EFFECTIVENESS OF FORESTRY BEST MANAGEMENT PRACTICES: EVALUATING WATER QUALITY FROM INTENSIVELY MANAGED WATERSHEDS

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Abstract. Silvicultural activities account for reduced water quality in only a small percentage of nonpoint source (NPS) impaired rivers and streams across the U.S. However, as state and national water quality issues have begun to focus on NPS pollution, the effectiveness of Best Management Practices (BMPs) for protecting water quality should be evaluated as a cost-effective means for NPS pollution control. The goal of this project was to evaluate silvicultural BMPs as they are applied to company timberlands to determine their effectiveness in protecting and maintaining water quality in small stream systems. Similar treatment and reference watersheds were selected in largely forested areas draining actively managed and relatively undisturbed company timberlands, respectively. Sites were monitored for the initial duration of one year using various physical, chemical, and biological monitoring techniques. Chemical monitoring, including monthly grab samples for sediment and nutrients, generally showed no significant difference between treatment and reference sites. Water quality standards were not exceeded in any given sample. Benthic macroinvertebrate samples yielded similar water quality ratings in both treatment and reference sites regardless of differences in stream habitat assessments. Results suggest that properly applied forestry BMPs are effective in maintaining and protecting water quality in small watersheds in the lower Piedmont/Upper Coastal Plain.

INTRODUCTION

Silvicultural activities account for reduced water quality from nonpoint source (NPS) pollution in only 1% of majorly impaired and 9% of overall impaired river and stream miles across the U.S. (EPA, 1995). However, concern for NPS problems continues to grow, regardless of the source of impairment. As states begin to develop Total Maximum Daily Load (TMDL) limits for impaired streams, consideration must be given to those land use practices that maintain and protect water quality. While TMDLs will be applied to point sources through the National Pollution Discharge Elimination System (NPDES) permitting program, application of TMDLs to nonpoint sources is less clear. The issue is especially confusing in watersheds with multiple ownership and in those with both point and nonpoint sources of pollution.

Forestry Best Management Practices (BMPs) have been established by states as a practical and effective means to minimize NPS pollution associated with forest management activities. While compliance with forestry BMPs is generally high (Ice et al., 1997), especially on industrial lands, the effectiveness of these practices in protecting aquatic resources and meeting water quality standards must also be demonstrated. This study is part of a more extensive pilot monitoring project whose objective was to evaluate the effectiveness of forestry BMPs for protecting and maintaining water quality in small perennial streams draining actively managed (treatment) and recently undisturbed (reference) watersheds across International Paper timberlands from east Texas to Maine. The following study focuses on study sites in Georgia. The information herein may be useful to land managers and state water quality personnel as TMDLs are developed for watersheds draining managed forest areas.

BACKGROUND

Sediment is the single most important water quality problem and the largest contributor by volume to NPS pollution in the U.S. (Neary et al., 1988). Likewise, it is undoubtedly the most common and widespread problem associated with silvicultural activities such as harvesting and mechanical site preparation. However, accelerated rates of erosion and sedimentation were once common throughout the Georgia Piedmont and much of the southeast due to non-conservative farming practices of the post-settlement era (Trimble, 1969). Long-term effects include eroded channels, loss of aquatic habitat, and less frequent flooding for severely degraded stream reaches (Ruhlman, in press).

Sediment delivery rates have subsequently decreased and the amount of suspended sediment in rivers and streams has fallen dramatically since the 1930's, mainly due to the conversion of agricultural lands to forest lands (Kundell and Rasmussen, 1995). While BMPs can be effective in preventing additional sediment inputs to streams from forestry operations, they cannot fully prevent the remobilization and deposition of unstable sediment deposited in valleys and streams perhaps over a century ago. Other potential forest water quality concerns include upslope or aerial inputs of nutrients and herbicides, organic inputs, and the maintenance of adequate riparian vegetation for shading and temperature control.

A state-wide study in Georgia found that there was no significant relationship between forest harvesting activities and turbidity in streams (Green and Rasmussen, 1995). In a recent study in Florida, BMPs were successful in controlling erosion and protecting stream habitat and biota following clear-cut harvesting, intensive mechanical site preparation, and machine planting (FDEP, 1997). A similar study in South Carolina found a high correlation between forestry BMP compliance and favorable habitat and biota ratings (Adams et al., 1995). These studies suggest that forest management can be compatible with healthy aquatic ecosystems, especially when forestry BMPs are effectively applied.

METHODS

A multi-factor approach was used to determine water quality effects of various silvicultural activities. Methods employed were not intended to pinpoint subtle changes in water quality, rather they were used as screening tools for general water quality assessment and trend development over time. Second-order perennial streams draining company timberlands were selected as they 1) were generally easier to work in than larger stream systems, 2) provided the opportunity for year-round sampling, and 3) eliminated the confounding effects of multiple land uses.

EPA guidance for monitoring water quality impacts from nonpoint source pollution suggests the use of reference streams to provide an attainable measure of ecosystem health (Dissmeyer, 1994). Physical, chemical, and biological measurements were made throughout 1998 in nearby treatment and reference watersheds (780 ac and 351 ac, respectively). Both were located west of Thomson, Georgia near the Piedmont/Upper Coastal Plain interface. The treatment site was selected in a watershed with immediate upstream forest management activities. Activities in the treatment watershed are given in Table 1.

An 80-foot streamside management zone (SMZ) was retained along perennial and intermittent streams. Selective cutting (i.e. removal of pines) was performed within the largely hardwood SMZs. Residual basal area was approximately 43 ft^2/ac. The clearcut harvest and selective SMZ cuts were 410 and 141 ac, respectively, or 53% and 18% of the watershed. Chemicals were excluded from SMZs and waterbodies. Sediment delivery to streams was minimized using other BMPs including road and stream-crossing stabilization, plowing on the contour, and exclusion of mechanical operations within ephemeral drains and SMZ corridors. The reference site drained a mature pine plantation and did include an 80 ac area on the ridge that was cut in late 1996. Because the cut area was not proximate to perennial water bodies and only included 5 ac of SMZ, it likely did not have a significant impact on monitoring results.

Chemical water quality sampling consisted of monthly grab samples for laboratory analysis. Sediment parameters included suspended sediment (SS) and turbidity. Nutrient analysis included ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), orthophosphate-phosphorus (PO_4-P), and total phosphorus (TP). Other physical measures included total dissolved solids (TDS) and chloride (Cl). Grab samples were sent to and processed by a certified lab. Results were analyzed using a nonparametric randomization method (Potvin and Roff, 1993) to compare treatment and reference sites. Using this method, the data set is randomly partitioned 5000 times and the absolute difference between the means is computed for each randomization. If fewer than 5% of the cases exceed the observed mean, it is concluded that the two means are significantly different.

Benthic macroinvertebrates were collected from streams in the spring and fall for use as indicators of both the inherent natural habitat conditions and the integrated effects of upstream watershed activities. Collections were made using a 650 micron aquatic dip-net (D-net) and employing a multihabitat qualitative sampling approach. An adequate number of sub-sample sweeps (~10) was taken across habitats. Benthic samples were picked in the field until a sufficient sample (100-200 organisms/site), was obtained for each station. Samples were then sent to a consultant for sorting and

Table1. Silvicultural treatment activities and dates.

Date	Silvicultural Treatment
fall 96 - winter 97	clearcut harvest
winter 98	SMZ firebreak construction
April 1998	aerial ultra light-weight (ulw) velpar application
June 98	site preparation burn
July 98	mechanical site preparation (subsoiling)

identification to genus/species. EPA Rapid Bioassessment Protocol (RBP) III (Plafkin, 1989) was utilized for interpretations of water quality. Finally, in-stream habitat assessments were done using Georgia Adopt-A-Stream (AAS) visual survey methods to identify gross differences in stream habitat condition (GA DNR/EPD, 1995).

RESULTS

Results presented herein are preliminary to the final outcome of the larger pilot monitoring project. Water chemistry results are presented as ranges in Table 2. P-values indicate no significant difference in sediment and nutrient concentrations between the treatment and reference site, with the exception of NH_4. It is not known at this time why NH_4 was detected in the reference site on three sampling occasions with high readings in April and December. NO_3-N was also commonly detected at the reference site. There is a small residential inholding that could be contributing excess nitrogen from a septic system. Differing mineralization rates may also explain such results. All results were within state and federal water quality standards. In several instances PO_4-P concentrations exceeded Total P concentrations. The lab indicated there were likely false-positive interference for PO_4-P. Differing analytical techniques and detection limits likely contributed to the problem. At least one observation was eliminated due to obvious lab error. All grab samples were taken during normal or low flow conditions. Chloride was measured as reciprocal indicator of flow: the higher the concentration, the lower the flow. Normalization of water quality parameters to flow using chloride concentrations tended to magnify observed concentration trends.

Table 2. Water chemistry results.

Parameter	Treatment	Reference	P-value
NH_4-N (mg/L)	BDL*	BDL-0.28	0
NO_3-N (mg/L)	BDL-0.12	BDL-0.12	0.37
PO_4-P (mg/L)	BDL-0.12	BDL-0.19	0.42
Total P (mg/L)	0.018-	0.024-	0.73
SS (mg/L)	BDL-10	BDL	1
TDS (mg/L)	38-88	42-87	0.58
Turbidity (NTU**)	4-14	2.7-12	0.08

*BDL = below detection limit
**NTU = nephelometric turbidity units

Benthic sample results were not yet available for fall samples. Spring samples were collected April 13, 1998. EPA's RBP III results are given in Table 3 for the spring collections. The total number of organisms in the treatment and reference samples was 215 and 201, respectively. EPA's RBP III indicates no impairment, with the treatment being comparable to the reference and having optimal balanced community structure (Plafkin, 1989). Stream habitat assessment results are given in Table 4. Assessments are performed by rating stream attributes (excellent, good, fair, poor) based on the visual inspection of percent composition or coverage of stream habitat assessment descriptors.

Table 3. RBP III metric results for macroinvertebrate samples.

Metric	Treatment Score	Reference Score	% Comparison to Reference	Biological Condition Score
Taxa Richness	50	34	147% (a)	6
Biotic Index*	4.07	3.69	91% (b)	6
Ratio of Scrapers/Filtering Collectors	1.32	0.789	167% (a,c)	6
Ratio of EPT** to Chironomid Abundances	1.28	2.62	49% (a)	2
Percent Contribution of Dominant Taxa	9.3%	29.9%	9.3% (d)	6
EPT** Index	17	15	113% (a)	6
Community Loss Index			0.28 (e)	6
Ratio of Shredders to Total	0.167	0.478	35% (a,c)	4
BIOASSESSMENT SUMMARY				**Nonimpaired**

* Hilsenhoff Biotic Index was modified using North Carolina Biotic Index (NCBI) values (Lenat, 1993) where possible.
** Total number of species within the pollution sensitive groups Ephemeroptera, Plecoptera, and Trichoptera.
(a) Score is a ratio of treatment site to reference site x 100. (b) Score is a ration of reference site to treatment site x 100.
(c) Determination of functional feeding group is independent of taxonomic grouping.
(d) Scoring criteria evaluate actual percent contribution, not percent comparability to reference.
(e) Range of values obtained. A comparison to the reference station is incorporated.

Table 4. Results of stream habitat assessments.

	Treatment	Reference
Stream bed	good-fair	excellent-good
Recent sediment deposits	poor	good
Streambank stability	good	good
Streambank cover	good	excellent

DISCUSSION

Monthly chemical monitoring for sediment and nutrients yielded no significant difference between the treatment and reference site for most water quality parameters. Ammonium-N and nitrate-N were commonly detected in the reference samples and may reflect a difference in soil type and mineralization. Orthophosphate-P was high (> 0.1 mg/L) in several samples, but may have been the result of a false-positive interference during lab analysis. Total P was slightly elevated (near 0.1 mg/L) in treatment samples on two occasions, but did not appear to be at a sustained level to impair aquatic life. Suspended sediment and turbidity were low for all samples. Total dissolved solids indicated a similar ionic content for treatment and reference sites.

Habitat assessment results indicated substrate differences between treatment and reference sampling sites. Both sites contained riffles, runs, and pools, but the reference site generally had more cobble and gravel throughout the stream. Nevertheless, multihabitat qualitative benthic macroinvertebrate sampling and RBPIII analysis indicated no impairment to the treatment site. Taxa richness was actually higher in the treatment site. Biotic indices for both sites fell into the excellent water quality class for the Piedmont/Coastal ecoregion (Lenat, 1993). EPT indices were also similar.

Results of this study support the assertion that forestry BMPs are effective in protecting water quality and maintaining aquatic ecosystem health. SMZs employed in association with intensive forest management activities provided adequate buffers as compared to a fully shaded reference stream. BMPs are a cost-effective means for controlling NPS pollution. BMP application techniques are generally high on industrial timberlands, and can be used as a model for the protection and restoration of NPS-impaired waterbodies.

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LITERATURE CITED

Adams, T.O., D.D. Hook and M.A. Floyd. 1995. Effectiveness monitoring of silvicultural Best Management Practices in South Carolina. *S. J. Appl. For.* 19(4):170-176.

Dissmeyer, G.E. 1994. Evaluating the effectiveness of forestry best management practices in meeting water quality goals or standards. For. Serv. Misc. Publ. 1520, July 1994.

EPA (Environmental Protection Agency). 1995. National water quality inventory: 1994 rpt. to Congress. EPA 841-R-95-005.

FDEP. 1997. Effectiveness of Forestry Best Management Practices: Okaloosa, Gadsen, Taylor, and Clay Counties. Comprehensive Quality Assurance Plan No. 870346G, FL DEP, Bureau of Laboratories, Div. of Admin. and Tech. Serv.

Green F. and T. Rasmussen. 1995. A study of stream turbidity following forest harvesting in Georgia. USEPA 319 report to the GA EPD.

Ice, G.G., G.W. Stuart, J.B. Waide, L.C. Irland, and P.V. Ellefson. 1997. 25 years of the Clean Water Act: how clean are forest practices? *J. For.* 95(7):9-13.

GA DNR/EPD (Georgia Department of Natural Resources Environmental Protection Division). 1995. Georgia Adopt-A-Stream Manual.

Lenat, D.R. 1993. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. *J. N. Am. Benth. Soc.*, 12(3):279-290.

Kundell, J.E. and T.C. Rasmussen. 1995. Erosion and sedimentation: scientific and regulatory issues. Developed for the Georgia Board of Natural Resources by the Georgia Board of Regents' Scientific Panel on Evaluating the Erosion Measurement Standard defined by the Georgia Erosion and Sedimentation Act.

Neary, D.G., W.T. Swank, and H. Riekerk. 1988. An overview of nonpoint source pollution in the Southern United States. In: Proceedings of the symposium, The Forested Wetlands of the Southern United States. Orlando, FL, July 12-14, 1988. For. Serv. Gen. Tech. Rpt. SE-50. pp. 1-7.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Highes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA 444/4-89-001. U.S. EPA, Washington, D.C.

Potvin, C. and D.A. Roff. 1993. Distribution-free and robust statistical methods: Viable alternatives to parametric statistics? *Ecology* 74:1617-1628.

Ruhlman, M.B. (in press) Channel morphology evolution and overbank flow in the Georgia Piedmont. J. Am. Wat. Res. Assoc. 35(2).

Trimble, S.W., 1969. Culturally Accelerated Sedimentation on the Middle Georgia Piedmont. Master's Thesis, Univ. GA, Athens, GA.