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IN THIS ISSUE

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PROJECT SPOTLIGHT

Long Creek Watershed Section 319 National Monitoring Program Project: Changes in Land Use/Management and Water Quality

Daniel E. Line and Laura A. Lombardo
NCSU Water Quality Group, Dept. of Biological & Agricultural Engineering, North Carolina State University, Raleigh, NC

Introduction

The Long Creek watershed is the site of a nine-year comprehensive watershed project initiated in 1993 to improve stream water quality while documenting the effectiveness of nonpoint source pollution controls. Long Creek drains an 8190-ha watershed located in the Piedmont physiographic region of North Carolina (see Figure 1). The watershed geology is typical of the western North Carolina Piedmont with a saprolite layer of varying thickness overlaying fractured igneous and metamorphic rock. Soils in the watershed are generally well-drained and have a loamy surface layer underlain by a clay subsoil. The topography of the watershed is generally hilly with land slopes of 5 to 15 percent.

The creek has documented water quality degradation caused by sediment, bacteria, and nutrients (NC DEM, 1989). Additionally, Long Creek drains into the South Fork Catawba River, which empties in Lake Wylie, a large (5040 ha) man-made lake used for recreation and electricity generation. Total phosphorus levels in the South Fork are about four times higher than the USEPA goal (0.05 mg/L) for streams entering a reservoir (Hughes et al., 2000). Therefore reducing total phosphorus levels in Long Creek, which subsequently would reduce phosphorus inputs to Lake Wylie, was a major goal of the project.

Potential pollution sources to Long Creek include agriculture (livestock and crop production), mining, forestry, urban runoff, septic system outflow, and streambank erosion. Approximately 20,060 m^3 of animal waste and 21,950 m^3 of municipal sludge is applied to agricultural land in the watershed annually.

The 1985-1996 Farm Bills and several incentive programs have combined to provide the impetus for extensive implementation of best management practices (BMPs) in the Long Creek watershed. The objective of this study was to assess the effect of the implementation of BMPs and changes in land use on the water quality of Long Creek. Accomplishing this objective requires that a change in water quality can be documented and that the change can be related to the implementation of BMPs (Spooner and Line, 1993). While many monitoring projects have attempted to relate BMP implementation to improvement in water quality, relatively few, especially for watersheds greater than several hundred hectares, have succeeded (Hallberg et al., 1983; Gale et al., 1993; Schilling and Thompson, 2000). The difficulties often include insufficient treatment of nonpoint sources to effect a water quality change, an inability to adequately track changes in land use and management, insufficient duration of monitoring to detect subtle or delayed changes, or an inadequate monitoring design (Gale et al., 1993). These difficulties were only somewhat overcome in this study.

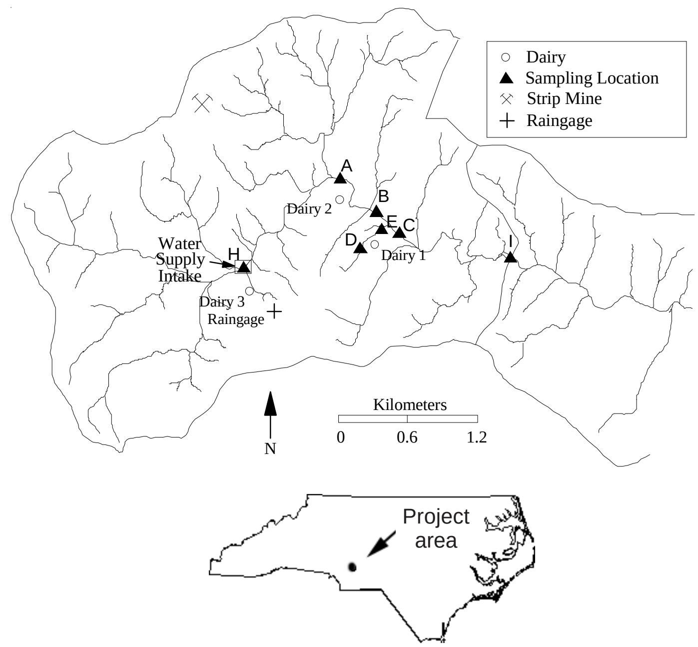

Figure 1. Long Creek watershed location and sampling sites.

Methods

Land use surveys of the 8,190 ha watershed were conducted in 1988 and 1998. The survey consisted of driving around the watershed during the growing season and identifying the land use on the open land. In some cases, fields were inspected more closely to determine what crops were being grown. The survey was focused on agricultural or recently converted agricultural land. Therefore, land that had been in woods or residential homes for several years was not surveyed directly, but the extent of this land use was computed by subtracting the area of agricultural land surveyed from the total watershed area as computed from maps. Some open land (<100 ha) was not visible from a public road; therefore, it was categorized as unknown (Table 1). Because of the remote location, the land use on most of the land classified as unknown probably did not change during the study. The area of urban/industrial land use was determined from county land zoning maps.

EDITOR'S NOTE

In this issue of *NWQEP NOTES*, we continue our series on National Nonpoint Source Monitoring Program (NMP) projects that have been completed and have documented improvements in water quality due to best management practice (BMP) implementation. A number of nonpoint source control projects have demonstrated BMP effectiveness at reducing pollutant levels in surface waters in small watersheds, particularly from livestock exclusion. However, it is rare to see a project implemented in a large watershed that has shown success in achieving water quality improvements and linking the improvements to BMPs, particularly with regard to reduced total phosphorus concentrations. This issue features one such project, the Long Creek Watershed NMP project in North Carolina. Land use and water quality have been monitored in the 8190-ha watershed over the past eight years, with results suggesting significant reductions in phosphorus and bacteria levels in Long Creek from the implementation of nonpoint source controls.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

Laura Lombardo
Editor, *NWQEP NOTES*
Water Quality Extension Associate
NCSU Water Quality Group
Campus Box 7637, NCSU
Raleigh, NC 27695-7637
Tel: 919-515-3723, Fax: 919-515-7448
Email: notes_editor@ncsu.edu

Land use	1988 ha	1988 %	1998 ha	1998 %	Change %
Row crops	806	9.8	324	4.0	-60
Hayland/pasture	1368	16.7	1229	15.0	-10
Residential (new)	10	0.1	230	2.8	+2200
Tree farm	0	0.0	142	1.7	NA
Idle land	404	4.9	642	7.8	+59
Strip mine	105	1.3	105	1.3	0.0
Unknown	204	2.5	233	2.8	+14
Urban and Industrial	463	5.7	463	5.7	0.0
Residential (old) & Forest	4830	59.0	4822	58.9	-0.2
Total Area	8190		8190		

Table 1. Summary of Land Use in Long Creek Watershed to Site I.

Land management practices or BMPs were also tracked by the Gaston Natural Resources Conservation District. The accumulated number of some of the practices implemented in the watershed is shown in Table 2. The most common in terms of number or area treated with BMPs are listed; however, many more BMPs were implemented in the watershed. Although the timing and locations of many of the BMPs were not readily available, records and observation indicate that most of the BMPs were implemented from 1989 to 1994 in the headwaters area of Long Creek, upstream of site H (Figure 1).

Conservation Practice	Number	Applied units	Units
Nutrient management	28	130	ha
Conservation tillage	51	229	ha
Crop rotation	82	884	ha
Diversion	6	1,082	m
Field border	49	16,933	m
Pasture/hayland management	24	79	ha
Streambank/shoreline protection	6	2,102	m
Terrace	19	23,187	ha
Waste utilization	22	71	ha

Table 2. Selected Conservation Practices Installed in the Long Creek Watershed.

A combination of weekly, biweekly, and monthly grab sampling along the main stem of Long Creek was used to document changes in water quality. The locations of the five sampling sites are shown in Figure 1. For most of the project duration, sites H, B, and C were sampled weekly from December through May of each year and then monthly for the rest of the year while sites A and I were sampled only bi-weekly from December through May and monthly the rest of the year. The increased sampling frequency during the December through May period was due to the expected increase in agricultural activity associated with crop planting in the spring and early summer. The sampling frequency was increased from monthly to bi-weekly during the June through November period during the last three years when additional resources became available.

A grab sample was collected at each site and analyzed for nitrite+nitrate nitrogen (NO_2+NO_3), total Kjeldahl nitrogen (TKN), TP, total suspended solids (TSS), FC and FS. Samples collected from Site H were not analyzed for nitrogen and phosphorus due to the emphasis on erosion and sediment control in the headwaters or water supply subwatershed area of the watershed.

Continuous precipitation (almost exclusively in the form of rainfall) measurements were made using three recording raingages located near the middle of the watershed (Figure 1). Due to delayed installation and equipment failure, rainfall data for the first year of the project (4/93-3/94) had several gaps (60 days total) which were filled in with data from another raingage located in the eastern part of the county. For other years, daily rainfall data for the watershed were computed as the average of the working gages. Daily mean discharge was computed from continuous stage measurements recorded at site I. The stage recording equipment and a stream stage-discharge rating table at site I were maintained by the U.S. Geological Survey.

Results and Discussion

Land Use/Management

Both land use and land management changed significantly since the beginning of the monitoring project in 1993. Unfortunately, the first land use survey did not coincide with the start of the monitoring. While the two surveys provide a good picture of land use changes for the period, they do not document the timing of the changes. Observation and local records indicate that much of the land use and management changes occurred prior to or near the beginning (1991-1994) of the monitoring project.

As shown in Table 1, the area of row crops, which included cotton, corn, soybeans, sorgham/milo, and small grain, decreased by 60% during the 10-year period between surveys. Most of this decrease was caused by fewer acres in soybeans and small grain. While no surveys were conducted during the 10-year period, observation indicates that much of the decrease in row crop acreage occurred during the first half of the period when the Conservation Reserve Program (CRP) and economic factors combined to cause a reduction in row crop acreage.

The acreage in hayland/pasture declined slightly during the period and also decreased as a percentage (16.7 to 15.0%) of the watershed area. Some of the pasture/hayland area was converted to residential lots, which increased from 10 to 230 ha. Also, there was a considerable increase in the tree farming acreage during the project. Much of this land, which was planted in pine trees, was taken out of row crop production as a result of the CRP. The amount of idle land, defined as fields grown up in more than 50% weeds and woody vegetation, also increased during the period to 7.8% of the total land area of the watershed. Some of this land may have been hayland/pasture but was not maintained within the last year or it may have been in the process of being developed, but no grading or infrastructure construction had occurred yet. The extent of strip mine and unknown land remained about the same during the period. The areas associated with the last two categories were estimated based on maps and total area and not by actual observation.

Concerning land management, much of the land remaining in agricultural production had conservation practices implemented on it sometime between 1987 and 1998. While the entire list of practices, which numbers more than 340, is too numerous to include here, the most extensively used practices, implemented between 1994 and 1998, are shown in Table 2. Other practices implemented included waste management systems, conservation cover planting, livestock exclusion fencing, and grassed waterways. Many of these practices were installed prior to or in the first year (1993) of the project, during a period of relatively intense conservation activity after the passage of the 1985 Farm Bill and state legislation.

From a nutrient and bacteria perspective, the most important BMPs implemented have probably been waste management systems, nutrient management, and livestock exclusion fencing. Of the three dairies currently operating in the watershed, only one had a waste storage pond at the beginning of the project and it was somewhat undersized. During the project, holding ponds were installed at all three dairies to properly contain the waste until land application. Nutrient management plans were written for each dairy to help minimize excess application of nutrients to cropland fields. More than 13 km of streambank fencing was installed to exclude beef and diary cows from direct access to streams. These BMPs have likely reduced direct nutrient and bacteria inputs to surface waters from the more than 29,000 m^3 of animal waste generated in the watershed.

Water Quality Monitoring and Land Use/Management Effects

This article focuses primarily on results of monitoring along the main stem of Long Creek (sites H, A, B, C and I). Sites D and E are located along the Kiser tributary to Long Creek, which drains the largest dairy farm in the Long Creek watershed. Results from monitoring at sites D and E prior to and after BMP implementation are presented in *NWQEP NOTES* issue #95 (July 1999, http://www5.bae.ncsu.edu/programs/extension/wqg/issues/pubindex.html) and also in Line et al. (2000). Livestock exclusion fencing and riparian vegetation establishment in the 57-ha dairy pasture resulted in significant reductions in sediment (83%), total phosphorus (76%), total Kjeldahl nitrogen (78%), and nitrate+nitrite (33%) loads in the Kiser tributary, and also a greater than 70% reduction in fecal coliform bacterial levels.

In order to assess water quality changes in Long Creek over time, monitoring data from sites H, A, B, C and I were grouped by monitoring year and summarized. Because the frequency of sampling was less during summer and fall (June-November), this period had fewer data, and because sites A and I were sampled less frequently, they only had 19 samples per year compared to 32 for sites H and C. Sampling results from sites B and C were nearly the same; therefore, for clarity, only results from site C were presented.

Monitoring data from each site was first assessed for statistically significant changes in each parameter over the eight year time period. If a change was detected, subsequent analyses included evaluating upstream (control)/downstream effects associated with BMP implementation, with site H acting as the upstream control.

A summary, in the form of boxplots, of the concentrations of TKN for sites A, C, and I grouped by project year is shown in Figure 2. Medians ranged from 0.22 to 0.34 mg/L with no definitive trend between sites or years, except that in most years, the median concentration at site A was less than at sites C and I.

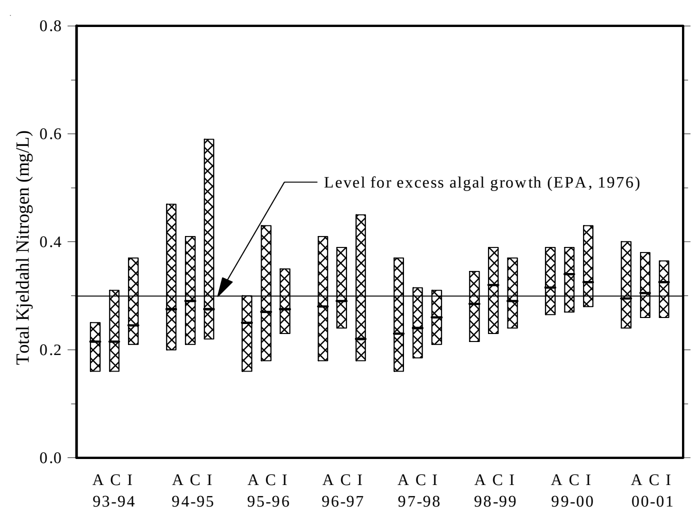

Figure 2. Total Kjeldahl nitrogen levels in Long Creek at sites A, C, and I.

To facilitate trend analysis, TKN concentrations were sorted by site and log-transformed. The significance of a linear regression relationship between TKN concentrations and time was evaluated using analysis of variance (ANOVA). This statistical test was used to determine if the regression adequately explains a significant amount ($P<0.001$) of the variation in TKN concentrations over time. The statistical tests indicated that there was no significant relationship between TKN concentrations and time for sites A, C, or I even though the box plot appears to show a slight increase during the last two years. Because there was no documented change over time, it appears that the changes in land use and land management had no significant effect on TKN concentrations. Given the improved handling and treatment of animal waste in the watershed, a decrease in TKN levels was expected; however, TKN can originate from many sources that were not affected by the BMPs implemented in the watershed.

Annual median concentrations of NO_2+NO_3 (Figure 3) ranged from 0.36 to 0.53 mg/L with the highest median of 0.53 mg/L occurring at site C during the 95-96 monitoring year. While median NO_2+NO_3 concentrations are variable, it appears that a decrease in concentrations at sites A, C, and I occurred during the last 4 years. An ANOVA of NO_2+NO_3 concentrations for each site over time suggested that there was a significant ($P<0.001$) negative relationship for sites A, C, and I, indicating a significant decrease in NO_2+NO_3 concentrations. The decrease in NO_2+NO_3 concentrations at sites A and I during the last four years was considerably greater than site C. Monitoring at sites D and E (Figure 1) on the Kiser tributary, which empties into Long Creek just upstream of site C, has documented a steady increase in NO_2+NO_3 concentrations, potentially contributing to the higher NO_2+NO_3 levels at site C. This tributary drains the pasture and farmstead area of a large dairy, which contains several dairy waste storage ponds. The median NO_2+NO_3 concentrations at site E along the tributary were 3.3 to 4.1 mg/L during the 99-00 and 00-01 years. The relatively low discharge of 99-00 and probably 00-01 made the influence of the tributary greater considering that the average discharge of the tributary is normally at least 100 times less than the discharge of Long Creek at site C, but during times of drought is likely a greater percentage of the discharge in the creek.

The median concentrations of NO_2+NO_3 at sites A, C and I are much higher than the level (0.08 mg/L) found in unpolluted streams of western NC (USGS, 1982) and within the range (0.3 to 0.5 mg/L) associated with NPS impacts (Omernik, 1977). Also, more recent monitoring has established a national background NO_3 concentration of 0.6 mg/L indicating that streams with concentrations greater than 0.6 mg/L are considered to have been adversely affected by human activities in a variety of land use settings (USGS, 1999). The median concentrations at sites A, C, and I were well below the national background level, indicating that Long Creek was not seriously affected by human activities such as agriculture in the watershed, with regard to NO_3. Nevertheless, the NO_2+NO_3 concentrations in Long Creek have declined in the last four years. The decrease may be attributed to nutrient management, which was applied to more than 125 ha of remaining cropland, improved animal waste management and utilization implemented on each remaining dairy farm, and many hectares of cropland that were converted to other less fertilizer intensive uses.

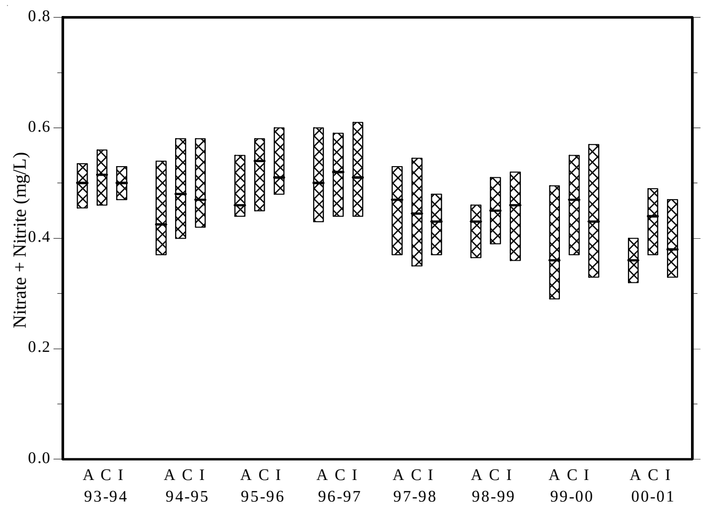

Figure 3. Nitrate and Nitrite levels in Long Creek at sites A, C, and I.

The annual medians for total nitrogen (TN) in Long Creek, or the sum of TKN and NO_2+NO_3, ranged from 0.63 to 0.89 mg/L. These medians are less than the national background level (1.0 mg/L) for TN in streams across the U.S. (USGS, 1999). Total nitrogen concentrations that were generally less than background levels indicated that nitrogen pollution was not a serious problem in the watershed.

A boxplot of TP concentrations is shown in Figure 4. Both the variability and annual medians of TP concentrations appear to have decreased considerably during the first three years of monitoring (93-94 to 95-96). The medians for the three sites decreased from between 0.18 to 0.22 mg/L in the 93-94 year to the method detection limit (MDC) of 0.05 mg/L in the 96-97 year. The MDC was lowered to 0.01 mg/L during the 97-98 year. Because half the MDC (0.025 mg/L) was used for concentrations less than the MDC, the medians for several years are shown as 0.025 mg/L. Median concentrations remained near 0.025 mg/L for all three sites for the 96-97 and 97-98 years until they began to trend up slightly in the 98-99 year and continued at about the same level through the 00-01 year. An ANOVA of TP concentrations versus time suggested a significant ($P<0.001$) relationship, thereby indicating a significant decrease in TP concentrations at all three sites with time.

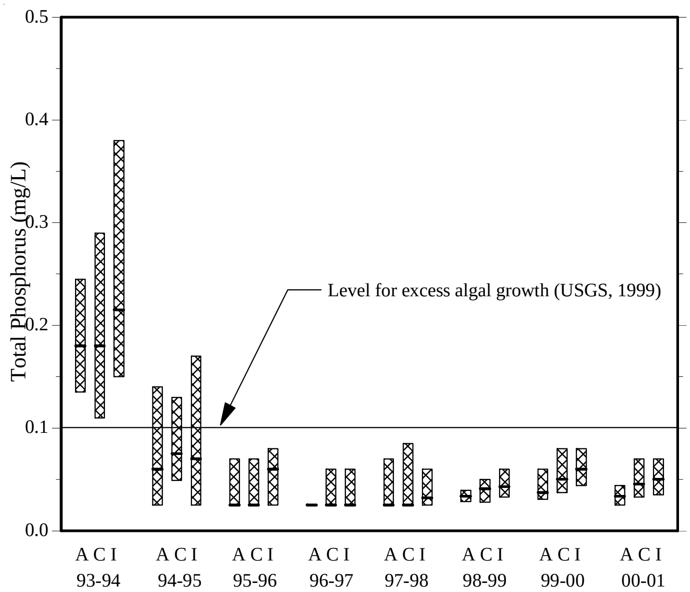

Figure 4. Total phosphorus levels at Long Creek at sites A, C, and I.

The median TP concentrations in Long Creek are much higher than unpolluted streams (0.01 mg/L) of western NC (USGS, 1982), but are less than the range (0.03-0.05 mg/L) reported for streams impacted by nonpoint source pollution (Omernik, 1977). The median TP concentrations were considerably less than the national background level (0.1 mg/L) or the U.S. EPA desired level of 0.1 mg/L for the prevention of nuisance plant growth in streams not discharging directly into lakes or impoundments (USGS, 1999). Using the recent background level of 0.1 mg/L, the TP levels in Long Creek have decreased below background or NPS impact levels. This reduction is particularly significant for Long Creek as it is a tributary to Lake Wylie, which has been classified as eutrophic due mostly to high phosphorus loading (Hughes et al., 2000).

The initial elevated concentrations of TP at sites A, C and I indicated that, because there were no permitted or apparent point sources in the watershed, NPS inputs of TP to Long Creek were excessive, and further, implementing BMPs should reduce TP significantly. Since TP concentrations decreased similarly at all three sites, most of the reduction probably occurred upstream of site A. In addition, because land use upstream of site A was primarily agricultural cropland and this cropland received the majority of BMPs during the late 1980s and early 1990s, a reasonable assumption would be that the BMPs reduced TP input to Long Creek.

Regarding phosphorus inputs, cropland in this and other watersheds in North Carolina have long been fertilized based loosely on crop nitrogen needs resulting in excess phosphorus application. This is particularly apparent on cropland receiving animal waste and domestic sewage sludge applications, which occurred on much of the cropland within the watershed during the early 1990's. Several soil samples collected from a typical waste application field in the watershed have contained on average 340 mg P/kg soil. Eroded soils with phosphorus levels this high would certainly contribute to elevated levels of TP in Long Creek. Conversely, the implementation of conservation practices on cropland and enrolling land into the CRP would have the potential to dramatically reduce TP levels in Long Creek. As stated previously, 142 ha of cropland were enrolled in the CRP and planted in trees and hundreds of conservation practices were implemented on the remaining cropland. Additionally, a biosolids application facility was created to manage sewage sludge in the watershed more effectively.

Boxplots of the TSS concentrations at site H appear with sites A, C, and I on Figure 5. Median concentrations of TSS at sites A, C, and I were remarkably consistent (6-7 mg/L) throughout the first five years of the project while medians at site H were consistently 1 to 3 mg/L less than A, C, or I. The annual median TSS concentrations at A, C, and I decreased during the last three years. Median concentrations at sites A and C were even less than at the upstream site H during the 99-00 and 00-01 years. An ANOVA suggested that there was a significant ($P<0.001$) negative relationship between TSS concentrations and time at sites A, C, and I, but not at site H. This indicates a reduction in TSS inputs downstream of site H; however, the TSS concentrations at site I remained slightly greater than those at site H until the last year.

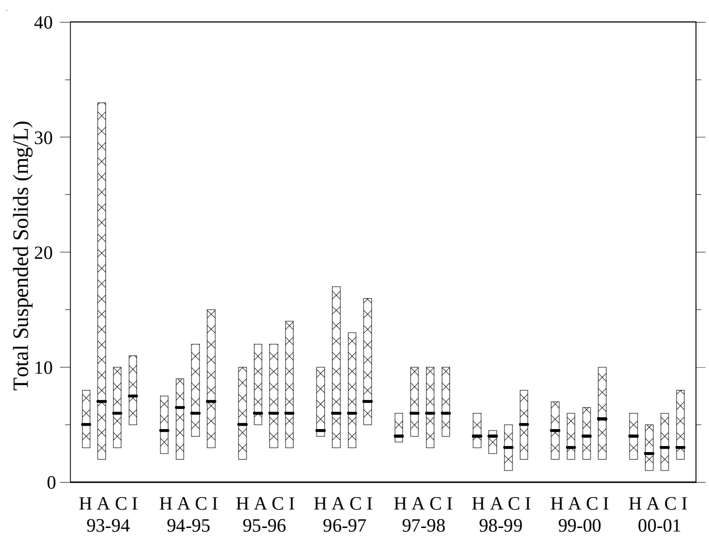

Figure 5. Total suspended solids levels in Long Creek at sites H, A, C, and I.

Along with the decrease in TP and the implementation of conservation practices, a concurrent decrease in TSS was expected. Given that many of the conservation practices were implemented upstream of site H, a decrease in TSS at site H was particularly expected. Possible explanations for the lack of decrease at site H is that most of the decrease in TSS levels occurred prior to the start of monitoring or that grab samples alone are not accurately representing the TSS levels at the site.

Evidence of reduced TSS loading to site H includes reduced Universal Soil Loss Equation (USLE) estimates for cropland erosion in the watershed area upstream of the Bessemer City water supply intake (site H). USLE estimates have decreased more than 50% from pre-project levels compared to 1995 levels. Also, the frequency of dredging of the backwater area upstream of a small dam across Long Creek about 200 m downstream of site H decreased. This backwater area was historically dredged to maintain a pool near the municipal water supply intake and to keep the intake from becoming plugged with sediment. Prior to 1995, this area was dredged two to three times per year to remove approximately 122 to 190 m^3 of deposited sediment annually. After 1995, the frequency of dredging has been reduced to once per year or less. This indicates a reduced sediment load in the upper reaches of Long Creek after 1995.

The decrease in TSS concentrations at site A, C, and I occurred primarily after the 97-98 year. There were relatively few conservation practices implemented in 97-98 so the reason for the decrease was probably not entirely NPS related. During the spring of 1998, the surface mine located upstream of site A (Figure 1) ceased operation and therefore, stopped pumping tailings water into the tributary to Long Creek. In addition, 15 km of eroding stream banks and 5.3 ha of cropland bordering Long Creek were stabilized in 1995 and 1996. The combination of decreased TSS inputs from the mine tailings and stabilization of critical areas likely resulted in the decrease in TSS concentrations at sites A, C, and I.

The FC and FS levels were highly variable during the first four years of the project (Figure 6, FS not shown) and somewhat less variable during the last four years (97-01). During the first four years of monitoring, yearly median FC levels at site H ranged from 540 to 630 cfu/100ml while medians for the other sites were 1.5 to 3 times greater. The high levels and variable nature of the FC and FS levels particularly at sites C and I was an indication of untreated animal waste entering Long Creek between the sites. During the fifth through eighth years of monitoring, both the median and number of extreme levels of FC and FS at sites A, C, and I compared to site H declined such that in years seven and eight, median levels at sites C and I were less than at H. An ANOVA of FC and FS levels versus time for each site suggested that there was a significant ($P<0.001$) decline over time for both FC and FS at sites C and I. No significant relationship was suggested at sites H and A, although FC levels at site A appeared to decrease after the 96-97 year.

Because of the significant change in FC and FS over time at sites C and I, and because of the relatively low and constant FC levels at site H, further analysis was performed to assess upstream/downstream effects of waste management BMPs on FC at sites C and I, using site H as the upstream control. An ANOVA and least significant difference tests were conducted on log-transformed data from each year. The more conservative Bonferroni T test was used for pairwise comparisons because all sites did not have the same number of samples. For FC, comparisons between sites H and C were significant at the 0.05 level for the first five years and comparisons between sites H and I were significant for years two through four, while no significant differences were found in the last three years. These results suggest that FC inputs from the dairies have been reduced, and therefore, that the waste management BMPs and the livestock exclusion fencing was effective. Dairy waste holding ponds and waste irrigation systems were installed on the three operating dairy farms between sites H and C in 1994, 1995, and 1997. In addition, livestock exclusion fencing was installed in 1996 on the Kiser tributary which enters Long Creek just upstream of site C (Figure 1) and drains the largest dairy. Monitoring on this tributary prior to the installation of fencing documented very high levels of FC and FS. Improved containment and handling of wastes should result in both lower median levels and fewer very high storm event related levels of FC as is indicated by the data.

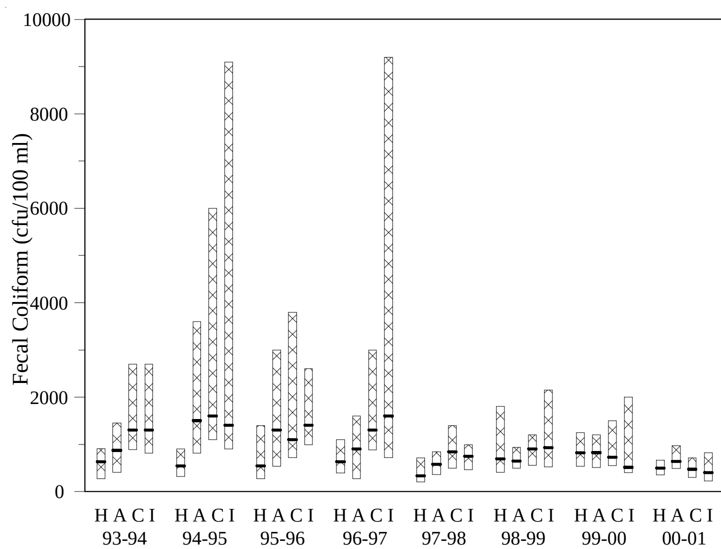

Figure 6. Fecal coliform levels in Long Creek at sites H, A, C, and I.

Climate Effects

In relating water quality and NPS control or BMP implementation data, changes in climatic conditions must be considered. Often changes in water quality can result from changes in rainfall alone and not from land use/management changes. Summary statistics of the rainfall data and discharge at site I were computed for each monitoring year (Table 3) to compare with trends in pollutant concentrations over time. The average daily rainfall was computed by dividing the total annual rainfall by the number of days of measurable (>0.25 mm) rainfall. Generally, the average daily rainfall was considered a measure of the size of storms occurring during the year and therefore, along with the total rainfall, may be an indicator of runoff and NPS pollutant concentrations, as they are runoff dependant. As expected, the year (4/95-3/96) with the highest average daily rainfall (12 mm) and greatest rainfall accumulation (1360 mm) also had the highest average daily mean discharge (1.30 m^3/s) and the greatest total annual discharge (499 mm). The ratio of runoff discharge to rainfall ranged from 0.20 to 0.42 with the 4/97-3/98 year having the highest ratio. This year had the greatest amount of rainfall falling in winter (426 mm), which contributed to the high runoff/rainfall ratio, given that evaporation and water use by plants is lowest during this period.

Year	Days of Rain no.	Average DRF mm	Annual Rainfall mm	Average DMD m^3/s	Annual Discharge mm	Runoff/ Rain
4/93-3/94	92	8.8	814	0.80	307	0.38
4/94-3/95	116	8.9	1033	1.03	394	0.38
4/95-3/96	113	12.0	1360	1.30	499	0.37
4/96-3/97	147	6.6	972	0.88	336	0.35
4/97-3/98	122	9.1	1114	1.21	464	0.42
4/98-3/99	120	8.8	926	0.69	265	0.25
4/99-3/00	110	8.5	931	0.49	187	0.20
4/00-3/01	128	6.7	856	NA	NA	NA
Average	122	8.7	1017	0.91	350	0.33

Note: DRF = daily rainfall; DMD = daily mean discharge.

Table 3. Summary Rainfall and Discharge Statistics.

The average of the daily mean discharges for each year ranged from 0.49 to 1.30 m^3/s with the 4/95-3/96 year being the highest. The last year (4/00-3/01) was not included because only part of the data for this year was available. Analysis of variance of the discharge data indicated that there were significant differences between years ($P<0.01$). The significant differences indicate that changes in rainfall and/or discharge did exist during the monitoring period. Whether they resulted in the changes in TP and FC levels will be discussed further.

In this study, if decreases in TP and FC were caused solely by changes in rainfall and discharge, the TP and FC levels should be correlated to rainfall or discharge. The decrease in TP levels from the 93-94 to 95-96 years (Figure 4) may be, at first glance, attributed to increases in annual discharge (Table 3), which may have the effect of diluting pollutant levels. However, the continued low levels of TP during subsequent years of decreasing discharge suggest that the decline in TP levels was not the result of increased discharge. The slight increase in TP concentrations during the last three years of monitoring may be attributed to lower discharge, but these increases are much less than the decreases during the first three years. The relatively low levels of TP during several years of varying discharge indicate that the decrease in TP was likely the result of changes in land use/management.

While annual rainfall and discharge are often good indicators, the occurrence of large storms also effects the movement of NPS pollutants. Dividing the number of days of rain by the total annual rainfall provides a measure of the size of storms throughout the year as indicated by the average daily rainfall in Table 3. During the 6 years of relatively low TP concentrations, there was a considerable range of average daily rainfalls for each year indicating that the decreases in TP concentrations were not rainfall related.

Bacteria levels at sites A, C and I decreased during the last four years of monitoring while rainfall and discharge for the sites remained similar to the first four years. This comparison with discharge indicates that the decrease in bacteria levels was likely not solely the result of a change in discharge associated with natural hydrologic variability.

Like bacteria, TSS levels at sites A, C, and I appeared to decrease during the last three years of the monitoring period, although pairwise comparisons similar to those of FC and FS suggested no significant differences in any of the eight years. As stated previously, the closing of the surface mine likely resulted in slight lower TSS concentrations and not changes in climate.

Summary

The Long Creek watershed has undergone considerable land use and management changes over the past eight years. Land use surveys have documented a 60% decrease in cropland area and a more than 200% increase in new home construction. In addition, more than 200 conservation practices have been applied to the cropland, and nutrient and animal waste management BMPs have been implemented on all dairy farms that remain in production. Weekly, bi-weekly, and monthly grab samples have been collected from five sites along Long Creek since April, 1993. The grab samples have documented a 70% reduction in median annual TP concentrations, small apparent reductions in NO_2+NO_3 and TSS, and no reductions in TKN levels. Bacteria levels declined in the last four years. Rainfall and discharge increased steadily until peaking in the third year of the monitoring period and decreased at varying rates thereafter. The varied rainfall and discharge totals for years of decreasing pollutant concentrations indicated that the decrease in TP, FC, and FS levels were not solely the result of natural hydrologic variability. The decrease in TP levels was attributed to a combination of a decrease in cropland acreage and an increase in conservation measures implemented on remaining cropland. This combination has also resulted in less sediment in Long Creek as evidenced by a decrease in the frequency of dredging at the Bessemer City water supply intake.

The decrease in FC bacteria levels at downstream sites A, C, and I can be attributed to improved handling and disposal of animal waste due to the implementation of waste management practices in the watershed. Statistical analyses confirmed a significant reduction in downstream as compared to upstream FC levels following the implementation of dairy waste management BMPs and livestock exclusion fencing. Thus, the array of observation, pollutant concentration, and hydrologic data provide considerable evidence to suggest that the implementation of BMPs in the watershed have significantly reduced phosphorus and bacteria levels in Long Creek.

For More Information

Daniel E. Line, PE
Water Quality Extension Specialist
NCSU Water Quality Group
Department of Biological & Agricultural Engineering
Campus Box 7637
Raleigh, NC 27695-7637
(919) 515-8243
dan_line@ncsu.edu

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References

Gale, J.A., D.E. Line, D.L. Osmond, S.W. Coffey, J. Spooner, J.A. Arnold, T.J. Hoban, R.C. Wimberly. 1993. *Evaluation of the Rural Clean Water Program*. U.S. Environmental Protection Agency. Washington, D.C. EPA-841-R-93-005.

Hallberg, G.R., B.E. Hoyer, E.A. Bettis III, and R.D. Libra. 1983. *Hydrogeology, Water Quality and Land Management in the Big Spring Basin, Clayton County, Iowa*. Iowa Geological Survey Open File Report 83-3.

Hughes, W.B., T.A. Abrahamsen, T.L. Maluk, E.J. Reuber, and L.J. Wilhelm. 2000. *Water Quality in the Santee River Basin and Coastal Drainages: North and South Carolina, 1995-98*. USGS Circular 1206. U.S. Geological Survey, Reston, VA.

Line, D.E., W.A. Harman, G.D. Jennings, E.J. Thompson, and D.L. Osmond. 2000. Nonpoint-Source Pollutant Load Reductions Associate with Livestock Exclusion. *J. Environ. Qual.* 29:1882-1890.

NC DEM. 1989. *North Carolina Nonpoint Source Management Program*. Report 89-02. North Carolina Division of Environmental Management, Raleigh, NC.

Omernik, J.M. 1977. *Nonpoint Source—Stream Nutrient Level Relationships: A Nationwide Study.* Corvallis Environmental Research Laboratory, Corvallis, OR. EPA-600-3-77-105.

Osmond, D.L., D.E. Line, J. Spooner. 1997. *Section 319 National Monitoring Program: An Overview*. NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC.

Schilling, K.E. and C.A. Thompson. 2000. Walnut Creek Watershed Monitoring Project, Iowa: Monitoring Water Quality in Response to Prairie Restoration. *J. American Water Resources Association* 36(5):1101-1114.

Spooner, J. and D.E. Line. 1993. Effective Monitoring Strategies for Demonstrating Water Quality Changes from Nonpoint Source Controls on a Watershed Scale. *Water Science Technology* 28(3-5):143-148.

U.S. EPA. 1976. *Quality Criteria for Water*. Office of Water. U.S. Environmental Protection Agency. Washington, D.C.

USGS. 1982. *Water Quality of North Carolina Streams*. Water Supply Paper 2185 A-D, U.S. Geological Survey. Alexandria, VA.

USGS. 1999. *The Quality of Our Nations Waters—Nutrients and Pesticides.* U.S. Geological Survey Circular 1225. U.S Department of the Interior, Denver CO.

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Information

2001 Summary of Section 319 National Monitoring Program Projects

The annual report for 2001 of the Section 319 National Nonpoint Source Monitoring Program Projects is available online at **http://h2osparc.wq.ncsu.edu/319index.html**. This report provides project profiles for 23 watershed projects, selected under the Section 319 National Monitoring Program, that are being monitored over a 6- to 10-year period to evaluate how improved land management reduces water pollution. These projects will help communities and citizens protect their local water resources by providing information on the effectiveness of tools and techniques for solving nonpoint source problems.

EPA Issues Final 2002 Integrated Water Quality Monitoring and Assessment Report Guidance

On Nov. 19, 2001, EPA issued final 2002 Integrated Water Quality Monitoring and Assessment Report Guidance which recommends an "Integrated Report' which will satisfy Clean Water Act requirements for both section 305(b) water quality reports and section 303(d) lists.

The objectives of this guidance are to strengthen State monitoring programs, encourage timely monitoring to support decision making, monitor increased numbers of waters, and provide a full accounting of all waters and uses. The guidance encourages a rotating basin approach, strengthened State assessment methodologies, and will lead to improved public confidence in assessments and lists.

EPA issued a rule on October 18, 2001 revising the date for submission of 2002 lists of impaired waters by 6 months to October 1, 2002. The date for submission of 2002 lists was extended 6 months to allow States, Territories and authorized Tribes time to incorporate some or all of the recommendations suggested by EPA in this 2002 Integrated Water Quality Monitoring and Assessment Report Guidance.

For a copy of this guidance, visit the following web site: **http://www.epa.gov/owow/tmdl/policy.html.**

Builders For the Bay Agreement

Before an audience that included Maryland Governor Parris Glendening, District of Columbia Mayor Anthony Williams and U.S. Environmental Protection Agency Administrator Christine Todd Whitman, representatives from environmental groups and home builder associations signed an agreement December 3, 2001 to create Builders for the Bay – a first-of-its-kind program aimed at reducing environmental impacts from residential and commercial construction within the Chesapeake Bay watershed.

Under the leadership of the Alliance for the Chesapeake Bay, the Center for Watershed Protection and the National Association of Home Builders, Builders for the Bay will encourage the voluntary adoption of 22 site design principles that reduce the environmental effects of residential and commercial development. Over the next two years, the organizations plan to expand Builders for the Bay into at least twelve local jurisdictions in the Bay watershed. The full press release can be read at the following web site: **http://www.cwp.org/builders_press_release_final.pdf.**

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Web Resources

New Smart Growth Online Resource from EPA

The U.S. Environmental Protection Agency has announced a new online resource designed to facilitate and support smart growth development. To learn more about smart growth policies, technical tools and more, visit **http://www.epa.gov/smartgrowth**.

Showcase of NPS Educational Products

The state of Washington's Department of Ecology has developed a site that will help people find educational products related to nonpoint source water pollution. The products come from many different sources in a variety of formats: publications, videos, classroom materials, etc. The site provides contact information as well as other useful background information. The URL is: **http://www.ecy.wa.gov/forms/showcase.**

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Meetings

Call For Papers

10th National Nonpoint Source Monitoring Workshop:

Monitoring and Modeling from the Peaks to the Prairies

September 9-12, 2002
Beaver Run Resort, Breckenridge, CO

About the Conference: This workshop will bring together land managers and water quality specialists to share information on the effectiveness of best management practices in improving water quality, effective monitoring techniques, and statistical analysis of watershed data. The workshop will focus on the successes of Section 319 National Monitoring Program projects and other innovative projects from throughout the U.S. The agenda will include three days of workshop sessions/presentations and a one-day field trip to visit stream restoration and legacy mine sites. **Call for abstracts to be announced shortly**. Contact Tammy Taylor at taylor@ctic.purdue.edu or call 765-494-9555.

Fifth Annual North Carolina Stream Restoration Conference: Restoration in the Coastal Plain - Stream and Wetland Processes: October 7-11, 2002, Wilmington, NC. Visit web site at: http://www.ncsu.edu/sri.

The 2002 Conference will feature topics including various aspects of coastal plain processes. North Carolina Stream Restoration Institute encourages those with research or experience focusing on coastal processes and/or stream and wetland restoration to submit an abstract for consideration. Those authors who are accepted will be asked to give a presentation at the October conference. The Conference will also feature several case study presentations of coastal stream and wetland restoration projects completed within the last five years. Projects implementing a natural channel design approach are preferred. Researchers, educators, consultants, agency personnel, contractors, and any others who are interested are encouraged to submit an abstract (up to 1-page) of your proposed case study presentation. **Send your proposal by March 31, 2002** to: Dani Wise-Frederick, NC SRI, Box 7637, NC State University, Raleigh, NC 27695-7637. Tel: 919-515-7475; Fax: 919-515-7448; Email: dani_wise@ncsu.edu.

Topics of emphasis include: estuarine systems, biology (benthos) of coastal streams and wetlands, vegetation for the coast, woody debris in coastal streams, buffer regulations, drainage issues, beavers, habitat and ecosystem scale restoration, mitigation, site selection, watershed assessment, effects of coastal urban areas, landowner education, and dam removal.

Educational exhibits (government programs, university research, non-profit organizations) are free of charge and can focus on any aspect of stream or wetland restoration, such as regulatory, landscaping, hydrology, biology, educational, etc. Commercial exhibit space is available for $500 per exhibitor.

Meeting Announcements - 2002

March

Agriculture and the Environment: The Challenge of Change: March 4-6, 2002, Ames, IA. Contact: Richard Larson, AEP Coordinator, Iowa State University, Ames, IA 50011. Tel: 515-294-6429; Fax: 515-294-1311. Website: http://extension.agron.iastate.edu/aged/water_quality/MainWQ/wqm.htm.

Fourth Biennial Conference on University Education in Natural Resources: March 14-17, 2002. Raleigh, NC. Website: www.ces.ncsu.edu/nreos/forest/feop/uenr2002.html.

Conservation Strategies for Growing Communities Conference: March 19, 2002, Ankeny, Iowa. Contact Alice Vinsand at 515-225-1051 or email avinsand@home.com.

Hardwood Reforestation for Wetland Mitigation: March 26-27, 2002, Raleigh, NC. Contact Becky Bowers at 919-515-9563; Fax: 919-515-6883; Email: becky_bowers@ncsu.edu. Website: www.ncsu.edu/feop.

April

Forestry Best Management Practices Research Symposium: April 15-17, 2002, Atlanta, Georgia. For more information, Tel: (352) 377-4708 Ext. 0; Email: registration@src-ncasi.org; Web site: www.trout.forprod.vt.edu/meetings/bmp.htm

15th Annual National Conference: Enhancing the States' Lake Management Programs - Managing Invasive Species in Lakes and Reservoirs: April 23-26, 2002, Chicago, Illinois. Contact Conference Coordinator: Bob Kirschner, Chicago Botanic Garden, 1000 Lake Cook Rd., Glencoe, Illinois, 60022. Tel: 847-835-6837; Email: bkirschn@chicagobotanic.org.

May

29th Annual Conference on Ecosystems Restoration & Creation: May 9 -10, 2002, Tampa, Florida. Hillsborough Community College, Institute of Florida Studies, Plant City Campus, 1206 N. Park Road, Plant City, Florida 33566. Email: fwebb@hcc.cc.fl.us or pcannizzaro@hcc.cc.fl.us.

AWRA's Annual Spring Conference: Coastal Water Resources: May 13-15, 2002, New Orleans, LA. Contact Michael J. Kowalski, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626; Tel: 540-687-8390; Email: mike@awra.org; Website: www.awra.org.

NWQMC 3rd National Monitoring Conference 2002: May 21-23, 2002, Madison, WI. Visit website: www.nwqmc.org. Email: dan@nwqmc.org; Tel: 405-516-4972.

7th Biennial Conference on Stormwater Research & Watershed Management: May 22-23, 2002, Tampa, Florida. Contact Amy Dolsom, McRae & Company, Inc., P.O. Box 12187, Tallahassee, FL 32317-2187. Tel: 850-906-0099; Fax: 850-906-0077; Email: AmyF@mcraeco.com.

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NCSU Water Quality Group
Department of Biological and Agricultural Engineering
North Carolina Cooperative Extension Service
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637

NC STATE UNIVERSITY

NCSU Water Quality Group
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637
Telephone: (919) 515-3723
Fax: (919) 515-7448
Web Site: http://www.ncsu.edu/waterquality/

Personnel

Jean Spooner	William F. Hunt
Robert O. Evans	Bonnie Kurth
Jon Calabria	Daniel E. Line
Garry L. Grabow	Laura A. Lombardo
Karen R. Hall	Catherine Smith
Frank J. Humenik	Dani E. Wise-Frederick