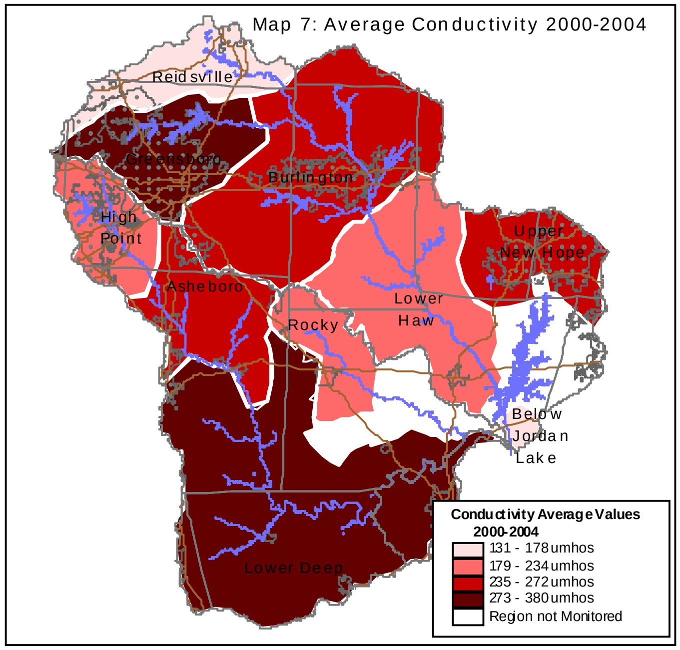
A comparison of conductivity by regions within the study area is presented in Map 7 and Tables 7 and 7a.

Table 7: Conductivity Upper Cape Fear Basin 2000-2004

	Mean	Std Dev
High Point	209	120
Asheboro	269	208
Lower Deep	380	590
Rocky	234	219
Reidsville	131	110
Greensboro	359	272
Burlington	272	177
Lower Haw	229	129
Upper New Hope Arm	252	157
Below Jordan Lake	178	58

Table 7a: Conductivity - Individual Lower Deep Stations 2000-2004

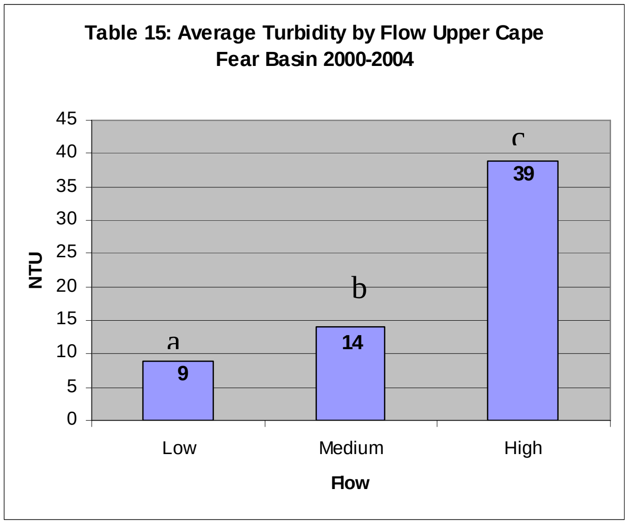
	Mean	Std Dev
Lower Deep Total	380	590
Below Star	1249	938
Below Robbins	196	110
Above Sanford	167	87
Below Sanford	183	95

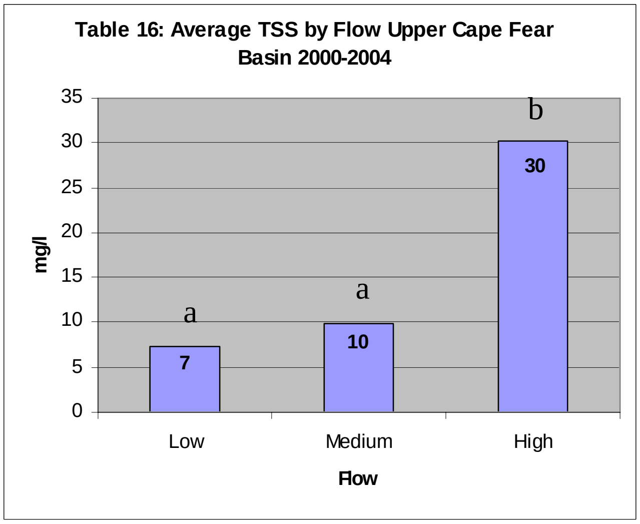


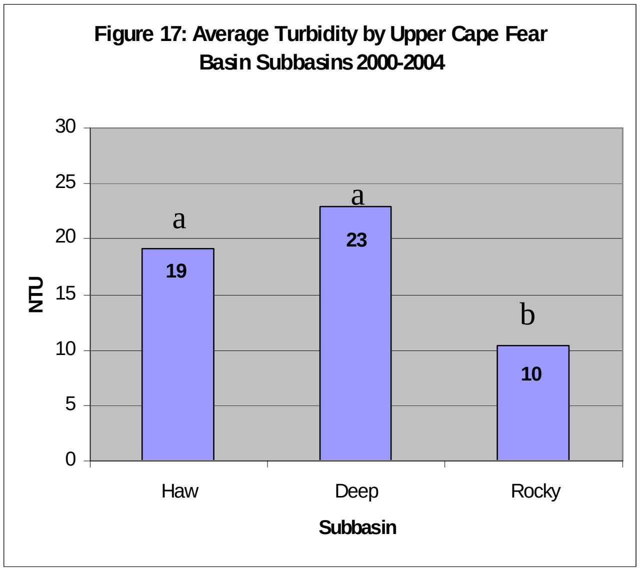
Map 7: Average Conductivity 2000-2004

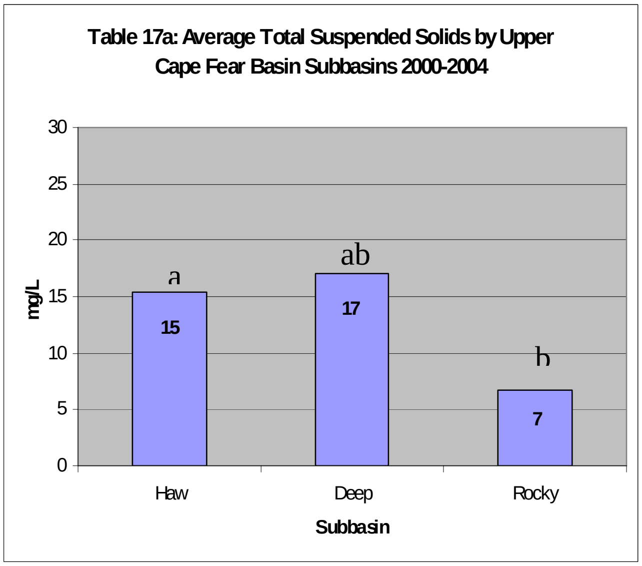
Turbidity and Total Suspended Solids

The relationship between streamflow, turbidity, and total suspended solids (TSS) is evident in Figures 15 and 16. Letters above the bars indicate whether the value represented by a single bar is significantly different at a 95% confidence level from the value represented by another bar. Figures 17 and 17a present a similar comparison of turbidity and TSS values by subbasin.









Both turbidity and TSS appeared to be higher downstream of wastewater treatment plants and urban areas in the Haw River Subbasin, but not in the Deep/Rocky Subbasin (see Figures 18 and 19).

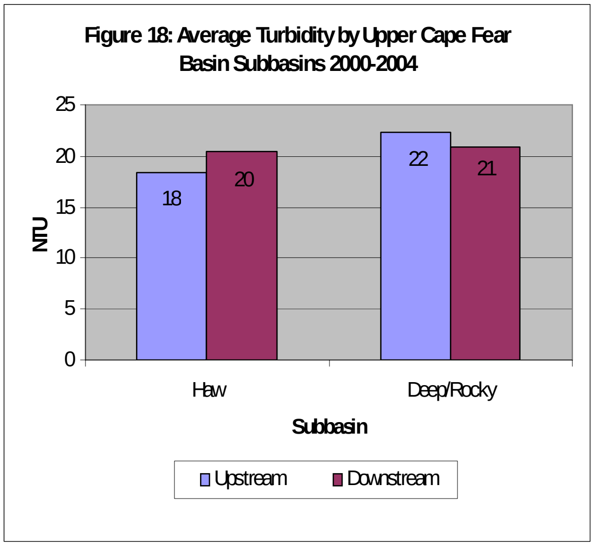


Figure 18: Average Turbidity by Upper Cape Fear Basin Subbasins 2000-2004

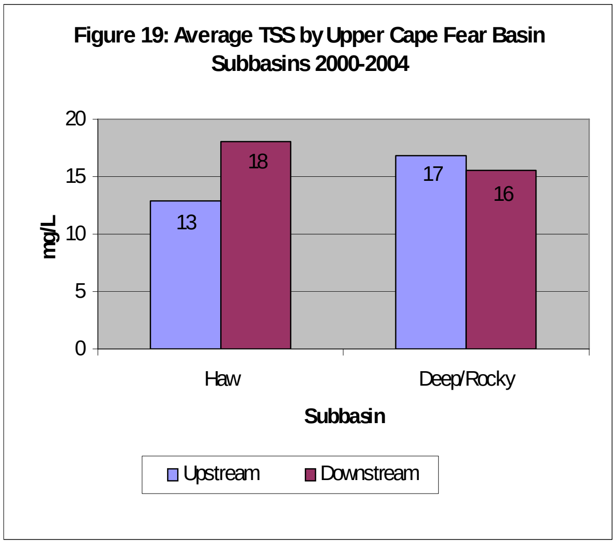
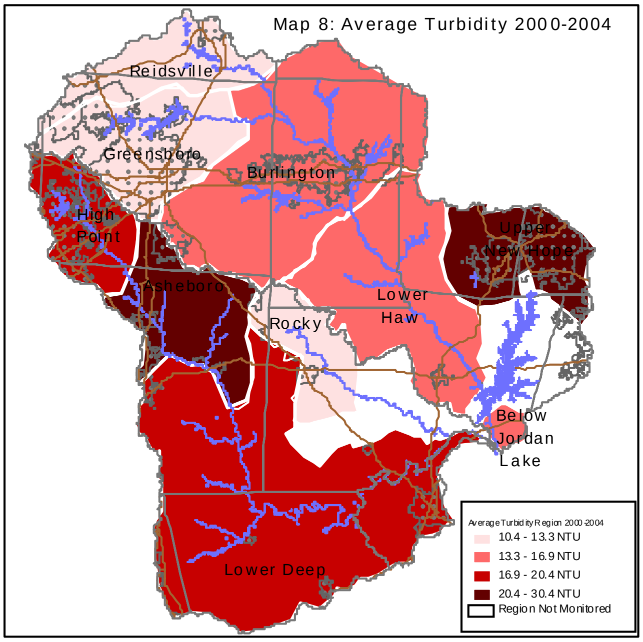


Figure 19: Average TSS by Upper Cape Fear Basin Subbasins 2000-2004

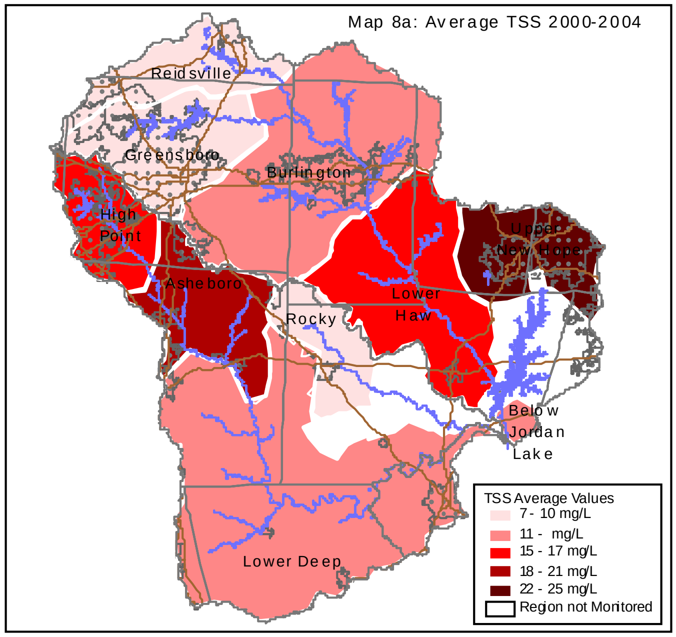
The Asheboro and Upper New Hope regions exhibited the highest mean values and the greatest variability of turbidity and TSS (see Maps 8 and 8a, and Tables 8 and 9).

Table 8:Turbidity Upper Cape Fear Basin 2000-2004		
	Mean	Std Dev
Randleman	20	46
Asheboro	27	44
Lower Deep	20	33
Rocky	10	16
Reidsville	13	17
Greensboro	12	19
Burlington	17	20
Lower Haw	17	23
Upper New Hope Arm	30	64
Below Jordan Lake	15	15



Map 8: Average Turbidity 2000-2004

Table 9: Total Suspended Solids Upper Cape Fear Basin 2000-2004		
	Mean	Std Dev
Randleman	15	51
Asheboro	21	48
Lower Deep	14	29
Rocky	7	9
Reidsville	7	10
Greensboro	10	19
Burlington	13	19
Lower Haw	15	26
Upper New Hope Arm	25	54
Below Jordan Lake	12	7



Fecal Coliform Bacteria

Fecal coliform bacteria levels in the Upper Cape Fear River Basin appeared to increase with streamflow (see Figures 20 and 21). The fecal coliform bacteria geometric mean values generally exceeded 200 cfu/100mL only during wetter years or periods of higher streamflow. The highest fecal coliform geometric means were observed in the Deep River Subbasin (see Figure 22), but the statistical significance of this difference was not determined.

Figure 20: Geomean Fecal Coliform Bacteria for Upper Cape Fear Basin by Year

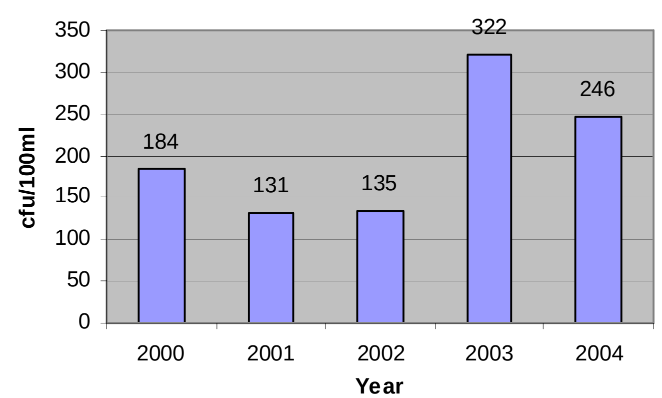


Figure 21: Geomean Fecal Coliform Bacteria for Upper Cape Fear Basin by Flow

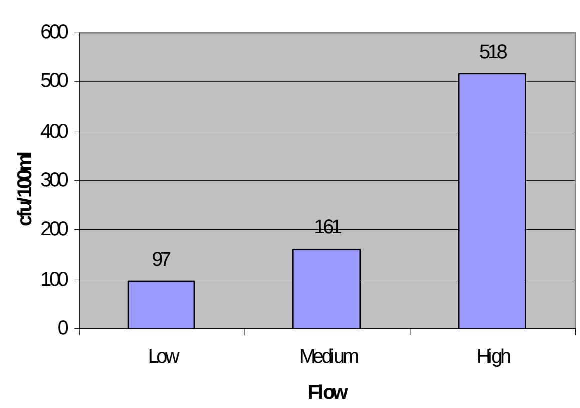
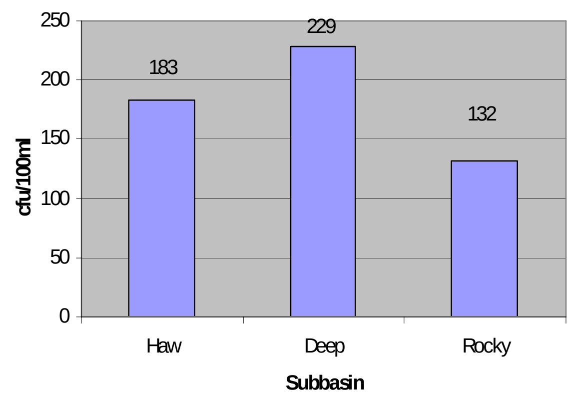


Figure 22: Geomean Fecal Coliform Bacteria by Upper Cape Fear Basin Subbasins 2000-2004



Fecal coliform data collected for this study are compared to the North Carolina Division of Water Quality (DWQ) ambient monitoring data for the Haw Subbasin from 2000-2004 in Figure 22a. Figure 23 illustrates fecal coliform geomeans for locations upstream and downstream of urban areas and wastewater treatment plants.

Figure 22a: Comparison to State Fecal Coliform Geomeans 2000-2004

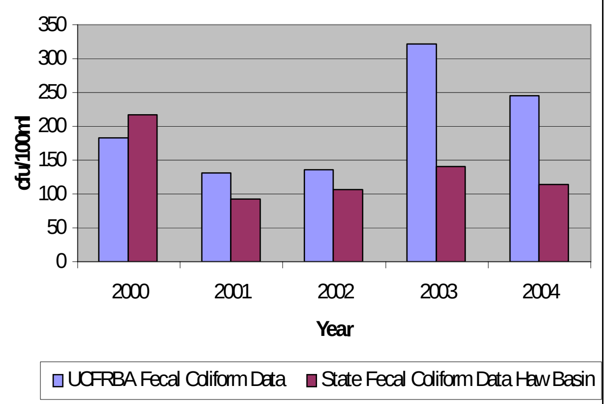
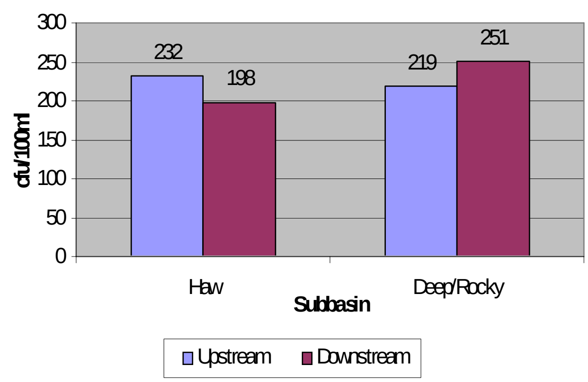


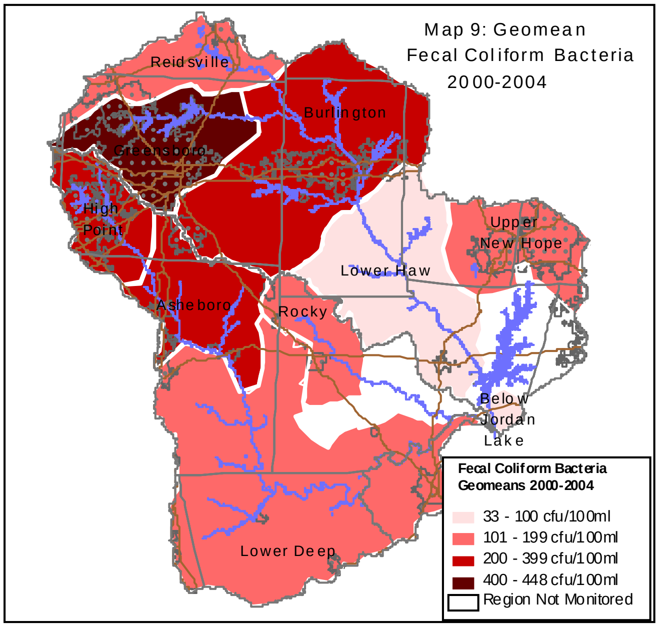
Figure 23: Geomean Fecal Coliform Upstrm vs. Dnstrm WWTP Upper Cape Fear Basin 2000-2004



The Greensboro region exhibited the highest geomean and the High Point region exhibited the greatest variability in fecal coliform concentrations within the study area (see Map 9). The lowest values were measured downstream of Jordan Lake.

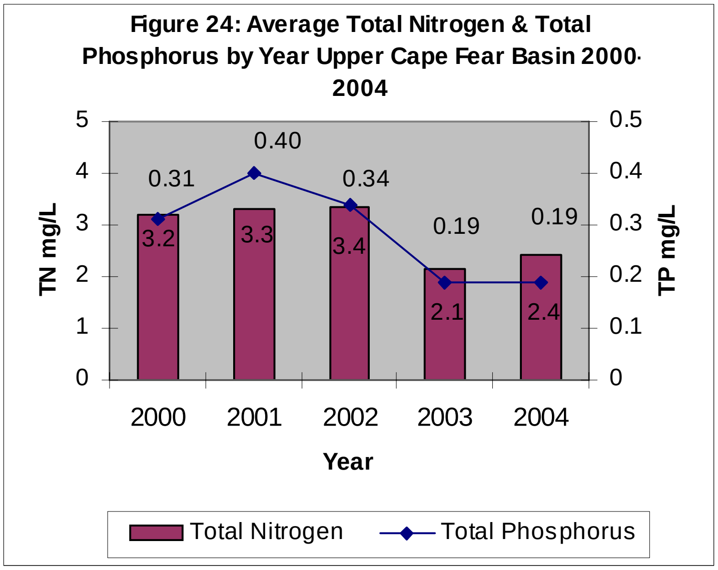
Table 10: Fecal Coliform Bacteria 2000-2004

	Geomean	Std Dev
High Point	385	8373
Asheboro	275	2853
Lower Deep	135	2299
Rocky	132	1400
Reidsville	101	1532
Greensboro	448	3108
Burlington	226	2473
Lower Haw	75	2008
Upper New Hope Arm	189	2621
Below Jordan Lake	33	270



Total Nitrogen and Total Phosphorus

Mean total nitrogen (TN) and total phosphorus (TP) concentrations for the study area are presented in Figures 24, 25a and 25b. Concentrations were lower for both TN and TP during the wetter years of 2003 and 2004 than for the years 2000-2002, perhaps reflecting the dilution of the relatively constant nutrient load of wastewater treatment plant effluent during periods of higher streamflow.



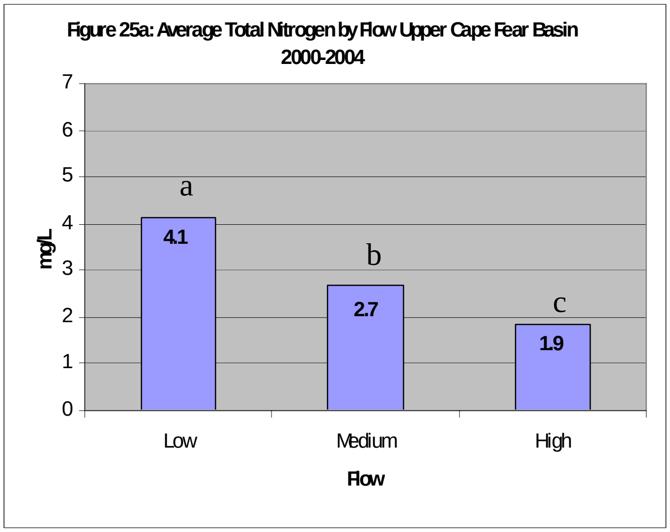


Figure 25a: Average Total Nitrogen by Flow Upper Cape Fear Basin 2000-2004

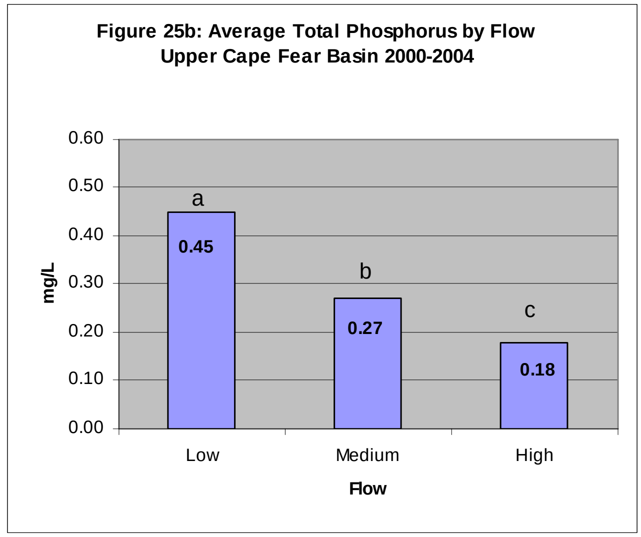


Figure 25b: Average Total Phosphorus by Flow Upper Cape Fear Basin 2000-2004

The Rocky River Subbasin exhibited the highest mean TN value of the three subbasins. The Deep River Subbasin exhibited the highest TP mean value (see Figures 26a and 26b). Statistically significant differences are indicated by the letters above each bar.

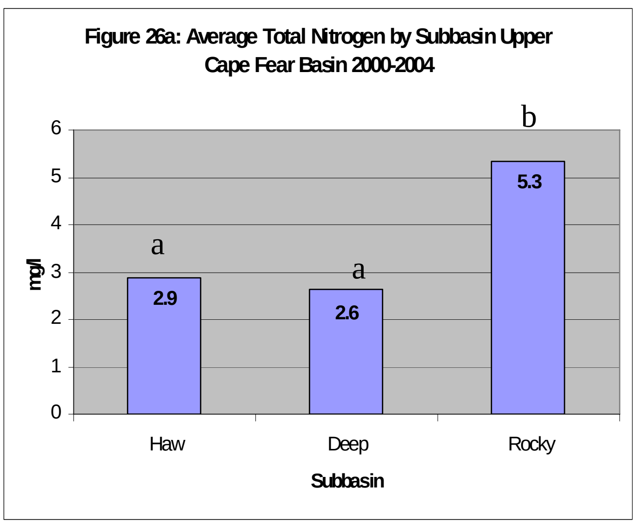


Figure 26a: Average Total Nitrogen by Subbasin Upper Cape Fear Basin 2000-2004

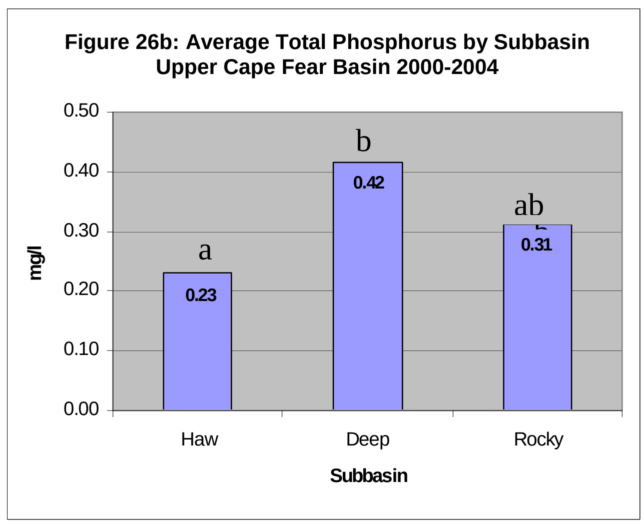
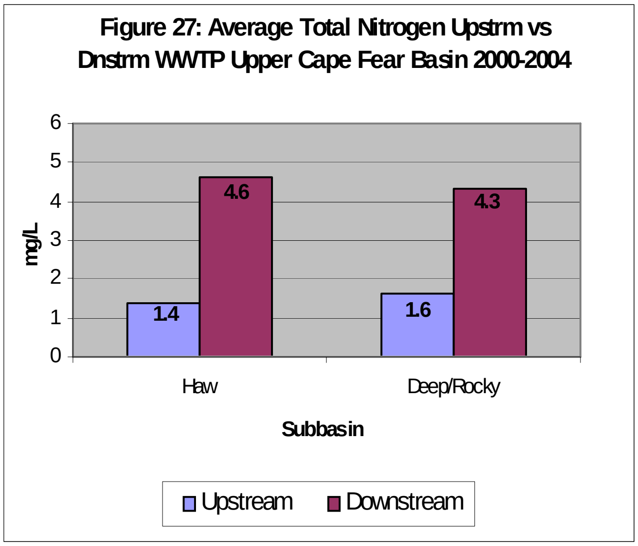


Figure 26b: Average Total Phosphorus by Subbasin Upper Cape Fear Basin 2000-2004

Total nitrogen and total phosphorus concentrations were substantially higher downstream of wastewater treatment plants/urban areas than upstream (see Figures 27 and 28).



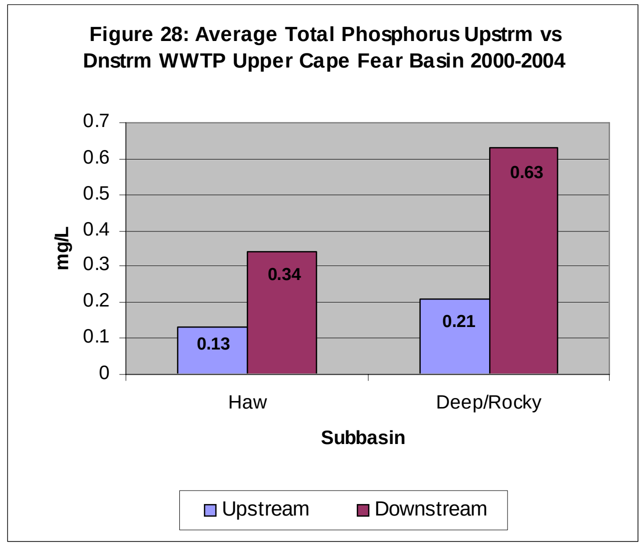


Table 11a compares these UCFRBA nutrient data to the findings of a recently completed USGS report. The USGS report noted that suspended-sediment, total nitrogen and total phosphorus concentrations have decreased in the Haw River near Bynum. "Concentrations of dissolved Kjeldahl nitrogen decreased by 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 nitrogen concentrations in the USGS data" (USGS 2005-5271, pp.22-23).

Table 11a: Comparison to Nutrient Data for UGSG Upper Cape Fear Study

	Total Nitrogen *mg/l*	Total Phosphorus *mg/l*
USGS Data Haw River @ Bynum	1.6	0.16
UCFRBA Data Haw River @ US 64	1.8	0.17
USGS Data Deep River @ Moncure	1.6	0.23
UCFRBA Data Deep River @ Old US 1 Moncure	1.6	0.3

Source: USGS Suspended Sediment and Nutrients in the Upper Cape Fear River Basin Report, 2005-5271

A regional comparison of nutrient concentrations is presented in Tables 12 and 13 and Maps 10 and 10a.

Table 12:Total Nitrogen Upper Cape Fear Basin 2000-2004		
	Mean	Std Dev
High Point	2.4	3.8
Asheboro	2.7	2.3
Lower Deep	2.7	2.7
Rocky	5.3	6.0
Reidsville	0.9	2.3
Greensboro	4.4	4.5
Burlington	3.0	2.7
Lower Haw	1.9	1.1
Upper New Hope Arm	3.2	4.4
Below Jordan Lake	1.3	0.4

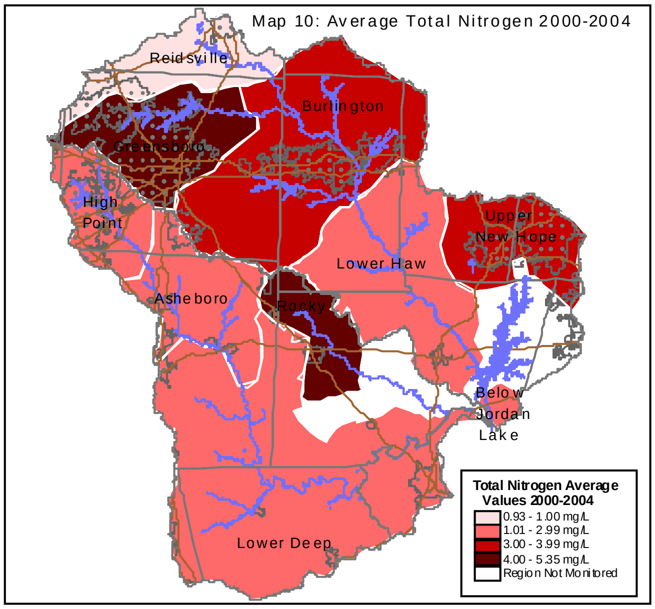
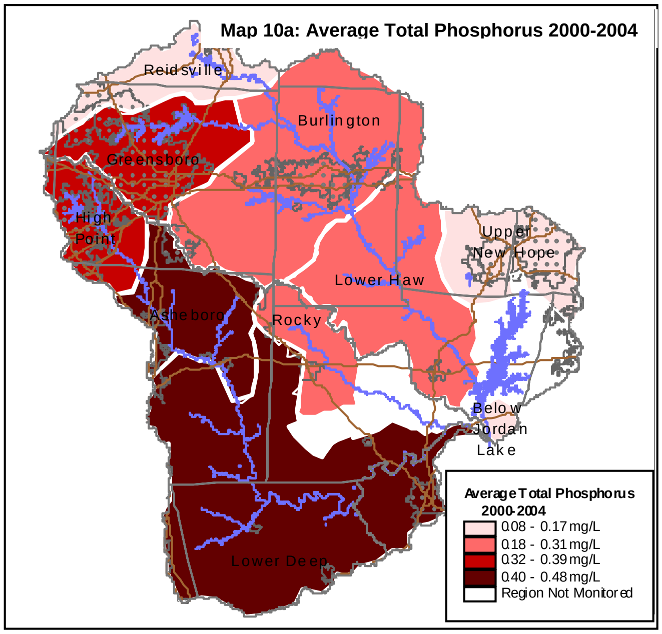
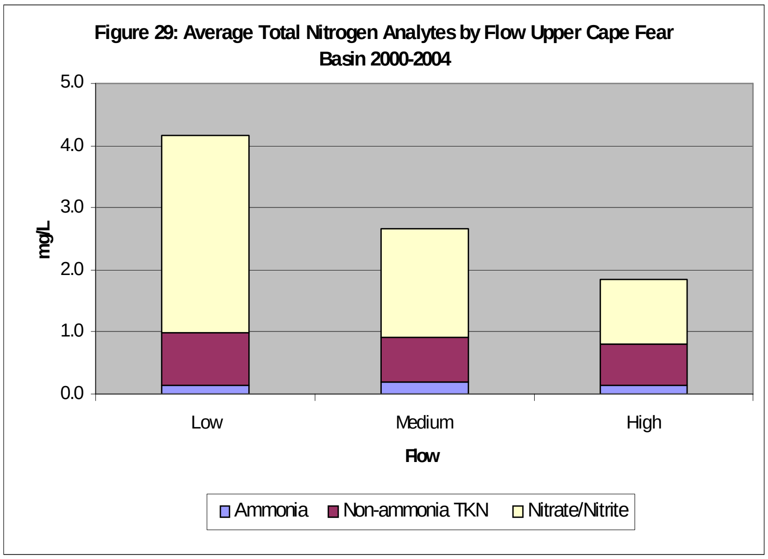


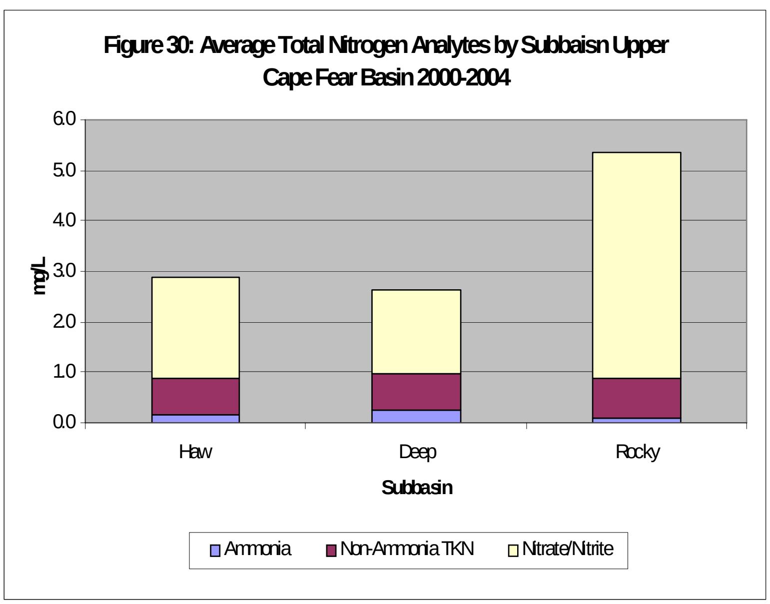
Table 13:Total Phosporus Upper Cape Fear Basin 2000-2004		
	Mean	Std Dev
High Point	0.33	0.66
Asheboro	0.43	0.47
Lower Deep	0.48	0.68
Rocky	0.31	0.44
Reidsville	0.08	0.09
Greensboro	0.39	0.57
Burlington	0.29	0.30
Lower Haw	0.18	0.16
Upper New Hope Arm	0.17	0.20
Below Jordan Lake	0.09	0.05



Total Nitrogen Analytes

Figures 29 and 30 compare the mean concentrations of three nitrogen species (ammonia-N, non-ammonia TKN, and nitrate/nitrite-N) under different streamflow conditions and by subbasin. The inverse relationship between nitrate/nitrite-N and streamflow may reflect the dilution of a relatively constant nitrate/nitrite load from wastewater treatment plants under different streamflow conditions.





Metals

Eleven different metals parameters were analyzed monthly at thirty-two locations during the study period. The first two years of data were invalidated due to quality control issues. Only data collected after November 2001 were retained. Because the detection levels for lead, nickel, chromium, cadmium and arsenic changed several times during the study period (see Table 4), the data for these parameters are not reviewed with respect to time.

Table 14 provides a summary of overall metals results. When metals were detected, the concentrations were generally below the applicable water quality standards or action levels. Exceptions occurred for iron, manganese and copper, which exhibited mean values that were close to or above the recommended action levels at exceedence frequencies greater than 10 percent; i.e., action levels were approached or exceeded in more than 10 percent of all samples.

Table 14: Metals Overview for Upper Cape Fear Basin 2001-2004

	Frequency of Detects	Detection Level (ug/l)	WQ Std/Act Level (ug/L)	Mean of Detects (ug/l)	Median of Detect Values (ug/L)	Exceedence Frequencies Based on Total
Manganese	100.0%	1	200(WS)	182	121	26.6%
Iron	99.9%	50	1000 (AL)	1296	1000	49.7%
Aluminum	99.5%	50	NA	636	332	NA
Copper	87.7%	2	7 (AL)	5.74	4.6	12.8%
Zinc	56.4%	10	50 (AL)	28	21	5.8%
Lead	30.8%	2 & 10	25	3.62	2.3	0.2%
Nickel	11.1%	5 & 10	88 (25 WS)	9.98	8.1	0.0%
Chromium	1.7%	5, 10 & 25	50	14.67	14	0.0%
Cadmium	1.7%	.5, 1 & 2	2	1	0.73	0.3%
Arsenic	1.0%	5 & 10	50 (10 WS)	11	12	0.2%
Mercury	0.0%	0.2	0.012	0	0	0.0%

Note: AL = Action Level   WS = Water Supply Watershed Standard

The following sections provide a more detailed review of the percentage of detects and the mean value of those detects. Only manganese, iron, aluminum, copper, lead, and zinc are analyzed in the trends section based on the number of detects. No further review is provided of nickel, chromium, cadmium, arsenic and mercury data, because these parameters were detected so infrequently.

Metals Observed Above Their Analytical Detection Limits

Figure 31 compares metals detects (i.e., analytically detectable) among the three subbasins, and Figure 32 presents the percentage of detects under high, medium, and low streamflow conditions. The natural abundance of aluminum, iron, and manganese in Piedmont soils is reflected in their presence in virtually all water samples. The increased frequency of copper, lead and chromium detects during high streamflow flow periods may indicate a nonpoint origin of these constituents (see Figure 32). By comparison, the higher frequency of zinc, nickel and cadmium detects during low flow periods may indicate a relatively constant (e.g., point source) origin of these elements.

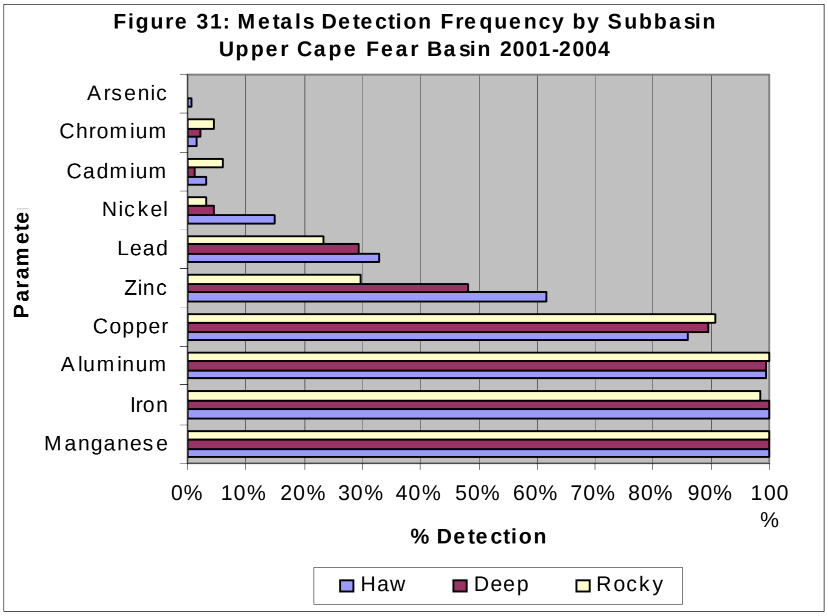


Figure 31: Metals Detection Frequency by Subbasin
Upper Cape Fear Basin 2001-2004
Arsenic
Chromium
Cadmium
Nickel
Lead
Zinc
Copper
Aluminum
Iron
Manganese
Paramete
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100
%
% Detection
Haw
Deep
Rocky

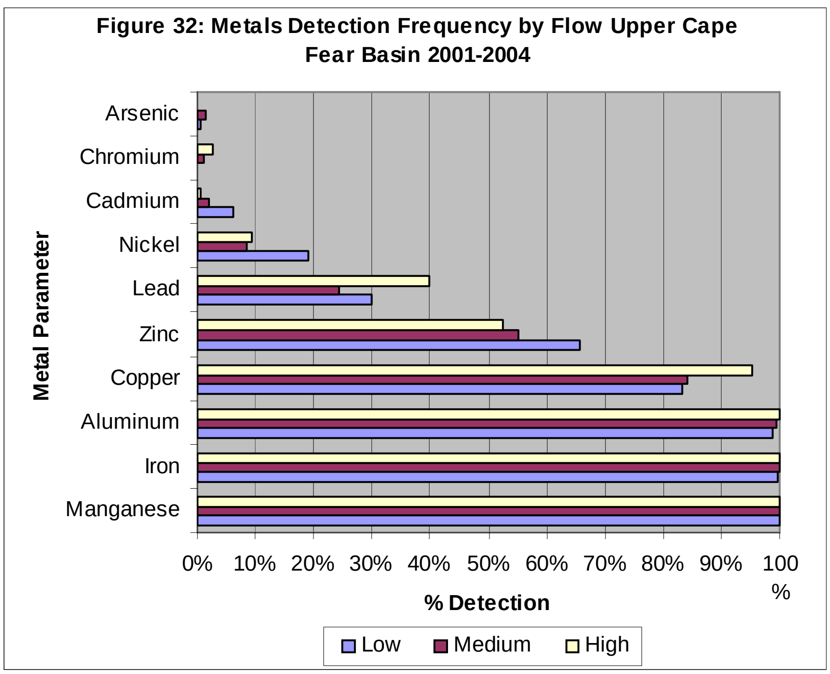
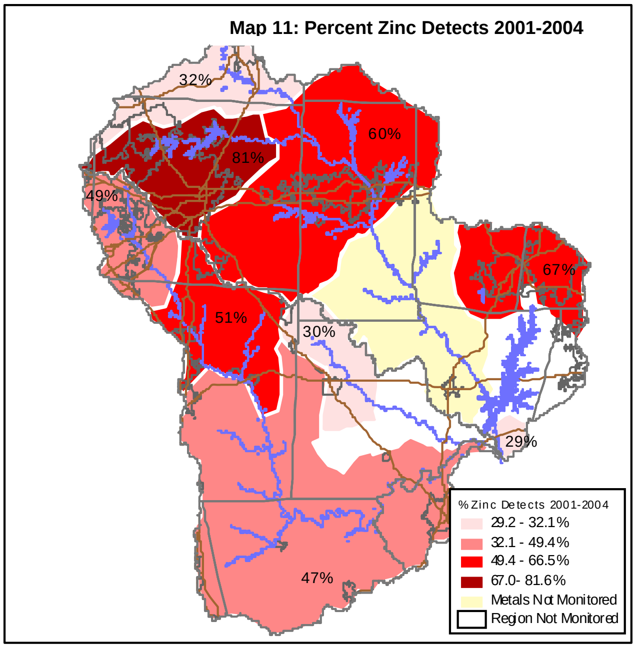


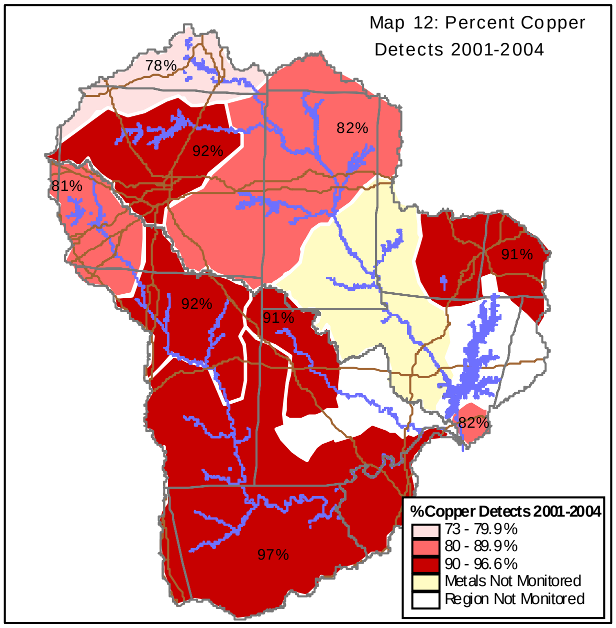
Figure 32: Metals Detection Frequency by Flow Upper Cape
Fear Basin 2001-2004
Arsenic
Chromium
Cadmium
Nickel
Lead
Zinc
Copper
Aluminum
Iron
Manganese
Metal Parameter
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100
%
% Detection
Low
Medium
High

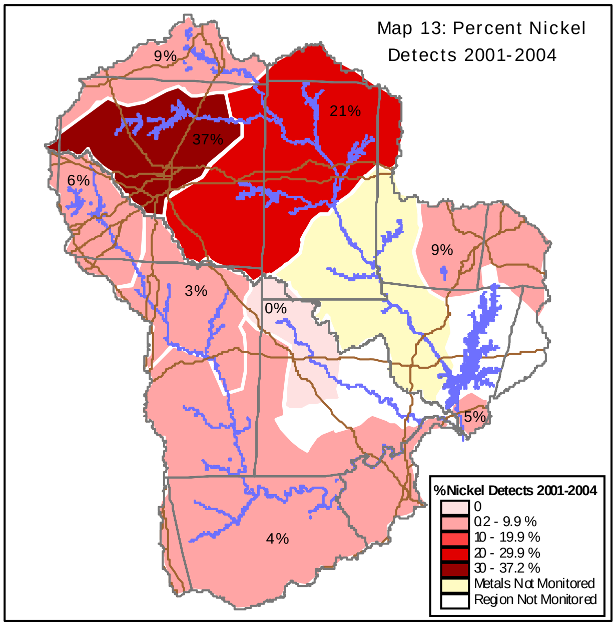
Maps 11 through 17 illustrate the frequency of metals detects in each region of the study area.

The highest percentage of zinc detection frequencies was observed in the Greensboro region (81 percent) versus less than 30 percent downstream of Jordan Lake (see Map 11). Urbanized areas generally exhibited a greater percentage of zinc detects than rural areas.

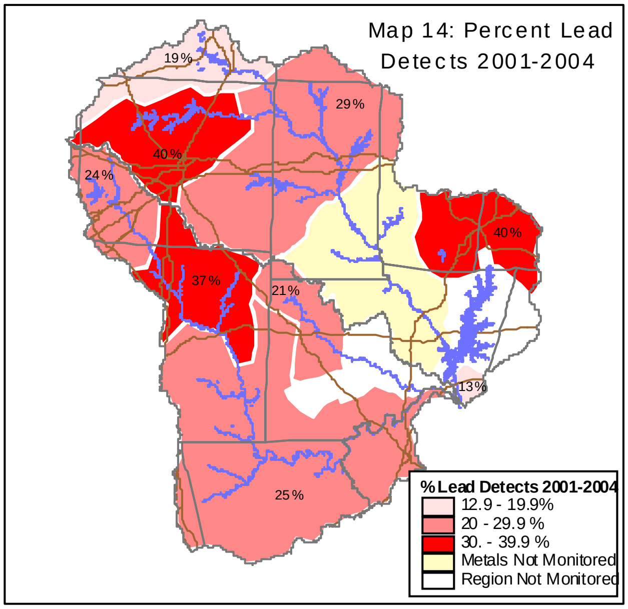


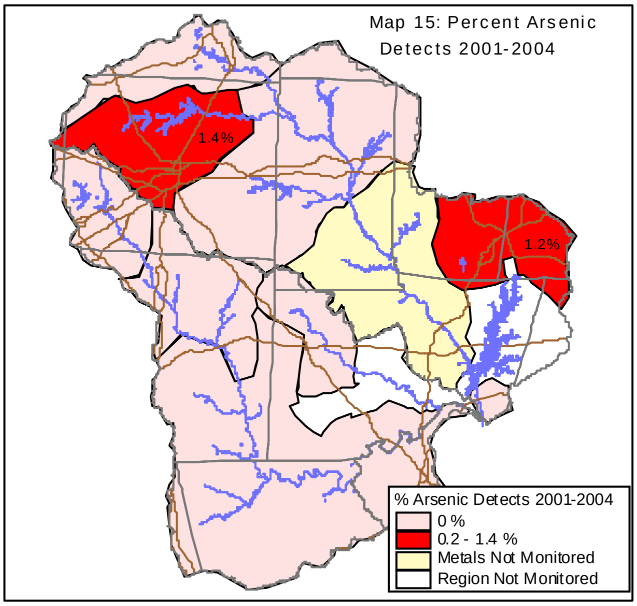
A high percentage of copper detects was generally observed throughout the study area, with little apparent difference between urban and rural areas (see Map 12). Nickel was less ubiquitous, except for the Greensboro and Burlington regions where it was detected in more than 20 percent of the samples (see Map 13).



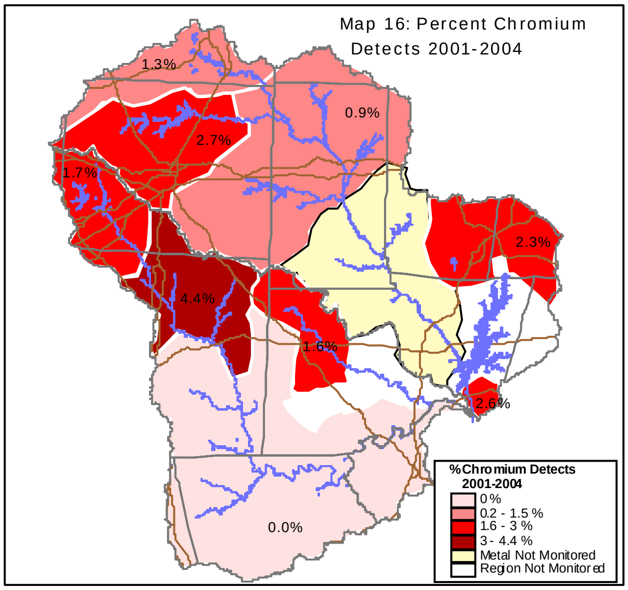


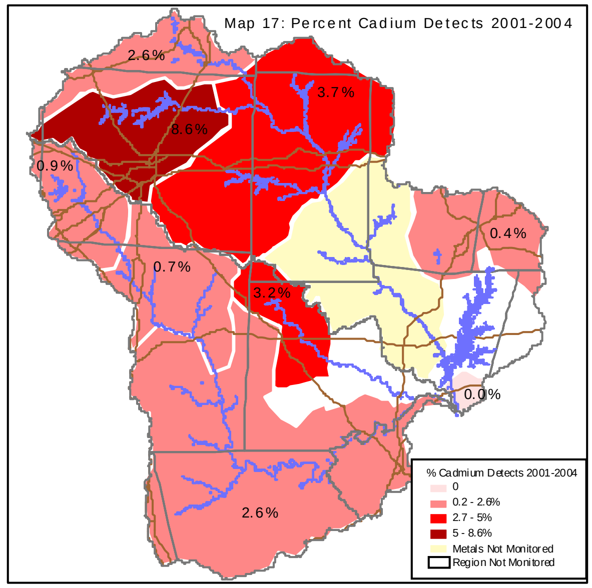
Lead was detected throughout the study area, with the highest frequency occurring in the Upper New Hope, Greensboro, and Asheboro regions (see Map 14). Arsenic was observed in only the Greensboro and Upper New Hope regions (see Map 15), but was detected in fewer than 2 percent of the samples from these regions.





Chromium and cadmium were detected in less than 10 percent of all samples (see Maps 16 and 17).





Metals Detected Upstream and Downstream of Urban Areas and Wastewater Treatment Plants

The frequency of copper, zinc, cadmium, and chromium detections was higher at locations downstream of urban areas and wastewater treatment plants throughout the study area (see Table 15). Nickel occurred more frequently in downstream locations in the Haw River Subbasin, but not in the Deep/Rocky River Subbasin.

Table 15: Percentage of Metals Detects by Upper Cape Fear Subbasin and Location to WWTP

	Haw		Deep/Rocky	
	Upstream %	Downstream %	Upstream %	Downstream %
Manganese	100	100	100	100
Iron	100	100	100	100
Aluminum	99	100	99	100
Copper	79	93	76	96
Zinc	42	82	40	55
Lead	30	35	28	28
Nickel	4	26	4	4
Cadmium	1	5	0	3
Chromium	1	2	1	3
Arsenic	1	1	0	0
Mercury	0	0	0	0

Other Metals Occurrence Patterns

Iron, lead, and aluminum concentrations throughout the study area were generally higher during periods of higher streamflow (see Table 16), which is consistent with their likely nonpoint origins. Iron and aluminum are naturally abundant in Piedmont soils, and lead is commonly found in runoff from urban areas. Compare the values for iron and manganese in Table 16 with the values in Table 17.

Table 16: Average Metal Values Based on Detects by Flow Upper Cape Fear Basin 2001-2004

	Low (ug/l)	Medium (ug/l)	High (ug/l)
Lead	2.1	2.9	5.8
Copper	5.4	4.7	7.2
Zinc	32	25	29
Aluminum	293	466	1095
Iron	800	1081	1925
Manganese	227	156	183

Table 17: USGS Comparsion Data

		Total Iron (ug/l)				Total Manganese (ug/l)			
Site Location	**Flow Conditions**	**N**	**Mean**	**Median**	**Range**	**N**	**Mean**	**Median**	**Range**
Dutchmans Creek near Uwharrie	Storm Flow	10	1,430	1,300	250-3,400	10	164	100	<10-380
	Low Flow	31	411	400	170-950	30	37	21	20-240
New Hope River trib. Near Farrington	Storm Flow	9	1,088	710	460-3,100	9	61	30	<25-280
	Low Flow	17	604	520	160-1,400	16	12	12	<10-30

Source: Caldwell, W.S., 1992, Selected water-quality and biological characteristics of streams in some forested basins on North Carolina, 1985-1988:U.S. Geological Survey Water-Resources Investigations Report 92-4129, 114p.

		Total Iron (ug/l)		
	Flow Conditions	**N**	**Mean**	**Range**
Several small, unpolluted streams in Piedmont	Storm Flow	10	5,100	770-13,000
	Base Flow	9	610	160.2-2,100

Source: Simmons, C.E. and Heath, R.C., 1982, Water-quality characheristics of forested and rural areas of North Carolina: U.S. Geological survey Water-Supply Paper 2185-B 33 p.

The spatial patterns of lead, copper, zinc, aluminum, iron, and manganese mean (detectable) concentrations are summarized in Tables 18 through 25 and Figures 18 through 23 below. Apparent differences among data groupings were not analyzed for statistical significance.

Table 18: Average Metals Value Based on Detects by Subbasin Upper Cape Fear Basin 2001-2004			
	Haw (ug/l)	Deep (ug/l)	Rocky (ug/l)
Lead	3.34	4.70	4.77
Manganese	228	107	125
Zinc	29	25	44
Copper	5.96	5.52	4.73
Iron	1355	1317	1030
Aluminum	644	728	313

Table 19: Average Metals Values based on Detects by Subbasin and Location to WWTP				
	Haw		Deep/Rocky	
	Upstream (ug/l)	Downstream (ug/l)	Upstream (ug/l)	Downstream (ug/l)
Lead	3.1	3.2	3.5	5.4
Copper	5.5	6.5	4.6	5.9
Zinc	12	28	12	16
Aluminum	510	752	587	696
Iron	1413	1325	1192	1293
Manganese	268	221	179	80

Table 20: Manganese Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
High Point	174	314
Lower Deep	84	71
Rocky	125	147
Upper New Hope Arm	245	213
Below Jordan Lake	133	115

Map 18: Average Manganese 2001-2004

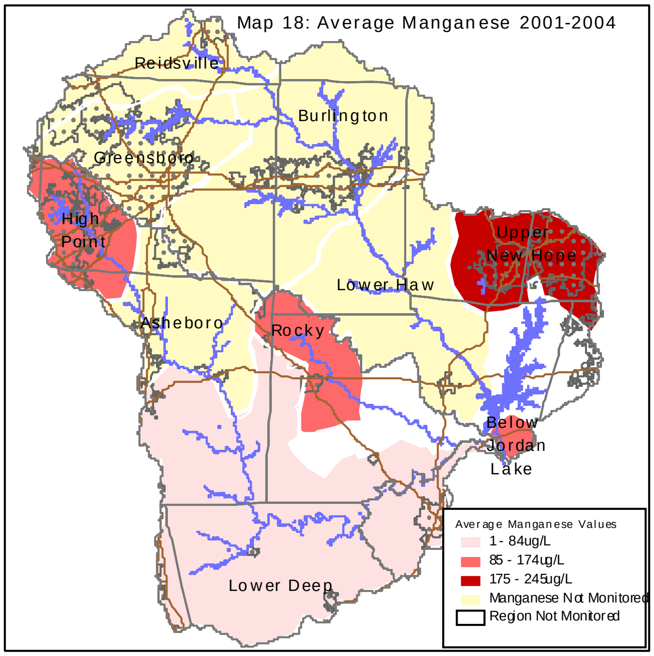


Table 21: Iron Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
High Point	974	968
Asheboro	1670	1744
Lower Deep	1191	1035
Rocky	1014	594
Reidsville	1837	988
Greensboro	908	789
Burlington	1344	862
Upper New Hope Arm	1561	1576
Below Jordan Lake	779	535

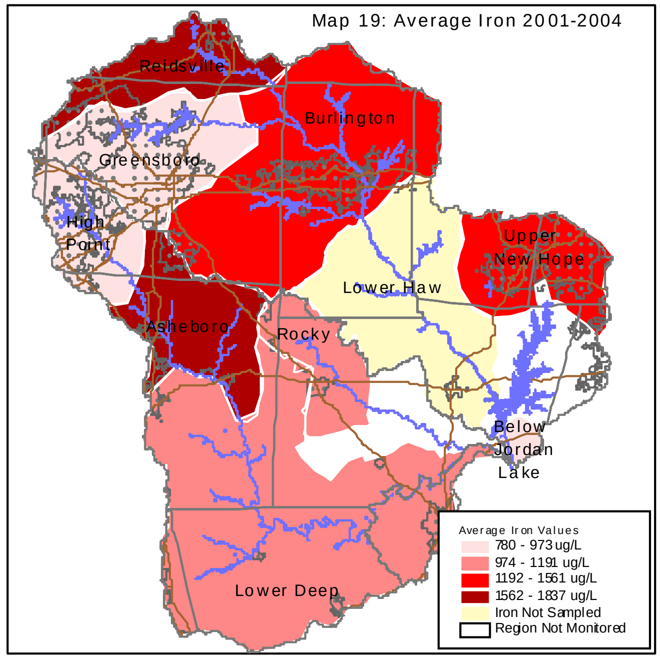


Table 22: Aluminum Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
High Point	550	586
Asheboro	982	1204
Lower Deep	559	708
Rocky	313	326
Reidsville	531	955
Greensboro	460	637
Burlington	522	651
Upper New Hope Arm	910	1831
Below Jordan Lake	377	306

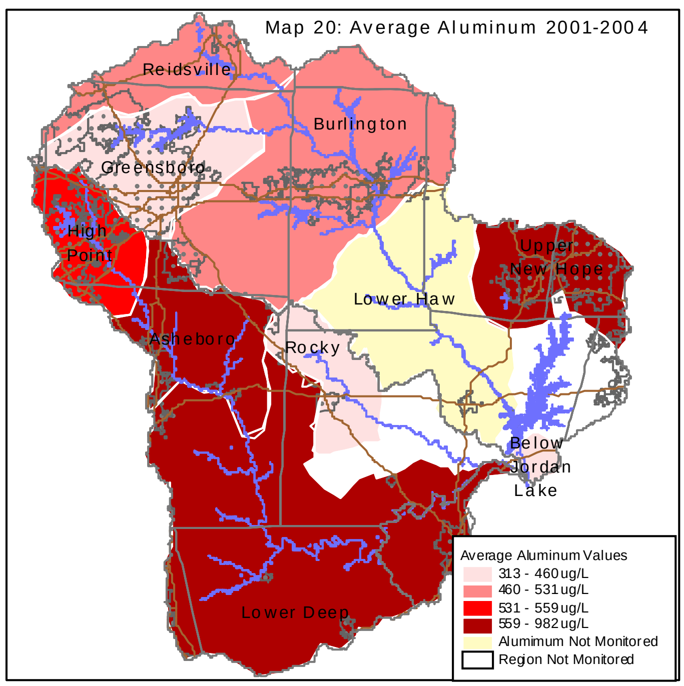
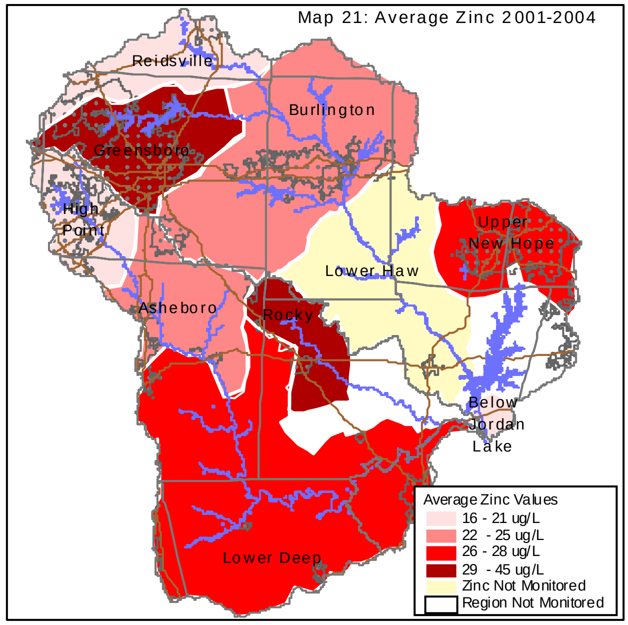


Table 23: Zinc Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
High Point	13	13
Asheboro	15	15
Lower Deep	16	19
Rocky	17	42
Reidsville	8	7
Greensboro	32	25
Burlington	17	14
Upper New Hope Arm	20	21
Below Jordan Lake	9	8



.

Table 24: Copper Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
Randleman	3.9	2.6
Asheboro	5.9	4.7
Lower Deep	5.1	3.2
Rocky	4.4	2.7
Reidsville	4.1	2.8
Greensboro	5.3	3.0
Burlington	5.7	14.7
Upper New Hope Arm	5.6	6.5
Below Jordan Lake	3.4	2.1

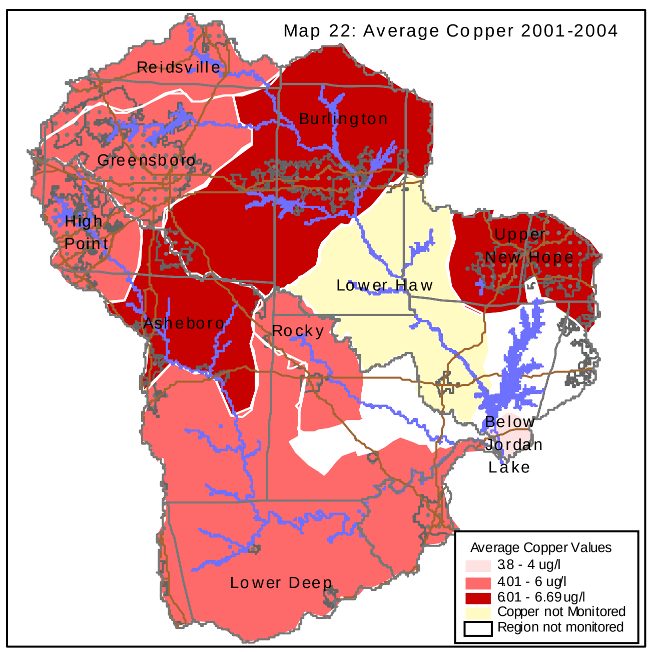
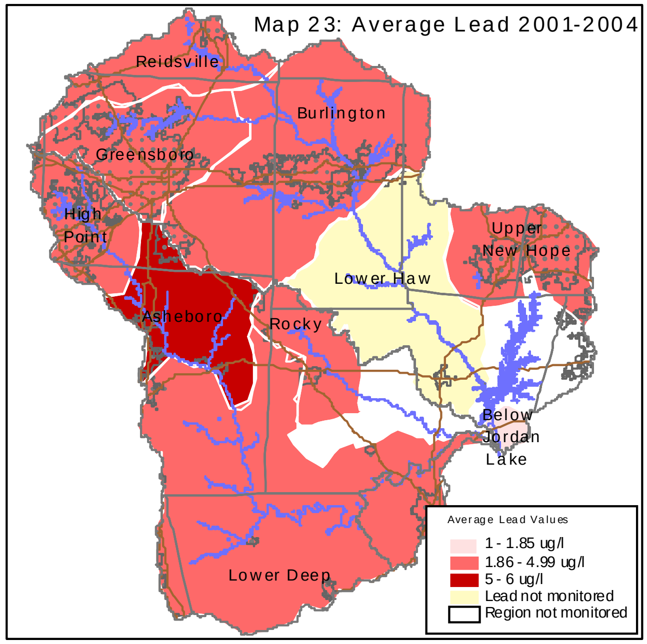
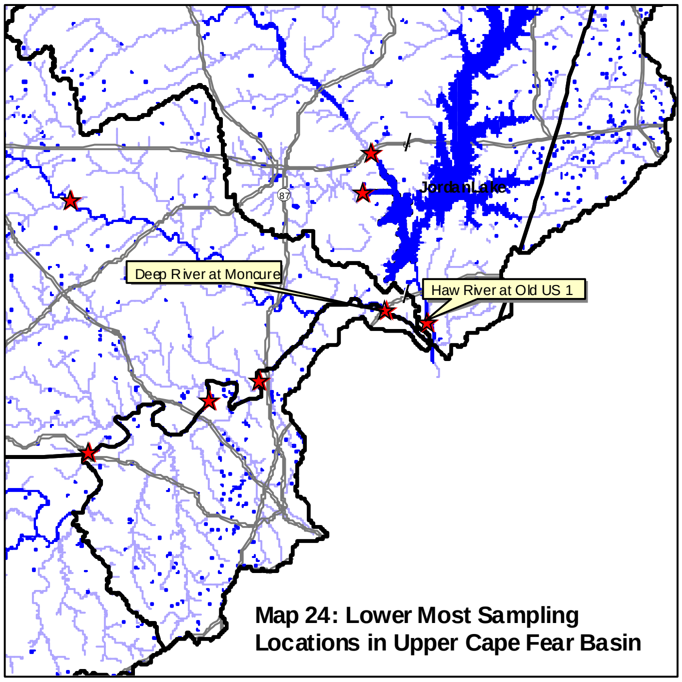


Table 25: Lead Upper Cape Fear Basin 2001-2004		
	Mean	Std Dev
Randleman	2.5	2.6
Asheboro	3.4	6.4
Lower Deep	2.5	2.9
Rocky	2.6	4.5
Reidsville	2.1	1.9
Greensboro	2.7	2.8
Burlington	2.2	1.9
Upper New Hope Arm	2.8	4.0
Below Jordan Lake	1.8	1.6



Water Quality Leaving the Upper Cape Fear Study Area

This last section compares data from the two most downstream sampling locations in the Upper Cape Fear River Basin on the Haw River at Old US 1 and the Deep River at Moncure (see Map 24).



Map 24: Lower Most Sampling Locations in Upper Cape Fear Basin

Mean value concentrations for many parameters were generally higher in the Deep River than in the Haw River (see Table 26), likely reflecting removal by Jordan Lake immediately upstream on the Haw River. A comparison of Deep River data from this study to data compiled in a recent USGS report indicates similar concentrations of total nitrogen and total phosphorus (see Table 27).

Table 26: Water Quality Leaving Upper Cape Fear Basin

	Haw River @ Old US 1	Deep River @ Moncure
Dissolved Oxygen	7.94 mg/l	8.53 mg/l
Saturation Percentage	84%	86%
Conductivity	178 umhos	166 umhos
Turbidity	15 NTU	26 NTU
TSS	12 mg/l	21 mg/l
Fecal Coliform Bacteria	33 cfu/100ml	83 cfu/100ml
Total Nitrogen	1.26 mg/l	1.62 mg/l
Total Phosphorus	.09 mg/l	.30 mg/l
Metals		
Lead	1.7 ug/l	4.1 ug/l
Copper	3.9 ug/l	4.7 ug/l
Zinc	20 ug/l	35 ug/l
Aluminum	377 ug/l	806 ug/l
Iron	779 ug/l	1479 ug/l
Manganese	134 ug/l	94 ug/l

Table 27: USGS Data Comparison		
	UCFRBA 2000-2004 Deep River @ Moncure	**USGS 2002-2004 Deep River @ Moncure**
Total Nitrogen	1.62 mg/l	1.6 mg/l
Total Phosphorus	.30 mg/l	.23 mg/l

Source: Sediment and Chemical Loads in the Haw and Deep River Basins, North Carolina 2002-2004 with an Analysis and Changes in Water Quality and Loads, 1976-2004.

Appendix

The following statistical analyses of Upper Cape Fear River Basin Association water quality data were provided by Dr. Janet MacFall of Elon University. Significant differences between values are indicated by differences in letters (a, b, c, etc).

Comparing stations 26 (Haw River) and 27 (Deep River):

Station	Conductivity	TN	TP
26	180.79 a	1.26 a	0.09 a
27	168.10 a	1.61 b	0.29 b

Station	TSS	Turbidity	NO3
26	11.92 a	14 a	0.48 a
27	19.10 a	23 a	0.90 b

Comparing subbasins and flow categories:

Effect	Conductivity	NH3
Deep	296 a	0.23 a
Haw	259 b	0.14 a
Rocky	238 b	0.07 b
Low Flow	376 a	0.12 a
Medium Flow	261 b	0.18 a
High Flow	171 c	0.14 a

Effect	NO3	TKN	Turbidity
Deep	1.72 a	0.93 a	21 a
Haw	1.97 a	0.88 a	19 a
Rocky	5.79 b	0.89 a	10 b
Low Flow	6.01 a	0.97 a	9 a
Medium Flow	2.27 b	0.91 a	14 a
High Flow	1.2 c	0.82 a	39 c

Effect	TP	TN	TSS
Deep	0.41 a	2.62 a	14.5 ab
Haw	0.23 b	2.89 a	15.4 a
Rocky	0.31 ab	5.44 b	6.5 b
Low Flow	0.45 a	4.14 a	7 a
Medium Flow	0.27 b	2.68 b	10 a
High Flow	0.18 c	1.87 c	30 b

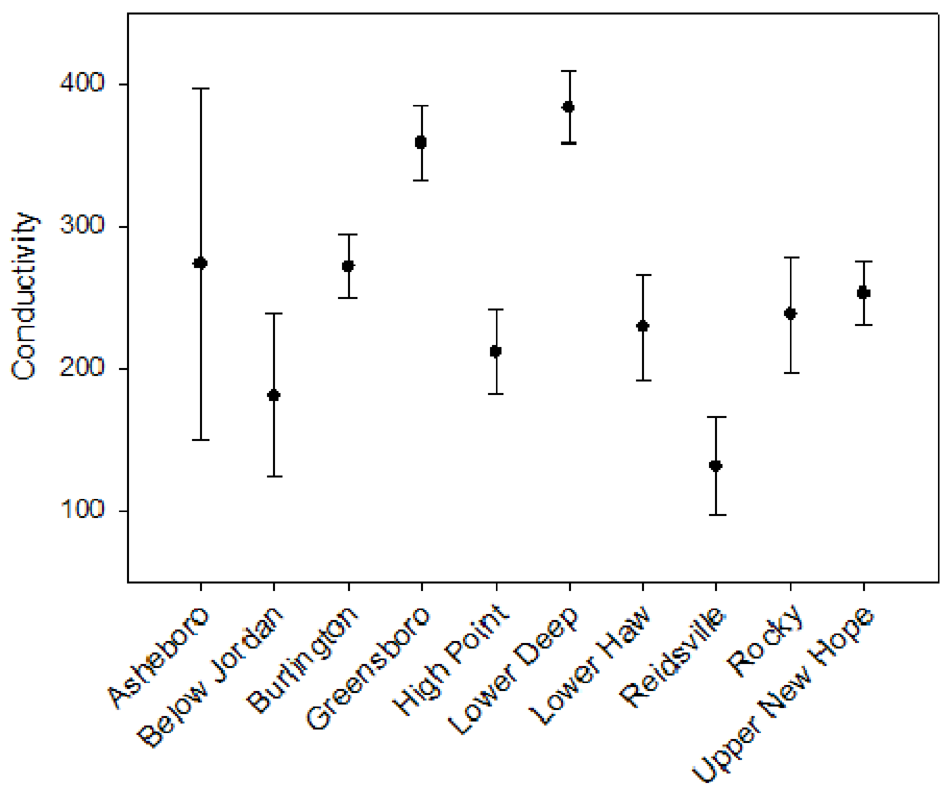
Analyses were done with SAS Enterprise, using Analysis of Variance.

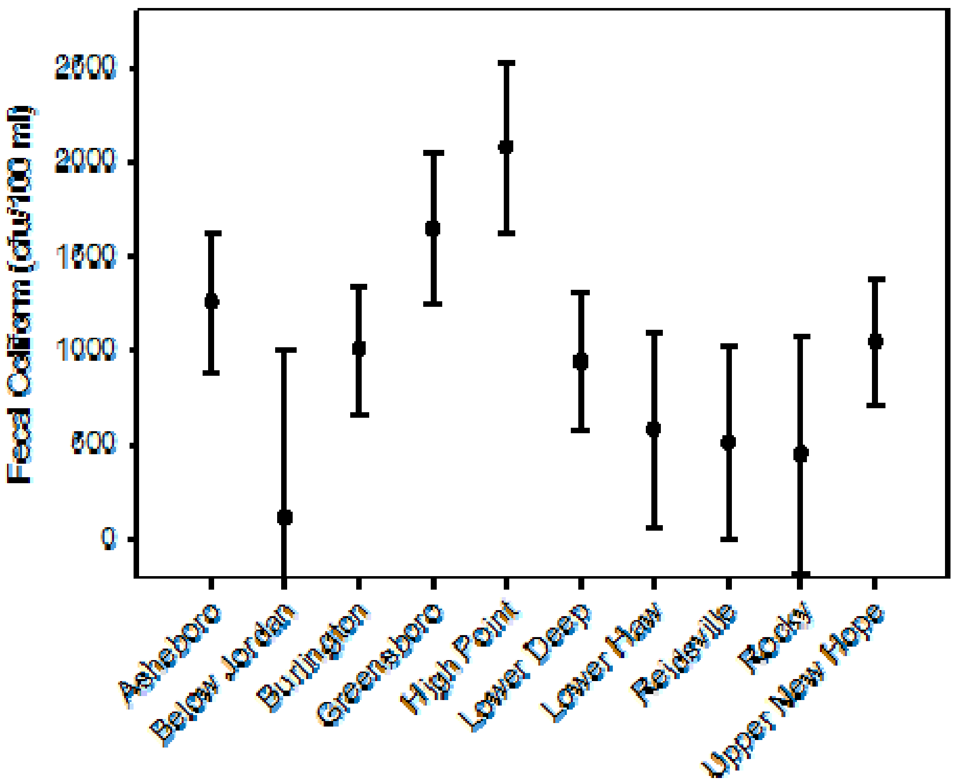
Non-Parametric Analysis of Fecal Coliform Data
From the Upper Cape Fear River Basin Association

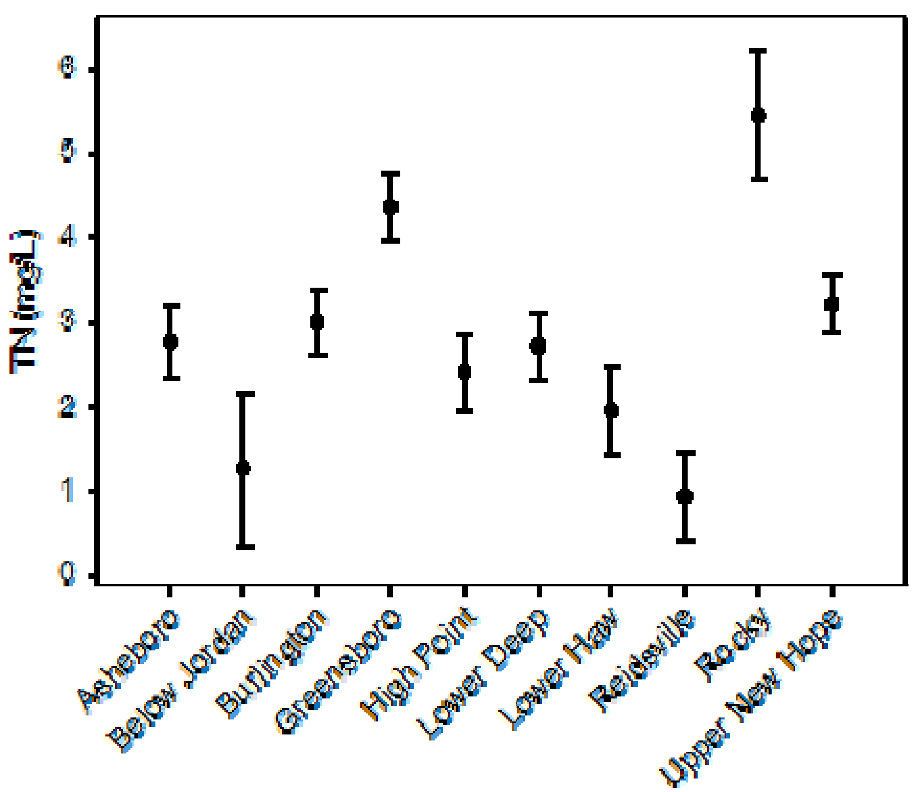
Treatment	Median
Low	100 a
Medium	130 b
High	480 c
Haw	145 ab
Deep	173 b
Rocky	110 a

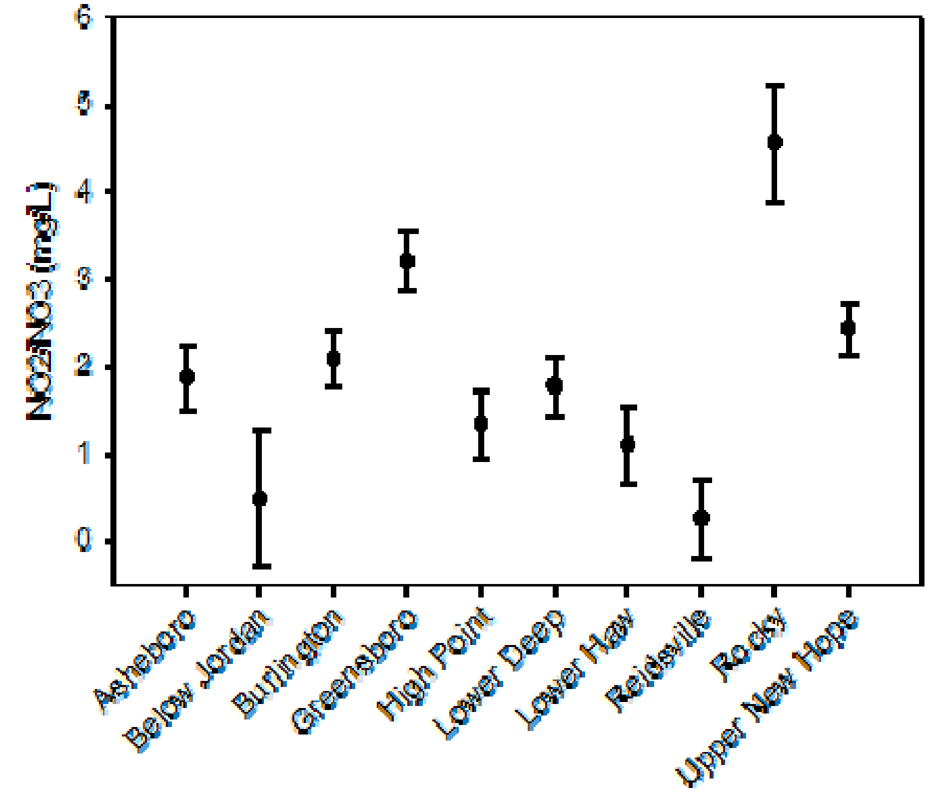
Analyses were done using the Kruskal-Wallis Non-Parametric One Way Analysis of Ranks. Analyses were done with SigmaStat 3.1 software.

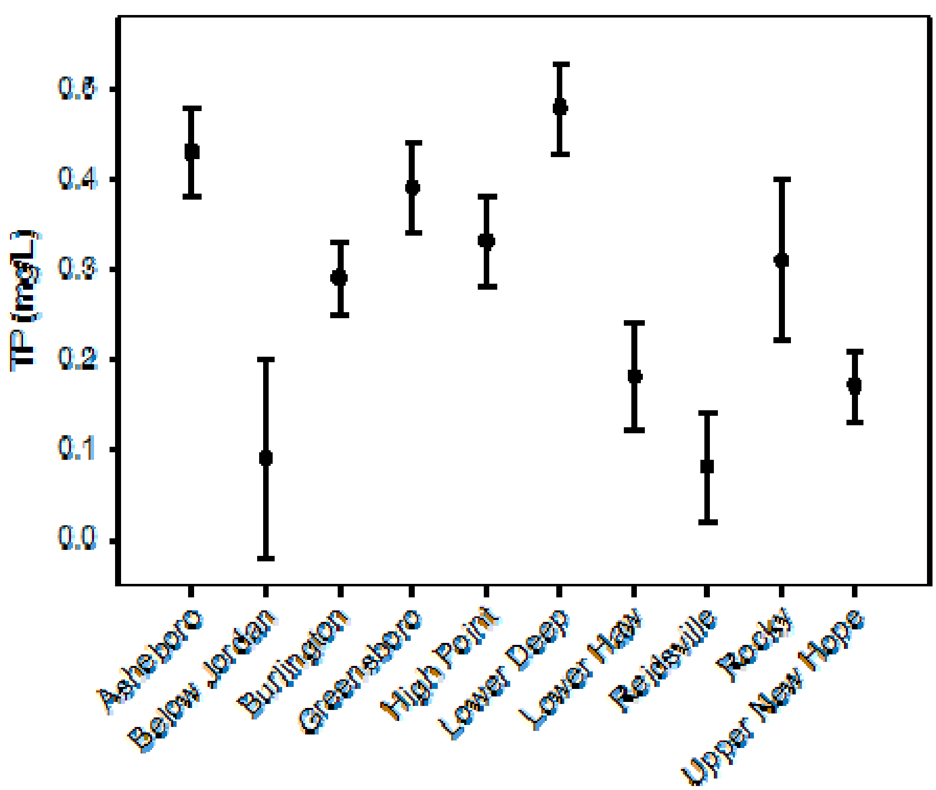
Regional Plots




Fecal Coliform (cfu/100 ml)
2500
2000
1500
1000
500
0
Asheboro
Below Jordan
Burlington
Greensboro
High Point
Lower Deep
Lower Haw
Reidsville
Rocky
Upper New Hope


TN (mg/L)
6
5
4
3
2
1
0
Asheboro
Below Jordan
Burlington
Greensboro
High Point
Lower Deep
Lower Haw
Reidsville
Rocky
Upper New Hope


NO2/NO3 (mg/L)
6
5
4
3
2
1
0
Asheboro
Below Jordan
Burlington
Greensboro
High Point
Lower Deep
Lower Haw
Reidsville
Rocky
Upper New Hope


TP (mg/L)
0.5
0.4
0.3
0.2
0.1
0.0
Asheboro
Below Jordan
Burlington
Greensboro
High Point
Lower Deep
Lower Haw
Reidsville
Rocky
Upper New Hope

Waste Water Treatment Plant Upstream/Downstream Comparisons of Mean Values

* - Parameter location is followed by the station number for upstream and downstream sites
** - X indicates p = 0.001 – 0.05, XX indicates p < 0.001
*** - if N < 10, statistics were not calculated for the station

Station Parameters	Conductivity (μmhos/cm)	TP (mg/L)	NO2/NO3 (mg/L)	TN (mg/L)	Fecal Coliform
Reidsville					
Upstream-2 *	95	0.05	0.20	0.62	284
Downstream-3	165	0.12	0.41	0.95	488
N	63	58	49	49	48
p-value	XX**	XX	XX	XX	NS
N. Buffalo Cr.					
Upstream-5	321	0.28	1.07	1.77	2050
Downstream-6	383	0.55	6.35	8.04	1656
N	74	60	53	53	55
p-value	X	XX	XX	XX	NS
S. Buffalo Cr.					
Upstream-7	238	0.08	0.46	1.08	1826
Downstream-8	605	0.77	6.12	7.91	2075
N	84	62	57	57	57
p-value	XX	XX	XX	XX	NS
Mebane					
Upstream-10	162				840
Downstream-11	424				861
N	84	2***	2	2	56
p-value	XX				NS
Burlington-East					
Upstream-9	284	0.34	2.79	3.81	1387
Downstream-12	279	0.29	2.1	3.06	1120
N	83	64	55	55	57
p-value	NS	X	NS	X	NS
Burlington-South					
Upstream-14	130	0.04	0.23	0.69	636
Downstream-15	348	0.28	1.11	2.15	851
N	82	41	55	55	57
p-value	XX	XX	XX	XX	X
Graham					
Upstream-13	282	0.27	2.2	3.13	1283
Downstream-12	277	0.29	2.08	3.03	1119
N	84	64	56	56	57
p-value	X	NS	X	NS	X
Durham City					
Upstream-19	157	0.11	0.31	0.96	997
Downstream-20	277	0.29	3.05	3.96	1245

N	84	64	56	56	57
p-value	XX	XX	XX	XX	NS
Durham County					
Upstream-21	192	0.07	0.14	0.86	1107
Downstream-22	407	0.26	8.24	9.4	939
N	84	64	55	55	57
p-value	XX	XX	XX	XX	NS
OWASA					
Upstream-24	168	0.07	0.32	0.74	808
Downstream-25	330	0.23	4.76	5.67	659
N	84	64	55	53	57
p-value	XX	XX	XX	XX	NS
High Point					
Upstream-48, 28	190	0.04	0.51	0.97	1859
Downstream-30	343	1.23	4.35	7.22	4242
N	86	59	50	50	53
p-value	XX	XX	XX	XX	NS
Randleman					
Upstream-33	269				1427
Downstream-45,34	400				1195
N	84	6	4	4	56
p-value	XX				NS
Asheboro					
Upstream-49,32	139	0.11	0.42	1.02	1455
Downstream-35	298	0.56	2.78	3.81	1270
N	60	64	55	55	54
p-value	XX	XX	XX	XX	NS
Ramseur					
Upstream-36	247				1006
Downstream-37	237				1168
N	83	1	1	1	56
p-value	X				NS
Sanford					
Upstream-41	167				531
Downstream-42	182				553
N	83	0	0	0	55
p-value	XX				NS
Siler City					
Upstream-43	105	0.12	0.55	1.3	406
Downstream-44	371	0.26	3.36	4.16	499
N	84	26	23	23	57
p-value	XX	X	XX	XX	NS