EXTENDED WATER QUALITY MONITORING OF THE LINCOLN LAKE WATERSHED

Arkansas Soil & Water Conservation Commission
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Cooperating Agencies
ARKANSAS WATER RESOURCES CENTER
ARKANSAS SOIL & WATER CONSERVATION COMMISSION

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*Current Address: Agricultural and Environmental Services Laboratories, University of Georgia, Athens, Georgia
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PROJECT DESCRIPTION

For seven years, the Lincoln Lake (Moores Creek and Beatty Branch) watershed was monitored for improvements in water quality resulting from agricultural best management practices (BMP) implemented to reduce nutrient transport. During the first three years of monitoring (1991 to 1994), nitrogen transport declined significantly (Edwards et al., 1994, 1996, and 1997) under both base and storm flow conditions. This decline in nitrogen transport was again observed in the three-year period following 1994 (Vendrell et al. 1998). This monitoring effort has demonstrated that water quality has improved in the Lincoln Lake watershed. However, since the nitrogen transport continued to decline and there was some indication that phosphorus may begin to decline, monitoring was extended for another year (1998).

In the Lincoln Lake watershed there is one monitoring site on Beatty Branch Creek and two on Moores Creek. Significant land use changes not related to the original BMP implementation have occurred above the lower Moores Creek site. The High Ocean Ranch that comprises approximately 800 acres of the Moores Creek bottom was sold. The new owners sold the timber rights and logging began in late 1995. Following the timber harvest in the spring of 1996 this area was subdivided into residential tracts. The first manufactured homes appeared in the spring of 1997. The Beatty Branch basin was unaffected. The result was a decline in forested areas in the Moores Creek watershed in favor of residential development. In response to this change in land use, a new monitoring site was installed above the harvested area.

Nutrient transport by Moores Creek and Beatty Branch, the two streams that feed Lincoln Lake, was monitored from September 1991 until April 1994 (Edwards et al.,
1994, 1996, and 1997). During storm flow conditions, significant decreases in mean concentrations and mass transport of nitrate-nitrogen (NO$_3$-N), ammonium-nitrogen (NH$_4$-N), total Kjeldahl nitrogen (TKN), and chemical oxygen demand (COD) were observed in this watershed and attributed to BMP implementation. There were no decreases in total phosphorus (TP) or total suspended solids (TSS). Likewise, during base flow conditions, significant decreases of NH$_3$-N, TKN, and COD were observed. After the end of this initial monitoring project, the stream monitoring continued on a limited basis in the Lincoln Lake basin for another three years, 1994 through 1997. A final report was made on this earlier continued monitoring (Vendrell et al., 1998) in which the results of the trend analysis over the period from 1994 through 1997 were compared to the earlier trends (Edwards et al., 1996) from 1991 to 1994. In this 1998 report, the conclusions were: 1) No increasing trends were observed for either mean concentration or mass transport of nitrogen. 2) Mean concentrations of NO$_3$-N, NH$_4$-N, and TKN in Beatty Branch Creek, NH$_3$-N and TKN in Moores Creek, and loads of NH$_4$-N in Beatty Branch Creek continued to decline. 3) A decreasing trend in TP mean concentration was observed for the first time at the Beatty Branch site during storm flow.

**OBJECTIVES**

The objectives of this extended monitoring are to 1) determine if nitrogen transport continues to decline, 2) determine if phosphorus and sediment transport trends are maintained, and 3) determine the effects of the timber harvest in the Moores Creek basin.

**MATERIALS AND METHODS**

The watershed description, water quality monitoring methods, and methods for statistical trend analysis were identical to those described in a previous report (Vendrell et
al, 1998) and the reader is referred to this report for these details. Water quality monitoring and trend analysis was carried out by these methods on data collected from January 1995 through December 1998 at the Lower Moores Creek (LMC) and Beatty Branch (BB) sites and from July 1996 through February 1999 at the Upper Moores Creek (UMC) site.

RESULTS AND DISCUSSION

Stream Discharge

Monthly discharge for LMC, UMC, and BB are given in Figures 1, 8, and 15, respectively. In these graphs, storm and base discharge are stacked into the same bar graphic and the combined height represents total discharge within an individual month. Discharge had the same seasonal character as described in a previous report of the three-year monitoring period (Vendrell et al., 1998).

No significant trends were observed at any of the monitoring sites for this four-year monitoring period. These results departed somewhat from those reported previously for the three-year monitoring period (1994 through 1997). Trend analysis over the three-year period showed significantly increasing trend in discharge at the BB site due to base flow. No significant trends were observed at the other two sites as a result of this shorter monitoring period. The only reasonable explanation for this discrepancy is that the shorter monitoring period ended with a wet year and that adding another year of monitoring was able to buffer this effect. In Figure 15 it can be observed that in fact that the late 1996 and early 1997 were periods of high discharge and the following months returned to the more usual discharge pattern. With no significant trends in discharge it
can be assumed that the significant trends in either load or mean concentration are more likely due to the BMPs and less to climatic variations.

**Loads**

Monthly base, storm, and total flow loads of NO$_3$-N, TP, NH$_4$-N, TKN, TOC, and TSS for the LMC site is given in Figures 2 through 7. In these bar-graph graphics base and storm loads are stacked together within an individual month and the total height of the bar represents the total monthly load. Figures 9 through 14 contain the mean loads for the UMC site. Loads for the BB site can be found in Figures 16 through 21. The LMC and BB sites have monthly loads from January 1995 through December 1998; whereas, the UMC site has loads from July 1996 through February 1999.

Table 1 contains a list of all the significant trends that were observed at all three monitoring sites and under all flow types. There were no significant load trends at the LMC or UMC sites. The LMC results agree with the most recent three-year trend analysis but contrast with the first three years of monitoring that showed downward trends of NO$_3$-N, NH$_4$-N, TKN, and TOC. The most available explanation for both this agreement and discrepancy is that these are the effects of the timber harvest and residential development.

Previously reported, the UMC site exhibited increased TSS loads. There was good reason to be skeptical of this trend because of the insufficient period of monitoring. Extending the monitoring period caused this anomalous trend to disappear.

Beatty Branch was the only site that showed significant load trends (Table 1). Ammonium-N and TKN decreased and there were no significant increasing trends ("=0.10). The NH$_4$-N decline agrees with the two previous reports. The TKN decrease
(α=0.10). The NH₄-N decline agrees with the two previous reports. The TKN decrease agrees with the first three-years of monitoring; however no NO₃-N decrease occurred as did in the first three-years of monitoring and no TSS decrease as did in the second three-year monitoring period. It is important to note that neither NO₃-N load nor load from any of the other parameters increased. This lack of increasing trends can be interpreted as the BMPs are expressing effects by preventing the increase in concentrations, keeping loads from increasing, and thus improving water quality.

**Mean Concentrations**

Monthly flow-weighted mean concentrations of NO₃-N, TP, NH₄-N, TKN, TOC, and TSS under base, storm, and total flow conditions for the LMC site are given in Figures 22 through 27. Figures 28 through 33 contain the mean concentrations calculated for the UMC site. Mean concentrations for the BB site can be found in Figures 34 through 39. The LMC and BB sites have monthly concentrations from January 1995 through December 1998; however, the UMC site has monthly concentrations from July 1996 through February 1999.

In the previous three-year report (Vendrell et al., 1998), significant downward trends for mean concentrations of NH₄-N, TKN, and TOC were observed at the LMC site. At this site, NH₄-N and TOC decreased during storm flow conditions; whereas, TKN decreased during base and total flow. The previous monitoring effort by Edwards et al. (1996 and 1997) showed decreases of NH₄-N, and TKN during base flow and NO₃-N, NH₄-N, and TKN during storm flow at this LMC site. The newer UMC site showed increasing trends of TP, NH₄-N, TOC and TSS. There were no previous monitoring
BB site significant decreases of NO$_3$-N, TP, NH$_4$-N, TKN, TOC and TSS were observed during storm flow. Ammonia-N and TKN decreased during base and total flow. Decreasing TP and TSS concentrations during storm flow was a new response.

Extending the monitoring period for another year resulted in fewer significant trends compared to the previous three-year monitoring reports (Table 2). Mean concentrations of NH$_4$-N decreased during base and total flow at the BB site and during storm flow at the LMC site. This is consistent with the previous findings except the longer monitoring period did not show NH$_4$-N decreases during storm flow at the BB site and no base or total flow decreases at the LMC site. Regardless of these inconsistencies, it is apparent that NH$_4$-N continues to decrease in tributaries to Lincoln Lake.

Total Kjeldahl nitrogen had the most widespread decreases. All three sites showed significant TKN decreases (Table 2) with the BB and LMC site decreasing during base and total flow and the UMC site during base flow. These results are consistent with those from earlier reports except that TKN declined at the UMC site. However, the previous increase reported for the UMC site was probably an anomalous statistical result caused by performing trend analysis on an insufficiently short time period and the trend reported here is more reliable.

Total phosphorus significantly increased during storm flow at the LMC site. No decreases were observed. The decreases reported previously are not supported by this longer period of monitoring.

A significant decreasing trend was observed for TSS during base flow at the UMC site. No other sites exhibited significant trends for TSS, NO$_3$-N, or TOC. Reported earlier, Nitrate-N significantly declining at the LMC and BB sites. The changes in land
use in the LMC watershed due to the timber harvest and residential development is the likely reason for changes at the LMC site. Apparently, since there is no longer a decreasing trend for NO$_3$-N, declines at the BB site experienced early in this monitoring project are leveling off or possibly even returning to higher concentrations.

The monthly mean concentrations and mass transport of parameters for the three sampling sites by stream flow conditions are provided in Tables 3-8. The flow conditions are combined flow, base flow and storm flow conditions.

**CONCLUSIONS**

Increasing trends were not observed for either load or mean concentrations of any nitrogen species (NO$_3$-N, NH$_4$-N, TKN). Loads of NH$_4$-N and TKN significantly decreased in BB. Mean concentrations of NH$_4$-N decreased in BB and LMC and TKN decreased at all three sites. Therefore, the BMPs were able to retard nitrogen transport early in their application and these early declines were effectively maintained throughout the seven years of monitoring and nitrogen continues to decline.

Nitrate-N was formerly reported to decrease both in concentration and load. Decreases of NO$_3$-N were not observed in this longer monitoring period. Therefore, the BMP have expressed their full ability to reduce NO$_3$-N transport.

No decreases in phosphorus were observed from the statistical trend analysis of this four-year monitoring effort. In fact, TP significantly increased at the LMC site. However, it is important to point out that no significantly increasing trends had been observed previously and this site had appreciable land use changes from timber harvest activities and residential development.
Mean concentrations of TSS decreased only at the UMC site and there were no load
decreases at any of the sites. Prior trend analysis showed TSS increasing at this site but
in the prior reports it was stated that these increases were probably an artifact of the
overly short monitoring period. This appears to be the case because the current analysis
shows significantly decreasing TSS mean concentrations.

The effects of the timber harvest and residential development appear to be that these
land use changes have stopped the decrease in nitrogen loads. At the affected site, mean
concentrations of TP were observed to increase and this is the first time that a significant
increase has been reported. These effects could possibly be due to some other
unobserved change in this watershed, but the logging and residential development was
the most obvious changes.

REFERENCES

Moores Creek monitoring project, Final Report, Arkansas Water Resources Center,
University of Arkansas, Fayetteville, Arkansas, 1994.


Edwards, D. R., T. C. Daniel, H. D. Scott, P. A. Moore, Jr., J. F. Murdock, and P. F.

Vendrell, P. F., M. A. Murdock. Continuation of the Illinois River water quality
Table 1. Significant trend coefficients and probabilities for loads of water quality parameters at the Beatty Branch (BB) site in the Lincoln Lake watershed. No significant load trends occurred at the Upper or Lower Moores Creek sites.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flow Type</th>
<th>Model Probability*</th>
<th>Trend Coefficient**</th>
<th>Trend Probability*</th>
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<tr>
<td>NH₄-N</td>
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<td>-0.033641</td>
<td>0.0277</td>
</tr>
<tr>
<td></td>
<td>Storm</td>
<td>0.0155</td>
<td>-0.069721</td>
<td>0.0098</td>
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<tr>
<td></td>
<td>Total</td>
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<td>Total</td>
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<td>0.0426</td>
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* Model and trend probabilities are considered significant if the P-values are less than 0.10.
** Negative coefficients represent decreasing trends and positive values represent increasing trends.
Table 2. Significant trend coefficients and probabilitys for water quality parameters at the Beatty Branch (BB), Lower Moores Creek (LMC), and Upper Moores Creek (UMC) sites in the Lincoln Lake watershed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site</th>
<th>Flow Type</th>
<th>Model Probability*</th>
<th>Trend Coefficient**</th>
<th>Trend Probability*</th>
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* Model and trend probabilities are considered significant if the P-values are less than 0.10.
** Negative coefficients represent decreasing trends and positive values represent increasing trends.
Table 3. Monthly mean concentrations of NO3-N, TP, NH3-N, TKN, TOC, and TSS during combined flow condi-
(base plus storm) for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites:

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<th>NO3-N</th>
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<td></td>
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<td>M³</td>
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<td>mg/L</td>
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<td>mg/L</td>
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Table 4. Monthly mass transport of NO3-N, TP, NH3-N, TKN, TOC, and TSS during combined flow conditions (base and storm) for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.
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Table 5. Monthly mean concentrations of NO3-N, TP, NH3-N, TKN, TOC, and TSS during base flow conditions for the Lower Moors Creek (LMC), Upper Moors Creek (UMC), and Beatty Branch (BB) sites.

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Table 7. Monthly mean concentrations of NO3-N, TP, NH3-N, TKN, TOC, and TSS during storm flow conditions for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.
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A-20
Table 3. Monthly mean concentrations of NO3-N, TP, NH3-N, TKN, TOC, and TSS during combined flow condition (base plus storm) for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.

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Table 4. Monthly mass transport of NO3-N, TP, NH3-N, TKN, TOC, and TSS during combined flow conditions (base and storm) for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.

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Table 5. Monthly mean concentrations of NO3-N, TP, NH3-N, TKN, TOC, and TSS during base flow conditions for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beauty Branch (BB) sites.

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Table 6. Monthly mass transport of NO$_3$-N, TP, NH$_4$-N, TKN, TOC, and TSS during base flow conditions for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.

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Table 7. Monthly mean concentrations of NO₃-N, TP, NH₃-N, TKN, TOC, and TSS during storm flow conditions for the Lower Moores Creek (LMC), Upper Moores Creek (UMC), and Beatty Branch (BB) sites.

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APPENDIX B
Figures 1-39
Figure 1. Base, storm, and total discharge at the Lower Moores Creek site.
Lower Moores Creek
Nitrate-N
Loads

Figure 2. Base, storm, and total loads of nitrate-N at the Lower Moores Creek site.
Figure 3. Base, storm, and total loads of total phosphorus at the Lower Moores Creek site.
Figure 4. Base, storm, and total loads of ammonium-N at the Lower Moores Creek site.
Figure 5. Base, storm, and total loads of TKN at the Lower Moores Creek site.
Figure 7. Base, storm, and total loads of TSS at the Lower Moores Creek site.
Figure 8. Base, storm, and total discharge at the Upper Moores Creek site.
Figure 9. Base, storm, and total loads of nitrate-N at the Upper Moores Creek site.
Figure 10. Base, storm, and total loads of total phosphorus at the Upper Moores Creek site.
Figure 11. Base, storm, and total loads of ammonium-N at the Upper Moores Creek site.
Figure 12. Base, storm, and total loads of TKN at the Upper Moores Creek site.
Figure 13. Base, storm, and total loads of TOC at the Upper Moores Creek site.
Upper Moores Creek
Total Suspended Solids
Loads

Figure 14. Base, storm, and total loads of TSS at the Upper Moores Creek site.
Figure 15. Base, storm, and total discharge at the Beatty Branch site.
Beatty Branch
Nitrate-N Loads

Figure 16. Base, storm, and total loads of nitrate-N at the Beatty Branch site.
Figure 17. Base, storm, and total loads of total phosphorus at the Beatty Branch site.
Figure 18. Base, storm, and total loads of ammonium-N at the Beatty Branch site.
Figure 19. Base, storm, and total loads of TKN at the Beatty Branch site.
Figure 20. Base, storm, and total loads of TOC at the Beatty Branch site.
Figure 21. Base, storm, and total loads of TSS at the Beatty Branch site.
Figure 22. Base, storm, and total mean concentrations of nitrate-N at the Lower Moores Creek site.
Lower Moores Creek
Total Phosphorus
Mean Concentrations

Figure 23. Base, storm, and total mean concentrations of total phosphorus at the Lower Moores Creek site.
Figure 24. Base, storm, and total mean concentrations of ammonium-N at the Lower Moores Creek site.
Figure 25. Base, storm, and total mean concentrations of TKN at the Lower Moores Creek site.
Figure 26. Base, storm, and total mean concentrations of TOC at the Lower Moores Creek site.
Figure 27. Base, storm, and total mean concentrations of TSS at the Lower Moores Creek site.
Upper Moores Creek
Nitrate-N
Mean Concentrations

![Graph showing nitrate-N concentrations over time]

Figure 28. Base, storm, and total mean concentrations of nitrate-N at the Upper Moores Creek site.
Figure 29. Base, storm, and total mean concentrations of total phosphorus at the Upper Moores Creek site.
Figure 30. Base, storm, and total mean concentrations of ammonium-N at the Upper Moores Creek site.
Figure 31. Base, storm, and total mean concentrations of TKN at the Upper Moores Creek site.
Figure 32. Base, storm, and total mean concentrations of TOC at the Upper Moores Creek site.
Figure 33. Base, storm, and total mean concentrations of TSS at the Upper Moores Creek site.
Figure 34. Base, storm, and total mean concentrations of nitrate-N at the Beatty Branch site.
Figure 35. Base, storm, and total mean concentrations of total phosphorus at the Beatty Branch site.
Figure 36. Base, storm, and total mean concentrations of ammonium-N at the Beatty Branch site.
Figure 37. Base, storm, and total mean concentrations of TKN at the Beatty Branch site.
Beatty Branch
Total Organic Carbon
Mean Concentrations

Figure 38. Base, storm, and total mean concentrations of TOC at the Beatty Branch site.
Figure 39. Base, storm, and total mean concentrations of TSS at the Beatty Branch site.