SUMMARY OF WATER QUALITY EFFECTS FROM FOREST PRACTICES IN THE SOUTH

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ABSTRACT: The results of many watershed research studies within the 13 States comprising the Southern Region of the USDA Forest Service are summarized for their reported effects of common forest management practices on water quality. The results are grouped by Major Land Resource Areas.

Sediment yields from forested basins in the Southeast are typically less than 0.25 ton per acre per year under undisturbed conditions, but can rise to 100 times this amount for brief periods following poorly conducted logging and road building operations. Recovery to pre-disturbance levels takes less than three years. A number of Best Management Practices (BMP's) are shown to minimize damage to water quality.

Some changes in chemical concentrations and export in streamwater have been noted in research studies, particularly in the mountains. Small increases in potassium and nitrates have been most common, but are thought to represent no ecological threat to aquatic communities. Forest insect pest epidemics can also cause increases in water nitrate-nitrogen concentrations.

Monitoring of commonly used forest herbicides has shown they pose no threat to aquatic plants, insects or fish when applied correctly. They also breakdown in forest soils very rapidly.

INTRODUCTION

Scope:

This document summarizes many watershed research studies through-out the 13 States (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA) that lie within the Southern Region of the USDA Forest Service. The effects of common forestry practices and operations on soil erosion, stream sedimentation and nutrient cycling are covered. It is intended for use by practicing forest hydrologists, soil scientists, aquatic and fishery biologists, foresters, water quality officials and others concerned with nonpoint sources of water pollution (Section 319 of the Clean Water Act of 1987). The period covered is typically the 1960's through the 1980's.

Forest Practices:

The common management practices included in this report are road construction, livestock grazing, use of herbicides, prescribed burning, logging, and various site preparation practices (chopping, chop and burn, KG blading, disking, bedding, bulldozing, fell and burn). Natural geologic erosion and sedimentation rates are also included where available.

Time Periods:

The length of time included is the research study period used by the original investigator, often from one to three years in duration. A few studies cover a longer time frame. Most of the studies were done in the 1970's and early 1980's. Published articles or their abstracts were used as much as possible, including computerized summaries obtained through INFOSOUTH.

Area Covered:

All or portions of the following States: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South

Carolina, Tennessee, east Texas, and Virginia. The portions covered are where forests exist. See page 5 for a map of the area covered.

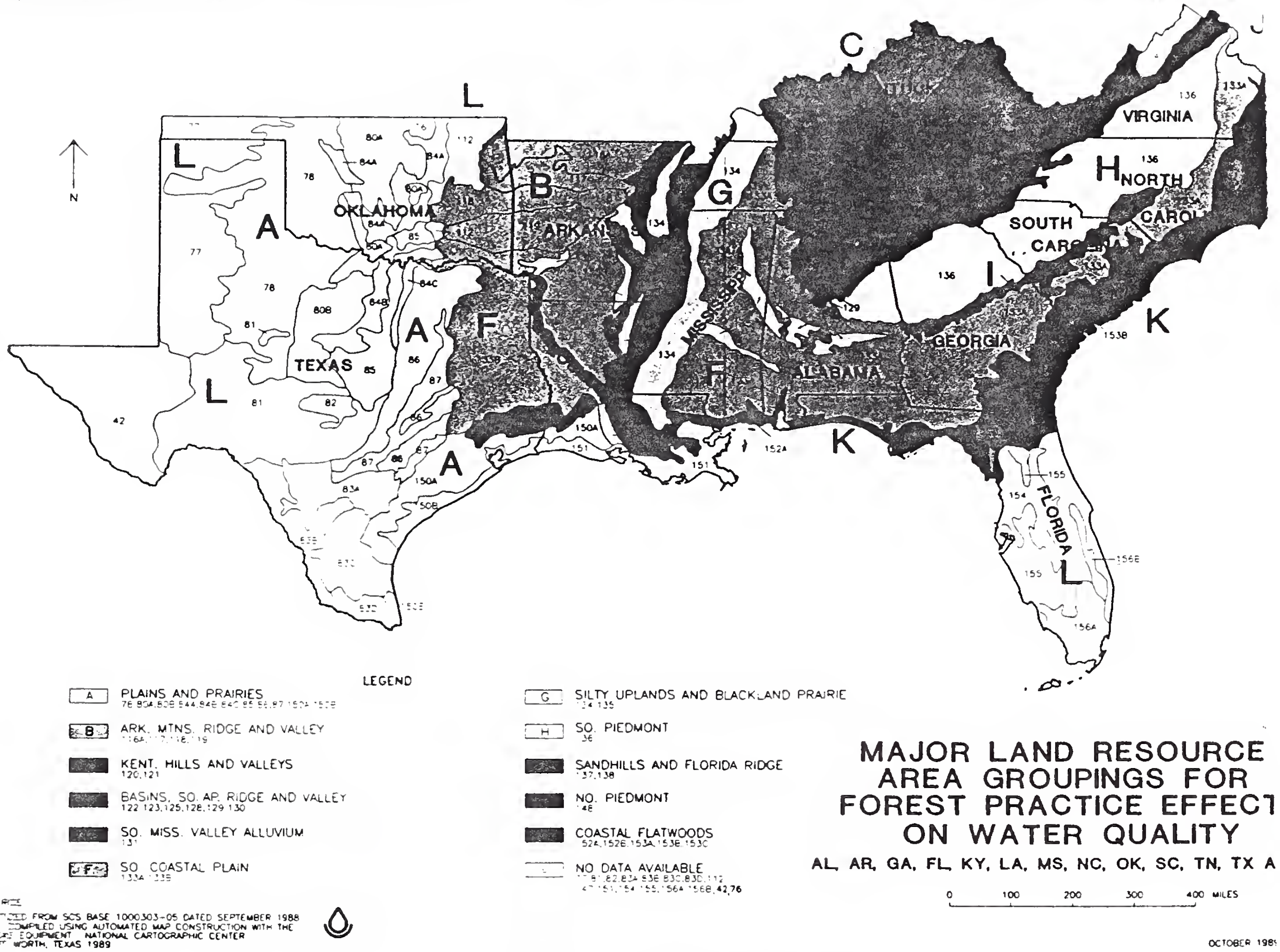
In terms of major Land Resource Areas (LRA's) present within the scope of this report, there are 30 LRA's included. These 30 LRA's were combined into 11 Groups, labelled A-K, as follows:

Group	Descriptive Name	LRA's Included in Group
A	Plains & Prairies	78;80A-B;84A-C;85;86;87;150A-B
B	Ark. Mtns, Ridge & Valley	116A,117,118,119
C	Kent. Hills & Valleys	120,121
D	Basins, So Ap Ridge & Valley	122,123,125,128,129,130
E	So. Miss. Valley Alluvium	131
F	So. Coastal Plain	133A, 133B
G	Silty Uplands & Blackland Prairie	134,135
H	So. Piedmont	136
I	Sandhills & Florida Ridge	137,138
J	No. Piedmont	148
K	Coastal Flatwoods	152A-B; 153A-C

A twelfth group, labelled "L" on the map on page 5, consists of some 14 MLRA's for which no data were found for this report. These MLRA's include 77, 81, 82, 83A-D, 112, 147, 151, 154, 155, 156A and 156B.

These LRA's are taken from "Land Resource Regions and Major Land Resource Areas of the United States" by the USDA Soil Conservation Service, Agriculture Handbook 296, Revised December 1981. Groupings A-K used here do not correspond with the Major Land Resource Regions used in Ag Handbook 296.

CONTENTS



MAJOR LAND RESOURCE AREA GROUPINGS FOR FOREST PRACTICE EFFECT ON WATER QUALITY
AL, AR, GA, FL, KY, LA, MS, NC, OK, SC, TN, TX A
N
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
FLORIDA
LEGEND
A PLAINS AND PRAIRIES
B ARK. MTNS. RIDGE AND VALLEY
KENT. HILLS AND VALLEYS
120,121
BASINS, SO. AP. RIDGE AND VALLEY
122,123,125,128,129,130
SO. MISS. VALLEY ALLUVIUM
F SO. COASTAL PLAIN
G SILTY UPLANDS AND BLACKLAND PRAIRIE
H SO. PIEDMONT
SANDHILLS AND FLORIDA RIDGE
NO. PIEDMONT
COASTAL FLATWOODS
NO DATA AVAILABLE
0 100 200 300 400 MILES
SOURCE
DIGITIZED FROM SCS BASE 1000303-05 DATED SEPTEMBER 1988
MAP COMPILED USING AUTOMATED MAP CONSTRUCTION WITH THE
FOCAS EQUIPMENT NATIONAL CARTOGRAPHIC CENTER
FORT WORTH, TEXAS 1989
OCTOBER 1989

Overview of Sediment Yields from Forested Watersheds:

Patric, Evans and Helvey (1984) analyzed erosion and sediment data from 812 forested plots and small watersheds throughout the United States. These watersheds were essentially undisturbed with minor influences from agriculture, roads or other land uses. Many were more than 80 percent forested. Forested streams along the Pacific coast yield much more sediment per unit area than anywhere else. No significant differences were found anywhere else among sediment yields in Eastern or Western US watersheds. About one-third of these produced sediment yields less than 0.02 ton/ac/yr, and 75% of them were less than 0.25 t/ac/yr. About one-fourth were between 0.25 - 1.00 t/ac/yr and a few exceeded 1.00 t/ac/yr.

In the Eastern U.S. region with 291 studies, the average sediment yield was 0.139 t/ac/yr, with a standard deviation of 0.198 t/ac/yr. The range in data was 0.01 to 1.97 t/ac/yr. Of the study sites, 65 were completely forested watersheds <2 sq.mi. that averaged 0.074 t/ac/yr. The 226 watersheds >2 sq.mi. usually contained mixed land uses and averaged 0.158 t/ac/yr sediment yield.

An average sediment yield of 0.25 t/ac/yr is similar to the regional denudation rates of 0.20 to 0.31 t/ac/yr for heavily forested regions of the U.S. reported by Judson and Ritter (1964). Sediment yields from Eastern forests were reported as 0.05 to 0.10 t/ac/yr by Patric (1976) and as 0.02 to 0.03 t/ac/yr naturally, but rising temporarily to as much as 0.50 t/ac/yr during manmade disturbances (Lull & Reinhart, 1972).

Fowler and Heady (1981) derived multiple regression equations for predicting sediment yields from basins that were at least 95% forested. Significant independent variables were: drainage area, mean annual runoff, elevation, mean slope and mean annual rainfall; correlation coefficients varied from 0.76 to 0.92, depending upon study region within the Southeast U.S. They found that suspended sediment rates are highest in the Northwest and Southeast U.S. due to steeper slopes, erosive parent materials, high rainfall and runoff.

In their summary of forest watershed management, Anderson, Hoover and Reinhart (1976) stated typical sediment yields or concentrations in forested watersheds under management were:

Piedmont: 2,000 milligrams per liter (mg/l) average.

Appalachians and Coastal Plain: 280 mg/l.

Loessial soils in Miss. River Basin: up to 6,000 mg/l average.

All land uses in Central and Southeastern hardwoods: 814 mg/l; 1.5 t/ac/yr.

All land uses in Southern pine forests of parts of the Piedmont and most of the Coastal Plain: 650 mg/l; 1.33 tons/acre/yr.

Coastal Plain's most turbid streams average 280 mg/l.

Channel Erosion

About 480,000 km of channels in USA are eroding and producing 450 million tons of sediment each year, an average of 940 t/km/yr (Robinson, 1977).

Channel erosion on Pigeon Roost Creek in northern Mississippi over a 15 year period contributed an average of 24 percent of the total measured sediment discharge from the basin. Straightening and dredging 6.3 km of channel eroded

2,480 t/km/yr first two years, then 34,400 t/km/yr during a flood during which bankfull flow velocity increased from 2.4 m/sec to over 4 m/sec as unvegetated stream banks no longer could hold the floodplain soils in place (Ibid).

Valley Deposition

1. Studies in the 1930's of Southern Piedmont floodplains found streams aggraded by several meters and locally up to 7.6 meters - mostly sand from earlier farming.

2. Surveys in the 1960's of the Yazoo Valley in Mississippi found the 1937-65 rate had decreased 30% from the average of previous 100 years. Most Yazoo streams have been mechanically dredged or trenched by erosion headward from the dredged main stem. Channel and floodplain erosion may now exceed the valley deposition rates and are new sources for sediment (Ibid).

Overview of Information on Sediment Delivery Ratios (SDR):

Not all eroded soil ever reaches a stream channel because of the many "traps" on the ground surface where soil particles can settle out from surface runoff, the filtering effects of forest litter, ground vegetation and other barriers. One problem faced by hydrologists and soil conservationists is quantifying just how much soil does remain on the landscape, compared to how much reaches a stream or lake.

The Sediment delivery ratio (SDR) is the percent of the sediment arriving at a given point on a stream system compared to the gross soil erosion on the basin. It is inversely proportional to the size of the basin. Figure 2 shows how SDR varied with drainage area in basins in Texas, Mississippi, Georgia, North Carolina, Iowa and Nebraska (Roehl, 1962).

Another problem is quantifying the relative contributions of upland erosion and streambank erosion to total sedimentation. Robinson (1977) showed that many studies on small basins in the U.S. found that soil conservation practices reduced upland erosion, but increased streambank erosion an equivalent amount so total sediment delivery to oceans has remained the same. Principal sources of sediment are: Agricultural lands - 40%, streambank erosion - 26%, pasture and rangeland - 12%, forest land - 7%.

The time lag between when soil erosion occurs and it reaches a stream, then a larger river and eventually an ocean can be several centuries. For example, in the Southern Piedmont only about 5% of all soil eroded since European settlement in 1700 has been exported to the Atlantic or Gulf of Mexico to date. Studies in the 1930's of Piedmont floodplains found streams had often aggraded by several meters and locally up to 7.6 meters by sand from poor farming practices, according to Trimble (1974). This fact will complicate current and future sedimentation studies and decisions by water quality regulating agencies because it is so frequently ignored.

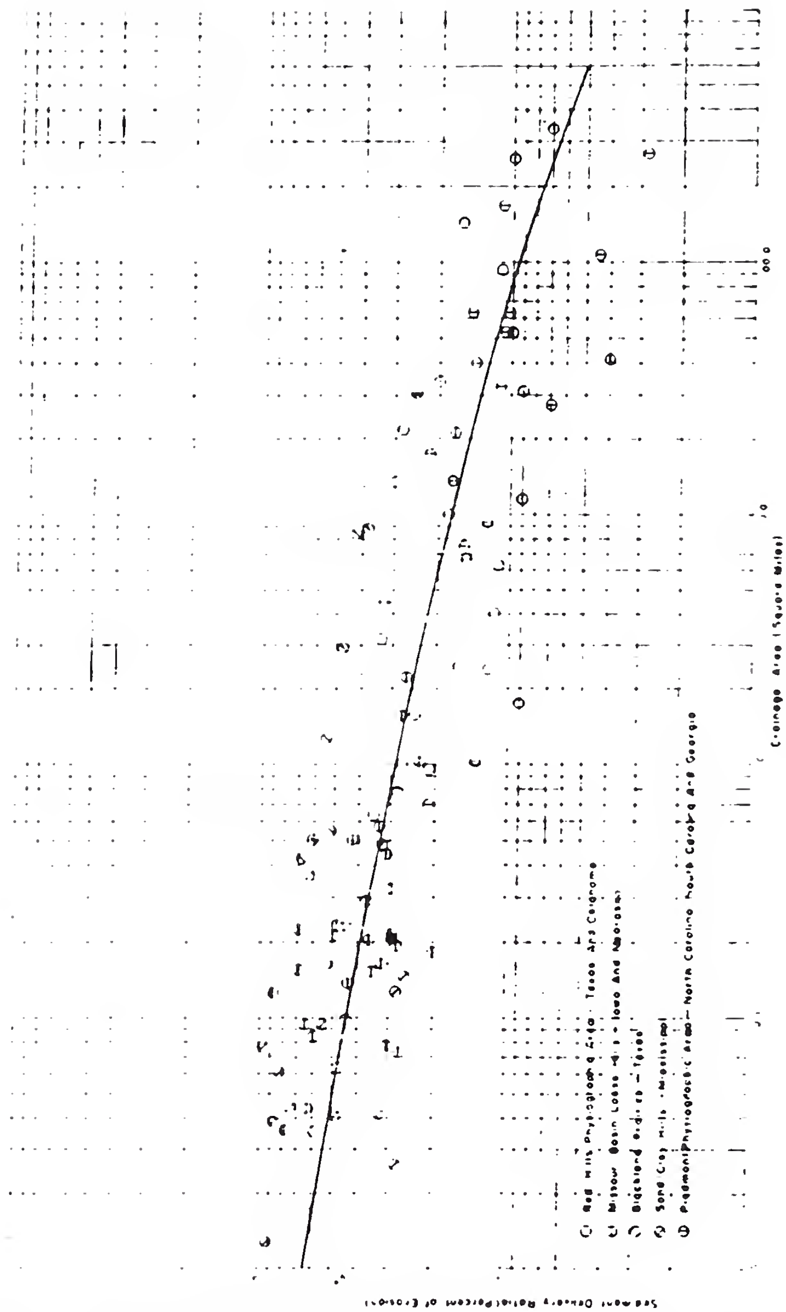


Fig. 2 Sediment delivery ratio versus size of drainage area.

Source: J.W. Roehl, 1962. Sediment Source Areas, Delivery Ratios and Influencing Morphological Factors. Extract of Pub. No. 59 of the I.A.S.H. Commission of Land Erosion, pp. 202-213.

How to Use This Report:

For the remainder of this report, the research literature is summarized by Land Resource Area (LRA) groupings defined on page 2. Some citations, such as those that immediately follow, cover more than one group and are placed into "All" or "Mixtures of" sections. Please refer to the map on page 5 for the location of the groupings used here and your geographical area of interest.

The format used includes the name of the article, the author(s), date, name and number of publication, page numbers and where published, if available.

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All Groups of LRA's:

"Summary of Sediment Yield Data from Forest Land in the U.S." by J. Patric, J. Evans and J.D. Helvey, 1984. J. Forestry Vol 82 No. 2, pages 101-104.

Erosion and sediment data from 812 forested plots and watersheds were statistically analyzed. Forested streams along the Pacific Coast yield much more sediment per unit area than anywhere else in USA. Elsewhere, no significant differences were found among sediment yields (SY) in forested watersheds in eastern and western US. About one-third of SY's were less than .02 ton/acre/yr, and three-fourths of them were less than .25 t/ac/yr. About one-fourth fell between 0.25 and 1.00 ton/ac/yr and a few exceeded 1 ton/ac/yr.

Eastern U.S. region with 291 studies: Mean SY with standard deviation is 0.139 +/- .198 t/ac/yr with a range of .01 to 1.97 t/ac/yr and coefficient of variation of 14.2%. These can be further broken down into completely forested small watersheds of less than 2 square miles: 65 watersheds with mean SY=.074 ton/ac/yr and range of .01 to 1.09 ton/ac/yr. Some 226 larger watersheds of mixed land uses and reservoir surveys had a mean SY = .158 ton/ac/yr and range of .01 to 1.97 ton/ac/yr.

An average sediment yield of .25 ton/ac/yr is close to regional denudation rates of 0.20 to 0.31 ton/ac/yr for heavily forested regions of the U.S. reported by Judson and Ritter, 1964. Sediment yields from eastern forests were reported as 0.05 to 0.10 ton/ac/yr (Patric, 1976) and as 0.20 to 0.03 t/ac/yr but rising temporarily to as much as 0.5 during human disturbances (Lull and Reinhart 1972).

"Suspended sediment production potential on undisturbed forest land" by J. Fowler and E. Heady, J. of Soil and Water Cons, January-February 1981, pages 47-50.

The authors used Iowa State University agricultural model of 18 river basins in U.S. on published forest watershed research results and existing land uses in these basins to derive multiple regression equations for sediment yields in seven geographic regions of the USA. Those of interest to the South are:

1) Central East, $n = 11$
   $SS = 5.79 \times 10^{-0} - 1.13 \times 10^{-2}\, RF + 7.9 \times 10^{-3}\, SL$; MSE = .009152, $r^2 = 76$

2) South East, $n = 15$

$SS = -5.0367 - 5 \times 10^{-6} D.A. + 2.719 \times 10^{-1} RO - 2.87 \times 10^{-3} EL$; $MSE = 1.444237$, $r^2 = .82$

3) South Central, n = 8
$SS = -1.0759 \times 10^{-1} + 2 \times 10^{-6} DA + 1.25 \times 10^{-3} RF + 9.10^{-3} SL$; $MSE = .000071$, $r^2 = .94$

4) North Central n = 10
$SS = 5.01389 \times 10^{-1} + 1.245 \times 10^{-2} RF + 1.099 \times 10^{-2} RO + 6.811 \times 10^{-3} SL$; $MSE = .004929$, $r^2 = .92$

where:

SS = suspended sediment rate, tons/acre/year
DA = drainage area in acres
RD = mean annual runoff in inches/yr
EL = elevation in feet
SL = mean slope in %
RF = mean annual rainfall in inches/yr

Suspended sediment rates are highest in NW and SE regions due to steeper slopes, parent soil materials and high rainfall/runoff.

"Relationship between Soil Erosion and Sediment Delivery" by A. Robinson in Erosion and Solid Matter Transport in Inland Waters, Paris Symposium, July 1977, pages 159-167.

Studies on small basins in U.S. show soil conservation practices have reduced upland erosion, but have increased streambank erosion so that sediment delivery has remained about the same. For the USA; sediment loadings by contributing land uses are estimated as follows:

	Land Use	Load, tonnes/yr	Percentage
1.	Agriculture	680×10^6	40
2.	Streambank erosion	450×10^6	26
3.	Pasture and rangeland	210×10^6	12
4.	Forest and woodlands	130×10^6	7
5.	Other federal lands	115×10^6	6
6.	Urban	73×10^6	4
7.	Roads	51×10^6	3
8.	Mining	18×10^6	1
9.	Other	14×10^6	1
		1,741	100

From page 15 of The Dow Chemical Co, 1972, "Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization" PB-209-212 available from NTIS.

In the Southern Piedmont, only 5% of all eroded material since 1700 has been exported. Important factors affecting sediment yields are: Size of watersheds, topography, soils, % ground cover, drainage density and sediment delivery ratio (SDR).

Group A: Plains and Prairies
LRA's 78, 80, 84-87, 150

"Sediment production under various forest-site conditions" by M. Chang, F. Roth and E. Hunt, Jr., 1982, in IAHS Publication No. 137, p. 13-22.

Sediment losses were measured on .02 hectare (ha) plots under six forest site conditions in east Texas during 1980-81 with Coshocton samplers. Soils are highly erodible Hapludalfs (Woodtell series) under 40 year old stands of loblolly and shortleaf pines. Sediment yields from 19 runoff producing storms over a 9 month period were: undisturbed 0.027 t/ac; 50% thinned 0.042 t/ac; clearcut without site prep 0.385 t/ac; clearcut and chopped 0.654 t/ac; clearcut and KG bladed 8.551 t/ac; clear cultivated 8.455 t/ac. Sediment loss was highly related to storm energy, storm runoff, soil moisture content, cover and site disturbance. USLE was used.

Group B: Ark. Mtns, Ridge & Valley
LRA's 116-119

"Fall and Burn for Low-Cost Ste Preparation" by J. Abercrombie Jr. and D. Sims 1986 in Forest Farmer 46(1):14-17.

New site preparation technique in these two LRA's of Spring (last April - 1 June) chainsaw felling of unwanted hardwoods followed by summer (July - August) burning within three days of summer rainshowers (moisture content 15% outside burn area and 10% inside burn area based on fuel sticks, then plant to pine.

No studies available yet of erosion or sedimentation from this new site preparation practice, but they should be relatively low.

"Sediment Yield and Storm Flow Response to Clear-Cut Harvest and Site Preparation in the Ouachita Mountains" by E. Miller in Water Resources Research Vol. 20 #4, pages 471-475, 1984.

Clearcut harvest and site prep, include chopping, burning and contour ripping were applied to three small watersheds (1.6-4.2 ha) in Oklahoma. Three undisturbed forested watershed were controls. No roads or drainage from roads occurred within study area. Hand planting was done. Trees were chain-sawed or sheared, delimbed, skidded to landings with rubber tired skidders. Skidding was only uphill to log decks within each watershed. Right after harvest, residual vegetation was mechanically chopped with self propelled tree crushers and then burned hot. Ephemeral channels were not buffered at any time.

Contour ripping or subsoiling with D-8's followed the burning, were on-contour, 20" deep, did not extend through ephemeral channels but were ripped up to channels. Watersheds were fenced to exclude cattle; no grass seeding was done.

Results

1. Sediment yields from treated watersheds were significantly higher than from control watersheds for years 1, 2, 3 after treatment, but not for year 4. There is a decreasing trend over time. Bedload is <1% of total yield. Decay rate is:

-------------------- Sediment Yields in metric tons/hectare ------------
Means of 3 watersheds

1979		1980		1981		1982	
cut	control	cut	control	cut	control	cut	control
.282	.036	.035	.008	.015	.005	.043	.024

Sediment yields on clearcut watersheds stayed low because contour ripping increased detention storage and infiltration at a time of minimal vegetative cover; soils are not highly erodible due to 70% surface rock fragments and revegetation was rapid growing from 0 to 47% from 11/78 to 7/79.

Stormflow sediment >20 mg/l occurred more frequently on treated watersheds in 1979 and 1980, but not in 1981-82. In 1979-80, difference between treated and control were very small yet significant (P <.01) at 50 and 100 mg/l levels. No cutting or scour of channels was seen. The only BMP used was no ripping in stream channels.

LRA 116:

"Hydrologic Characteristics of Mixed Hardwood Catchments in the Ozark Plateau" 1976. T. Rogerson in Proceedings Central Hardwood Forest Conference, pages 327-333.

Precipitation, runoff and sediment losses were measured for ten years on three small (4-6 ac) undisturbed forested basins in northern Arkansas' Koen Experimental Forest near Harrison. Karst terrain, 30% slopes, 5-6' deep well drained to 2' deep, poorly drained, slow permeable soils cover sinkholes. Wet weather springs are common in area. Average annual precipitation is 45" and evapo-transpiration is 32 inches. Measured runoff over ten years was 2.16" or 4.6% of precipitation, indicatingpossible leakage past the flumes.

Average sediment losses 1966-74 were 20 lb/ac/yr, with a high of 64.4 lb/ac in 1973 to low of 1.9 lb/ac in 1972. Range is due to storm frequency, size and intensity. Large storms flush out drainage channels. Discharge rates > 0.50 cfs occurred in only 24% of the runoff-producing storms, but they accounted for 91% of the sediment losses.

LRA 119, Ouachita Mountains in Arkansas and Oklahoma

"Stormflow, Sedimentation and Water Quality Responses Following Silvicultural Treatments in the Ouachita Mountains" by E. Miller, R.S. Beasley, E. Lawson in Forestry and Water Quality: a mid-south symposium, Little Rock, Arkansas, 1985, pages 117-129.

-Two areas studied, 1978-1983, effects of forest harvest and site preparation on suspended sediment, water quality and stormflows.

-Oklahoma study: Six small (6-8 ac) watersheds; two treatments clearcut harvest and site prepped, contour ripping, and untreated forested control.

-Six months pre-log baseline data. Watersheds were divided into three blocks of two each, randomly assigned treatments.

-Summer 1978 harvest, fall 1978 tree crush residual vegetation, broadcast burn and contour rip 11/78, hand plant pine seedlings on clearcut watersheds 3/79.

-Arkansas study: Nine small (10-15 ac) watersheds in completely randomized block design. Three blocks three each. Watershed instrumented 6/77 - 8/78, flow gaging starts 10/78, stormflow moniting starts 10/79.
Treatments:

a)	Hardwood control on selection cut watershed	4/80
b)	Clearcut harvest	6-8/80
c)	Selection harvest	6-8/80
d)	Site prep of clearcuts (chop residual veg)	8/80
	(broadcast burn)	9/80
e)	Hand plant pine seedlings on clearcut watershed	2/81

Apparently no roads were constructed or reconstructed in either area.

Results:

1. Annual sediment yield (SY) increased by factors of 8:1, 4:1, 3:1, 2:1 in Oklahoma and 20:1, 6:1 and 3:1 in Arkansas after clearcutting. Increases persisted three years in Oklahoma and only one year in Arkansas. Bedload is a minor component in both places.

2. Only a few storms produced the bulk of annual SY: e.g., 71% in 1979 in Oklahoma came from two of twenty-seven measurable winter storms, and 83% of the 1981 yield in Arkansas came from three of thirty storms.

3. Maximum SY from clearcutting during first year was 250 lb/ac. (.12 ton /ac/yr) and maximum from selection cutting was 80 lb/ac.

4. Sediment yields from control watersheds ranged from .002 to .03 t/ac./yr.

5. Four factors prevented higher erosion and sediment rates:

a) Detention storage was high after normal site preparation and contour ripping in Oklahoma increased it even more.
b) Surface soils were not erodible due to loamy texture, high rock content and fine root mat on mineral soil.
c) Broadcast burns were done well, preventing sealing of surface or loss of organic matter.
d) Revegetation following site preparation was rapid.

6. Sediment sources:
-Overland flow occurred only adjacent to stream channels, the result of exfiltration in saturated zones or source areas near the channel.
-In Arkansas, some specific channel sources of sediment and recent sediment movement were found, but most channels were stable and well armored.
-Watershed source areas were found.

7. Water Quality - Cutting and site preparation affected amount of time that given levels of Total Suspended Solids (TSS) are exceeded, but magnitude of

differences was small and short duration. "Peak levels of TSS exceeded standards on all treatments, although peaks on cut areas were higher than on controls" by factors of two to twelve. TSS of 1550 ppm were recorded on one Arkansas clearcut block while its control was 125 ppm.

8. Mean annual SY from selection harvests were significantly lower than first year losses from clearcutting, but projected over a thirty-five year rotation, little difference in total sediment losses are expected.

9. Apparent BMP's used: 1) harvest and site preparation work during dry season, 2) prescribed burning was hot enough to kill hardwoods but not so hot as to consume organic matter, 3) no herbicides were used.

10. Stormflow volumes were related to annual precip amounts (OK: 4-28%, ave. 15%; ARK: 2-59%, ave.26%) and generally not to treatments. Seasonal differences exist: stormflows greater from clear/ selection cut watershed during growing season and fall soil-water recharge months, with 5-800 cfs/sq.mi. in Oklahoma.

11. Peak flows did not increase significantly following treatment in either place generally, but one block of watersheds in Arkansas showed up after clear and select cutting. Ouachita mountains do have flashy streamflow responses.

LRA 119 Ouachita Mountains

"Forest harvest and site preparation effects on erosion and sedimentation in the Ouachita Mountains" by E. Miller, R. Beasley and E. Lawson, J. of Env. Quality, Vol. 17, #2, 1988.

Alum Ck and Cedar Mountain Watersheds (9 small, ephemeral, <15 ac size watershed) between 1979 - 1983. No roads were included in watersheds. Skid trails and mechanical site preparation (drum chop and broadcast burn) activities occurred on the clearcut watersheds, but not on the selection cut ones.

Annual Sediment Yields Measured

	1981	1982	1983
	------pounds per acre------		
	------milligrams/liter------		
Clearcut	209*	79 n.s.	156 n.s.
ave SS conc.	75.3	32.8	23.4
Select cut	32	32	74
ave SS conc.	11.3	14.0	11.8
Control	12	13	60
ave SS conc.	5.7	8.2	12.0

Using the single-storm sediment yield approach, nonsignificant differences the first and second post-treatment years and a significant difference the third year occurred. The annual yield and single-storm totals differ because:

a) In 1981, annual sediment yields increased in all blocks (watersheds) from control to clearcut and differences in yields were relatively large, hence 1981 clearcut is significant.

b) The 1981 single storm yields varied greatly by storm and the ranking procedures equalized the individual storm yields, large or small, hence a nonsignificant effect for 1981.

c) 1983 annual sediment yields did not increase consistently from control to clearcut across all blocks and treatment differences in mean SY's were small, hence nonsignificant.

d) Single storm yields in 1983 were less variable than 1981 and were clearly ranked along treatment lines, hence a statistically significant treatment effect.

Sediment sources were observed to be the ephemeral channels and alluvial fans. Suspended solids in stormflows were less than 100, 50 and 20 mg/liter at least 99, 98 and 97% of the time, respectively, across all treatments.

LRA 116 Ozark Highlands
LRA 117 Boston Mountains
LRA 119 Ouachita Mountains

"Effects of Forest Practices on Water Quality in the Ozark-Ouachita Highlands" by E. Lawson in Forestry and Water Quality: a Mid-South Symposium, Little Rock, Ark., 1985, pages 130-140.

LRA 119 - Alum Ck mini-watersheds of 1.3 to 1.6 acres. Shallow soils, moderately permeable, low water storage capacities. Shortleaf pine over mixed hardwood understory. Annual precip 52.5" during 1961-69 calibration period fairly evenly distributed as rain; total E.T. 34", runoff 3-9" flow peaks of 2-3 cfs. Average runoff is 11% of annual precip.

Average annual sediment losses = 13.8 lb/ac, with a range of 5.6 - 26.4 lb/ac in 1963 and 1968 respectively.

Eleven percent of runoff producing storms account for 68% of sediment production.

1970 - Treatments start: WS #1 is control

WS #2 herbicide injection of hardwood, pine shelterwood cut, sprout control by hand spray 1971, 72, 73.

WS #3 pine was clearcut, hardwoods injected and sprayed with 2,4,5-T similar to WS #2.

1973 Logs were skidded by mules to upper area landings in both watersheds.

Results

WS #2 sediment yield increased from 10.6 #/ac pre-treatment average to 31.3 lb/acre (14 mg/l) first year; 5.1 #/ac in second year and 11.2 #/ac in third year.

WS #3 sediment yield increased from est. 15.8 #/ac pre-treatment to 116.8 #/ac (33.4 mg/1) first year; 6.3 #/ac in second year and 12.7 #/ac in third year.

Re-treatments

WS #2 - By 1977 natural shortleaf pine regeneration developed and remaining pine overstory was then harvested. In 1981, pine saplings were precommercially thinned.

WS #3 - Dense grass cover within two years - left until 12/76 when it was burned to remove grass and replanted with shortleaf pine seedlings and replanted once. Grass returned.

Results of Re-treatments

Turbidity (NTU) levels were monitored 1977-81 - no significant difference among watersheds with averages being: WS #1: 10.8; WS #2: 18.1; WS #3: 32.4. Values are believed to be affected by organic materials.

Ozark Plateau (LRA 116) - Five watersheds on Henry Koen Experimental Forest near Harrison, AR, were established in 1964 and measurements began 1965. Sizes 4-18 acres, in karst terrain, 2-6' silt loam soils, water capacity = 11". Mixed hardwoods, Rainfall 45", 10-yr calibration period precip 46.5", stormflow runoff is 2.2", only 5% of rainfall. Peak flow recorded 4.3 cfs. Sediment losses averaged 19.7 lb/ac, with range of 64 lb/ac in 1973 to 1.9 lb/ac in 1972.

Treatments

WS #1 thinned 5/1979 to 60% stocking density, leaving better oaks, herbicided.
WS #3 thinned 5/1979 to 40% stocking density, leaving better oaks, herbicided.
WS 2, 5, 6 were not disturbed.

Results

No conclusions could be drawn due to lack of runoff-producing storms during two years of post-treatment.

Boston Mountains LRA 117 - Four watersheds on Ozark NF, 14-33 acres in area on flat bedded sandstone, shales and siltstone. Sandy loam soils 1-6' thick. Mixed hardwoods, 50" annual precip with some snow. Started measurements in 1973. Calibration 1973-80, average precipitation 57", average runoff 21.7" (8-45"). Most stormflow in Spring and early Winter.

No sediment data collected during calibration, but turbidity was taken. Average turbidities: WS-1 19.2 NTU; WS-2, 26.4 NTU; WS-3, 28.8 NTU; WS-4 34.7 NTU.

In 1981, automated pumping samplers and Coshocton wheels were installed and treatments decided. Treatments:

WS #1 Chemical conversion from hardwood to pine

WS #2 Control - no disturbance
WS #3 Shelterwood harvest
Ws #4 Clearcut

Results

$$$$$$ See later papers - too early here.

LRA 119 - Ouachita Mountains

"Forest Road Sediments" Production and Delivery to Streams", by E. Miller, R.S. Beasley and J. Covert in Forestry and Water Quality: a mid-south symposium, Little Rock, AR., 1985, pages 164-176.

The Alum Ck WS (see Lawson, 1985) - measured erosion and sediment yields from four instrumented road segments to project basin-wide road sediment production and delivery to streams in watershed. Included a December 82 rainstorm >100 yr 24 hr event and wettest October on record which caused significantly greater erosion rates than expected.

Results

1. Erosion rates from the four instrumented road segments averaged 60 tons/mi yearly, mostly from road ditches and cut banks. Rates projected for entire 140 mile road system are 72 tons/mi/yr, or 25 tons/ac/yr of road surface, ditches and banks.

2. Estimated road erosion delivery to streams averages 7.9 tons/mi/yr (11% of erosion) or 0.038 ton/ac/yr over entire basin. Erosion rate from managed forest lands, exclusive of roads, is .015 ton/ac/yr.

3. Stormflow volumes from the four measured road segments greatly (6-25 times) exceeded precip inputs because of contributions from forested areas upslope of cutbank - this needs to be included in road design and cutslope erosion control planning.

4. The numbers, types and locations of USFS road drainage measures were appropriate, generally operating as designed and "in our judgement constituted the application of BMP's". The number of points where road runoff and sediments are delivered directly to a stream is more important than road mileage in a basin for sediment predictions.

"Sediment Losses from Forest Management Mechanical vs. Chemical Site Preparation after Clearcutting" by Beasley R S; Granillo A B; Zillmer V., Dept Forest Resources Univ. of Arkansas at Monticello and Arkansas Agricultural Exp. Stn., Monticello, Arkansas 71655 in J Environ. Quality 15 (4), 1986, 413-416.

The comparative effects of mechanical and chemical site preparation on water yields and sediment losses following forest clearcutting were evaluated over a 4-yr period in the Athens Plateau area of southwestern Arkansas. After one yr of pretreatment measurements, three forested watersheds were clearcut and the residual vegetation and debris were sheared and windrowed but not burned. Three watersheds were clearcut in a similar manner, but received chemical site

preparation. Residual trees on two watersheds were injected with 2-4,D amine; the third watershed was aerially sprayed with a mixture of Tordon (active ingredient; picloram [4-amino-3,5,6-trichloropicoline acid]) and Garlon (active ingredient; triclopyr [3,5,6-trichloro-2-pyridinyloxyacetic acid]). Three additional watersheds were left undisturbed for controls.

Mean annual sediment losses on the mechanically site prepared watersheds during the first post-treatment year were significantly higher than those from either the chemically site prepared watershed or controls. Chemical site preparation did not significantly increase sediment losses. Although 2nd yr losses for the mechanical site preparation and control treatments doubled over 1st-yr levels, no significant treatment effect was detected for either site preparation treatment. Third-year losses decreased below 1st-yr losses for all treatments, but not to pretreatment year levels. The relatively sharp declines in sediment losses during the third post-treatment years were attributed to rapid regrowth of natural vegetation on the sites.

Mixture of Groups B, D and H

"Sediment and Forestry Practices in the South" by S. Ursic, in Fourth Federal Interagency Sedimentation Conference, 1986, Vol. 1, pages 28-37.

Some base rates for sediment concentrations (tons of sediment yield divided by sum of stormflow volumes) in tons per acre inch for several LRA's are:

	LRA	Ton/A-I
a) Loblolly and shortleaf pine plantations and natural stands.	133	.007
b) Native grass cover on abandoned land	133	.026
c. Poorly stocked hardwoods on abandoned land	133	.026
d) Continuous fallow field	133	3.50
e) Undisturbed pine, hilly C.Plain & Piedmont		.006
f) Pine in Ouachita Mountains	119	.001
g) Hardwoods in Ozark Plateau	116	.004
h) Lower Coastal Plain wetlands		.001-.002
i) Piedmont, pine	136	.003-.004
j) Piedmont, hardwoods and pine	136, 130	.007

2. Practices:

Prescription burning pine plantations and grass cover in LRA 136 produces no change in sediment yields, while similar treatment in LRA 133 will result in some increase in sediment yield. Burning or herbiciding hardwoods in LRA 133 will cause large increases in sedimentation for several years afterward.

Timber harvesting, excluding roads, will cause increases in sediment yields for two or three years after harvest in the Piedmont and Coastal Plain, especially if mechanical site preparation methods are used.

GROUP C Kentucky Hills & Valleys
LRA's 120, 121

No reports were found.

Group D Basins, So. Appal. Ridge & Valley
LRA's 122, 123, 125, 128-130

LRA 125

"Long-term Effects of Repeated Logging on An Appalachian Stream" by J.H. Patric and G. Aubertin, J. Forestry, August 1977, pages 492-494.

A 38 acre watershed (Elk Lick Run) was logged 1901-11 by cutting old growth at 15 mbf/ac and horse skidding with little erosion (brook trout fishery). In 1930's chestnut blight killed 25% of the timber volume which was tractor logged during WWII on ridgetop roads. In 1958 a diameter-limit cut of (17"+) oak and maple were removed over roads located and managed with minimum care. Water yield increased 2.5" first year and 1.4" next year after cutting, minor increases in turbidity from log roads and large increases from one skid trail located too near channel resulted.

Period	Non-storm Ave. Turb.	Range
Before logging (1951-7)	2	1-68
During logging 1957	897	1-5000
First year after	6	1-88
Second year after	2	1-8
Third year after	2	1-7

In 1972, compartment 2A was again diameter-limit (17") cut (23% of B.A.) and tree-length logs skidded by tractor and arch along established trails to prepared landings. Skid trails were properly located, waterbarred and grass seeded after logging. Buffer strips of 33-66 feet were left along streams. Results of turbidity monitoring were:

Period	Logged WS		Control Watershed	
	Mean	Max.	Mean	Max.
1960-72 Calibration				
Growing season	2	10	2	20
Dormant season	3	16	2	25
1972 Logging, grow season	3	14	1	4
1972-75 Post-logging				
Growing season	2	6	2	5
Dormant season	1	7	1	4

Recommendations:

1. Do not log in streams.
2. Build the fewest roads or far from streams as possible.
3. Cross streams on bridges or culverts.
4. Winch logs near streams upslope to machines or roads.
5. Keep road grades under 10%.

6. Log bottomlands in dry weather; ridgetops in wet weather.
7. Water-bar skid trails and roads immediately after logging.
8. Plant grass within 50' of streams.
9. Log out bottomlands quickly.
10. Exclude vehicular traffic from all temporary roads not in use for logging.

LRA 130

"Soil Losses from Roadbeds and Cut and Fill Slopes in the Southern Appalachian Mountains" by L. Swift, Jr, in So. J. of Applied Forestry, Vol. 8, No., 4, November 1984, pages 209-215.

Two sections of road were re-constructed in 1976 to have outsloped 22' wide roadbeds drained by broad-based dips without inside ditches. Each test site was defined as a broad-based dip plus the 190 ft or less length of roadbed drained by that dip. Size and angle of cut and fill slopes were similar and ranged from 3/4:1 to 1:1 and fills from 1:1 to 1 1/4:1. Toe of each fill had brush barriers. Berms along top of fill. Grades of 5% and 7%. Grass planting and gravelling were intentionally delayed 9.5 months after construction. After the timber sale was done, all cut and fill slopes were fertilized, limed and seeded to rye and fescue. Roadbeds were graded and surfaced with 6" of crusher-run gravel. Measurements continued 13.5 months. Study period total was 9/76 - 8/78. Average annual rainfall is 74 inches. Soils were a micaceous deep sandy loam with a low hard rock content, on a 35% south facing slope. Dozer compaction of fills.

Results

1. First year road erosion averaged 56 tons/acre; second year 11.3 tons/acre.

2. Initially, the roadbed produced 1/2 - 2/3 of the total roadway erosion due to loose soil following construction. Later, the roadbed always produced less than one-half of the soil losses.

3. Largest soil losses for all surfaces occurred the first winter: in four months roadbeds yielded 42% of their two year total and the fill slopes 52% and cut slopes 83%. Cut slopes were highest due to frost heaving and dry ravel. Cut slopes lost 9X that of fill slopes during first winter; 4X for whole period.

4. Large losses from fill slopes started in early spring from soil liquefaction and slumping.

5. Some rutting of roadbeds occurred during Spring thaw and from March rains but < 20% of total erosion is from roadbed. The 7% grade lost 57% more soil than the 5% grade roadbed. More than 1/2 of roadbed erosion was fine particles transported by water while <20% of loss from fill and cut slopes was in this class.

6. Logging traffic has a tendency to increase erosion from roadbeds in early Spring.

7. During June-November 1977 period, 6.5" rain in five days in August on newly germinated grass increased the rate of erosion on cut and fill slopes - up to 5 tons/ac/month. However, roadbed losses decreased 80% when gravelled.

8. As a result of the gravel and grass cover, soil losses during the last eight months (12/77 - 8/78) were only 1-3% of the two-year total losses for all cuts, fills and roadbeds. The grass stopped the frost heaving and dry ravelling of cut and fill slopes.

LRA 130

##"Stream Chemistry Responses to Disturbance" by W. Swank in Ecological Studies, Vol 66: Forest Hydrology and Ecology at Coweeta, 1988, Springer-Verlag New York, Chap. 25, pages 339-357.

Following pre-treatment calibration monitoring, watershed 7 was roaded, clearcut and site prepared by felling the remaining stems. Cable yearding was done and most of the forest floor remained intact. Watershed 2 is an adjacent control.

Results

1) Concentrations of potassium (K) in stream water increased significantly in the clearcut watershed for four years after treatment. Increases were from 20-50 percent (0.5-2.40 kg/ha), but pose no environmental or human hazard.

2) Calcium concentrations also increased after roadside fertilization and logging. The increase peaked the third year after treatment and is persisting at about 1.2 kg/ha above predicted levels some five years after logging.

3) Nitrate nitrogen increases began some 9 months after commencement of logging, remained in the 50-75 ug/l range into the next summer, peaked (100-150 ug/l) during the second winter after logging and then declined toward baseline concentrations.

4) Annual export of stream solutes was greatest the third year after treatment for nitrates, potassium, sodium, calcium, magnesium, sulfate and chloride. By the fifth year, all were approaching pre-treatment levels. Export rates were not correlated well with the increase in streamflow which steadily declined from the first to the fifth year after logging. Cutting had little effect on ammonia or phosphate exports, with only small increases in most years.

5) As vegetative succession from grass to hardwood forest occurred on WS 6 over a 13 year period, cation concentration seasonal patterns changed, the amplitude of some concentrations were dampened and reduced. It is thought biotic processes within the forest floor and aquatic ecosystem are responsible for the changes and they will eventually produce water quality typical of forested watersheds in the area.

6) Insect epidemics can change stream chemistry. An outbreak of fall cankerworm consumed 33% of the total leaf biomass of a heardwood forest in 1974 and caused nitrate-nitrogen concentrations in the watershed to rise frequently by 40 ug/l or more. As the epidemic declined, so did the concentration of nitrate. The same changes in nitrate also occurred in two other Coweeta watersheds

experiencing various other insect epidemics over the years. Changes in other cations are masked by bedrock mineralogy differences in watersheds.

LRA 130

"Gravel and Grass Surfacing Reduces Soil Loss from Mountain Roads" by L. Swift, Jr., in Forest Science, Vol. 30, No. 3, 1984, pages 657-670.

Soil loss from a 13-16' wide timber sale access road construction without any surfacing (bare soil) and later with grass cover was compared with test sections of new road surfaced with different types and thickness of rock. In first two months after construction in a deep sandy loam saprolite, soil loss rates were 8 X larger on the bare soil surfacing than from 6-8 inches of gravel surfacing. Loss rates decreased over a six month period of light traffic. Total loss over eight months:

> 200 t/ha with no-surfacing
< 35 t/ha with surfacing with graded crushed rock or 3" washed stone, mostly in the first 30 days after gravel was laid. Losses rose as logging traffic began and the roads were re-shaped and grass seeded at end of timber sale use. A 2" layer of crushed rock was inadequate to prevent severe rutting.

In third year, erosion rates on the 2" layer gravel equalled that of the bared roadbed, and was twice that of the grassed roadbed.

Where road was built with the B horizon of sandy clay loam, soil losses with both 2" and 6" of gravel were intermediate between the high and low losses from similar surfacing on the sandy loam saprolite.

Difference in soil loss and trafficability persisted into the fourth year. Road grader maintenance of road re-disturbed stabilized road surfaces and contributed to further erosion and sedimentation.

BMP's used: Brush barriers at toe of fill slopes
Planting grass on non-graveled roadbeds of intermittent use roads
Outsloping, broad-based dips, no inside ditch

15 cm (6") of crushed rock or 20 cm (8") of 3" stone both work well, while only 5 cm (2") of crushed rock is not enough.

"Long-term effects of repeated logging on an Appalachian stream" by Patric, J. and Aubertin, G., Journal of Forestry, 1977, 75 (8): 492-494.

A report of the effect of 4 logging operations (between 1901 and 1972) on streams in the forested Fernow Watershed 2, N. central W. Virginia. Data on streamflow and turbidity are recorded for diameter-limit fellings (selective logging over 17 inches d.b.h.) in 1958 and 1972, together with chemical analysis of water samples for the 1972 felling. Both fellings increased streamflow slightly, but had no effect on water quality except for a temporary increase in turbidity near poorly located and ill-managed logging roads. It is concluded that diameter-limit felling will not harm forest streams if responsible road practices are followed.

"Picloram Movement in an Appalachian USA Hardwood Forest Watershed" by Neary D G; Bush P B; Douglass J E; Todd R L in J Environmental Quality 14 (4). 1985. pages 585-592.

Picloram (4-amino-3,5,6-trichloropicolinic acid) was applied at a rate of 5.0 kg ha-1 acid equivalent to 4 ha of the 28-ha Watershed 19, Coweeta Hydrologic Laboratory in western North Carolina [USA]. The herbicide was broadcast manually as a pellet formulation (10% acid equivalent) in May 1978. The objective was to eliminate a poor-quality mixed oak overstory and rhododendron -laurel understory prior to planting white pine.

Picloram residues in samples from an Umbric Dystrochrept soil peaked in concentration in the upper 0.07 m at 11.58 mg/kg, had a half-life of about 4 weeks, and declined to near detection limits 28 weeks after application. Soil solution contained the highest picloram levels at 0.6 m (peak of 350 mg m-3). Picloram residues were detected in soil solution 1.2m into the soil, but concentrations were < 25 mg m-3, and persisted for only 60 weeks. Intensive sampling to two springs detected trace levels for a period of 18 days. Only sporadic, low-level picloram residues were detected in streamflow from nested 10-ha and 28-ha watersheds during a 70-week period. Use of the herbicide picloram did not affect the quality of streamflow from Watershed 19 for domestic or agricultural purposes.

"Forestry activities and water quality in Alabama: effects, recommended practices and an erosion-classification system" by Golden, M.; Tuttle, C. Kush, J. and Bradley, J. M., III. Bull. 555, Agr. Exp. Sta., Auburn U., 1984.

Literature is reviewed on types and sources of stream pollutants in forested catchment areas and on effects of major silvicultural and harvesting activities on water quality. Recommendations are made on principles and practices in catchment area management to minimize adverse effects of forestry. A framework, based on land type classification, is presented to assess the erosion hazard of the diverse forest sites in Alabama.

"Monitoring herbicide residues in springflow after an operational application of hexazinone" by Neary, D. in Southern Journal of Applied Forestry, 1983, 7 (4): 217-223.

Parts of two forested catchments in central Tennessee were aerially treated in May, 1980 or 1981 with 15 lb/acre of hexazinone pellets (10% a.i.) to remove broadleaved competition before establishing Pinus taeda. Residues of hexazinone were monitored in treated catchments and a control for 7 months. Detectable residues or the two primary metabolites of hexazinone were found only in 7 samples collected in July and August, but not in samples collected before, between and after these dates. It is suggested that the few positive results were due to sample contamination.

"Plant succession and hydrologic recovery on a deforested and herbicided watershed" by Kochenderfer, J. and Wendel, G. in Forest Science, 1983, 29(3): pp. 545-558.

A 60-acre catchment area of mixed broadleaves in West Virginia was treated in 1963-69 with a variety of herbicides, effectively clearing it of vegetation and maintaining it barren; sawtimber was cut in 1963-64. Biomass, % ground cover by species, mean vegetation height, tree reproduction and streamflow were monitored between 1970 and 1979. Growing season water yield returned to pretreatment values after 5 yr. Aboveground biomass increased as woody vegetation became dominant, averaging 14.7 ovendry t/acre at the end of 10 growing seasons. In 1979 the area was well stocked with 3800 stems/acre of commercial tree species (mainly sweet birch, and yellow poplar. There were close relations between biomass, height, % ground cover and water yield. Specific conductance of streamflow increased from 19 micromho/cm before herbicide application to 57 micromho/cm when treatment was terminated. As vegetation regrew specific conductance decreased to about 24 micromhos/cm in 1979.

"Erosion on Very Stony Forest Soil During Phenomenal Rain in Webster County, West Virginia" by Patric, J. and Kidd, W., Northeastern Forest Experiment Station, Broomall, PA. Research Paper NE-501, 1982. 13 pp.

On July 15-16, 1979 at least 6 inches of rain fell in central West Virginia during a 3 hr period. Six miles of logging roads were examined for soil erosion and sediment delivery to streams. Erosion was negligible on very stony soils where logging roads were litter covered, road grades were under 15%, and volumes of overland flow on logging roads had been small. The average rate of erosion from logging roads was about 5 tons/acre of logged-over land.

Severest erosion ranged from 0.6 to 0.8 ton of soil and rock per foot of road. Approximately two-thirds of the detritus from the most severely eroded road was thought to reach a nearby river and contribute to its sediment load, but only about one-third of the detritus reached the river from less severely eroded roads. Construction of an erosion pavement on most of the roads prevented greater soil loss. These studies suggest that with proper location and management of logging roads, erosion on very stony soils may be held to little in excess of geologic rates.

"Monitoring Herbicide Residues in Springflow After an Operational Application of Hexazinone" by Neary, D. in Southern Journal of Applied Forestry, Vol. 17, No. 4, p 217-223, November 1983.

Hexazinone, a symetrical triazine herbicide, shows promise to be a cost-effective tool in pine regeneration. Parts of two forested watersheds in central Tennessee were aerially treated with 15 lb/ac of hexazinone pellets (10% active ingredient) to remove hardwood competition prior to establishing loblolly pine. Both treated watersheds and a control were monitored to determine if hexazinone residues were entering groundwater and appearing in springflow. Seven months of monitoring included two intensively sampled periods during application and the first storm.

No detectable residues of hexazinone or its two primary metabolites were measured in samples from the Coleman Hollow watershed in which hexazinone was applied up to 66 ft. from the monitoring point in 1981. Springflow samples from a spring monitoring site 1000 meters from the portion of the Lost Creek watershed treated in 1980 were also clear of herbicide residues. A delayed subsurface movement of detectable amounts of hexazinone did not occur through

the cherty loam soils of Coleman Hollow within the first seven months after application.

"Nutrient Budgets for Undisturbed and Manipulated Hardwood Forest Ecosystems in the Mountains of North Carolina" by Swank, W. and Douglass, J. in Watershed Research in Eastern North America: A workshop to compare results, Feb 28-Mar 3, 1977, Chesapeake Bay Center for Environmental Studies, Smithsonian Institute, Tidemark Printing, Inc., Vol. I, p 343-363.

Stream chemistry was monitored for 8 mature hardwood ecosystems and 16 forested systems that were altered by cutting, species conversions, and changes in land use. Net budgets (input minus output) of NO3-N, NH4-N, PO4-P, Cl, K, Na, Ca, Mg, SO4, and SiO2 were estimated for 15 ecosystems based on dissolved ion concentrations and the quantity of precipitation and streamflow.

None of the manipulations produced long-term nutrient discharges that would adversely affect water quality for municipal or fishery use. Of the nutrients studied, NO3-N provided the most sensitive index of ecosystem disturbance. When the forests were cut and in various stages of revegetation, elevated NO3-N discharge was observed at least 13 years after cutting, but appeared to return to baseline levels 20 years after treatment.

No changes in the discharge of NH4-N and PO4-P were observed for any of the watersheds; all ecosystems showed very large accumulations of SO4=. A grass-to-forest succession watershed that had been fertilized, limed, and herbicided showed large nutrient losses. Conversion of deciduous forests to eastern white pine reduced the loss of most nutrients, and net budgets of young coppice forests indicated nutrient cycles that were as closed or tight as mature hardwood forests. Results demonstrate the importance of both hydrologic and biologic processes in evaluating ecosystem response.

Mixture of LRA Groups D, F, H:

"Sediment Characteristics of North Carolina Streams, 1970-79" by C. Simmons, 1988, USGS Open-file Report 87-701.

Sediment concentrations and yields were measured on many streams in North Carolina. Seven basins from 1.0 to 51.9 sq.mi. were 94-100% forested and judged to be without development (pristine). Mean annual sediment yields (MASY), annual streamflows in cfs (Q), number of samples (#S), and the mean (Mn), maximum and minimum sediment concentrations are given in the following table:

Site	Name	Province	D.A. sq.mi.	MA SY t/sm	Q cfs	#S	Mn	Max	Min.
							--mg/liter--		
21	Black Swamp	C. Plain	1.02	6	>1	17	8	35	2
52	Cave Ck	Piedmont	0.64	47	>1	49	5	120	2
68	Ellis Ck trib	C. Plain	1.81	5	>1	21	5	50	4
96	Dutchman's Ck	Piedmont	3.44	41	4	23	6	108	4
132	Beetree Ck	Blue Ridge	5.46	31	4	51	3	88	1
141	Cataloochee R	Blue Ridge	49.2	43	122	110	3	383	0
146	Nantahala R	Blue Ridge	51.9	58	232	34	5	111	0

Mean sediment yields for Piedmont and Blue Ridge: 44 tons/sq.mi/yr; Coastal Plain: 5 tons/sq.mi/yr with a transition at the Fall Line. Major sediment sources were bank caving, channel scour and more subtle channel changes. No landslides were noted. In the Asheville area, 1970-79 sediment yield was 117% of long-term (80 yr) sediment yield of French Broad River.

Suspended sediment ranged from one to eight mg/l doing low flow periods when flow was 50 to 90% duration. High flow (0.1% duration) concentrations ranged from 17 mg/l at Black Swamp in Coastal Plain to 220 mg/l at Cataloochee Creek in Blue Ridge. Peak instantaneous sediment concentration observed during floods ranged from 35 mg/l in Black Swamp to 383 mg/l at Cataloochee Creek.

Organic matter comprises an average 30 - 50% of suspended sediment in Coastal Plain and 10 - 30% in Piedmont and Blue Ridge provinces. Particle size composition (%) for inorganic matter during high flows was:

	Sand	Silt	Clay
Blue Ridge	48	36	16
Piedmont	24	36	40
C. Plain	15	32	53

Seven other sites were essentially forested (88-99%) but also contained paved and unpaved roads near channels, or agricultural activities (sites 64, 107, 112, 142) or summer resort homes (site 112). These other land uses resulted in the highest sediment yielded by a forested basin at 280 t/sq.mi/yr.

Site	Name	Province	D.A.	MA SY	Q	#S	Mn	Max	Min
64	Buckhorn Ck	Piedmont	76.3	76	81	26	23	329	5
66	Flat Ck	Coastal P.	7.6	60	15	32	7	145	1
107	Linville R.	Blue Ridge	66.7	110	189	24	5	277	1
112	Jacob Fork	Piedmont	25.7	280	54	28	7	2600	2
128	Davidison R.	Blue Ridge	40.4	60	148	29	3	555	1
136	W.F. Pigeon R.	Blue Ridge	27.6	210	113	31	2	721	0
142	S. Toe R.	Blue Ridge	43.3	130	169	44	2	75	0

Summary of mean annual sediment yields for forested basins with and without development, by province:

	Tons/sq.mi /yr		# Sites	
	Pristine	Roaded	Pristine	Roaded

Blue Ridge	44	130	3	4
Piedmont	44	180	2	2
Coastal Plain	5	60	2	1

Some twenty years after channelization, sediment yields were still several times greater than for nearby non-channelized streams, down from a ten-fold increase in year 1.

Highway and large scale land clearing operations had sediment yields 1.5 to 4 times that from only agriculture.

Sediment levels during storms on Piedmont urban sites are 10-60 times those on the Coastal Plain with peak flow sediment concentrations averaging 100 mg/l in forested, 870 mg/l rural, 1600 mg/l in urban watersheds. Statewide yields indicate 40% of gross erosion in forested basins, 20% in urban basins and 10% in rural or agricultural basins were transported as sediment by the gaging station.

Groups D,F,H,J for State of Virginia:

"Estimates of Erosion and Sedimentation from Forest Practices in Virginia" by Samuel H. Austin, Virginia Dept. of Forestry, 1988.

Based on 2800 sample plots on 800 tracts across Virginia over a period of five years, and using modified Musgrave equation and a series of assumptions, Austin predicts a 47% decrease in erosion from 1979 levels, a 55% decrease in sediment levels from 1979 by 2000 by improved implementation of forestry BMP's.

Please see Appendix B for Austin's estimated annual erosion and sedimentation rates from logging operations and road or trail construction for the mountains, Piedmont and Coastal Plain provinces within Virginia.

Group E So. Mississippi Valley Alluvium
LRA 131

No reports were found?????

Group F Southern Coastal Plain
LRA's 133, 149

LRA: 133 Southern Coastal Plain

"Effects of Land Use and Topography in Some Water Quality Variables in Forested East Texas" by M. Chang, J. McCullough, A. Granillo, 1983, <u>in</u> Water Resources Bulletin Vol. 19, No. 2, p 191-196 .

"Spatial variation of five variables were analyzed using composite water samples collected periodically from 8 small (11.4 - 71.6 sq.km.) watersheds

near Nacogdoches over 1977-1980. Based on 31 observations over the 4-year period, average +/- standard deviation, maximum and minimum values were:

Variable	Average	Std. Dev.	Max.	Min.
Nitrate + nitrite nitrogen	1.43 kg/ha/yr	1.38	4.27	.07
Total kjeldahl nitrogen	21.96 kg/ha/yr	8.45	32.73	9.87
Total phosphorous	3.09 kg/ha/yr	1.55	5.34	0.74
Chloride	50.11 kg/ha/yr	22.68	74.02	15.42
Total suspended sediment	90.39 kg/ha/yr	51.90	191.11	26.75

Forested area in the study watersheds ranged from 65 to 98% with a mean of 77%, pastured land area was 21% and built-up area was 2%.

Of 31 sediment samples, only two exceeded 80 mg/l: 81 and 90. The average sediment concentration was 16 mg/l with std. error of est. of 22%. Lowest average was 13.2 mg/l for Bernaldo Ck and highest average was 22.5 mg/l for Wanders Ck. The best equation for predicting sediment concentrations (TSS) was based upon percent forest (%For) and stream frequency (SFQ):

TSS = 142.35 - 1.64 (%Forest) + 745.28 (SFQ)   r=.87

"Water Quality Effects of Clearcutting Upper Coastal Plain Loblolly Pine Plantations" by D. McClurkin, P. Duffy, S. Ursic and N. Nelson, in J. of Envir. Quality, Vol 14, No. 3, 1985.

1. Effect of clearcutting loblolly plantations on sediment and nutrients in stormflows on 4 small (0.3-1.5 acre) watersheds was evaluated near Lexington, TN. Tree length skidding on contour to the nearest ridge or landing was done, but no roads were built. No stream crossings allowed. Slash and forest floor left intact. No site preparation, hand planted. Fragile soils. In the table below, sediment concentrations are flow-weighted means from four replicate samples each.

Results

1. Rainfall and Mean annual sediment concentrations in stormflows; mg/l

Yr.	Rainfall, cm	Control WS	Clearcut WSs
1975(May-Dec. only)	102	142	295
1976	114	141	362
1977	155	45	127
1978	140	57	46
1979	203	25	84
Mean **	-	82	183*

* Significantly different from control WS at the .05 level
** means for the 5 annual means

Since the control WS values declined from the 1975 and 1976 levels, it's likely some of the 1975-76 sediment was due to flume installation disturbances.

2. One-third or more of total Kjeldahl nitrogen and two-thirds of total phosphorus exported is via sediment phase. Solution phase TKN and T.P. concentrations were similar on all watersheds. Potassium export was always higher in clearcut WS. Rainfall inputs of TKN, TP, K exceeded stormflow outputs.

"Sediment and Nutrient Transport from Pine Watersheds of the U. S. Coastal Plain" by J. Schreiber and P. Duffy, 1982.

Five ephemeral watersheds in N. Mississippi on severely eroded former crop land were planted in 1939 to mix of loblolly and slash pines. The area is sedimentary rock covered by a shallow loess mantle with the watersheds 4-6 acres in size. The study period was 1974-78.

Results

1. During study, ratio of stormflow to rainfall ranged from 0.19 in wettest year to .01 in driest . Loessial watersheds (#1,2) produced 1.4X flows that of coastal plain watersheds (#4,5) due to their greater fragipan extent (18-19 cm vs 11-15 cm)

2. Sediment concentrations, mg/l, and sediment yield, lb/ac, over 5-yr by watershed:

	Conc.,Mean mg/l	Range mg/l	Yield, Mean lb/acre
WS 1	49	31-85	77
2	59	44-154	101
3	228	67-950	387
4	109	55-230	142
5	100	64-300	98
Mean			161

WS-1 and WS-2 are in loess, broad channel without any steep banks.
WS-3 has incised channels with steep banks and lots of frost heaving erosion. It also has an active gully and headcut about 200 ft above the flume.
WS-4 and WS-5 are both in the Coastal Plain.

LRA 133 Coastal Plain

"Comparative Hydrologic Effects of Silvicultural Alternatives on Flat Terrain in the Gulf Coastal Plain" by R. Beasley and A. Granillo in Forestry and Water Quality: a mid-South Symposium, Little Rock, AR, 1985, p 94-106.

Nine small forested watersheds were either (1) clearcut, mechanically site prepared (shear, windrow and burn) and replanted with loblolly, (2) selectively harvested with deadening hardwoods, (3) undisturbed controls. All slopes < 3%, intermittent flow channels, 5.6-10 ac. size, 3 replicates of each treatment.

Harvesting done July and August 1981, site preparation on clearcuts Sept. 81. Planting during winter of 81-82. No roads present. Measurement through 1984.

Results

1. Clearcutting upped stormflow and annual runoff about 5" over control first year, and about 3" over slection cut. No effect during next two years.

2. Selection cutting had no significant effect on stormflows or annual runoff.

3. Clearcutting increased peak flows more than selection cutting and no cutting by 0.5 cfs 1st year and .2 to .3 cfs both of next 2 years.

4. Mean annual sediment and water yield changes were significantly affected by clearcutting during first 2 post-treatment years:

WY	Treatment	Sediment Yield and Concentrations Annual Loss lb/ac. +/- SD	Concentration mg/l +/- SD	Water Yield inches
Baseline 1981	CC	37 +/- 47	52 +/- 48	2.5
	SC	46 +/- 30	106 +/-118	
	Control	46 +/- 54	68 +/- 71	
After Treatment				
1982	CC	236 +/- 55	208 +/- 52	5.2
	SC	12 +/- 1	28 +/- 11	
	Control	4 +/- 6	22 +/- 21	
1983	CC	56 +/- 25	14 +/- 7	17.6
	SC	23 +/- 15	7 +/- 1	
	Control	17 +/- 7	6 +/- 2	
1984	CC	74 +/- 45	24 +/- 9	12.9
	SC	13 +/- 10	9 +/- 4	
	Control	41 +/- 34	24 +/- 17	

LRA 133 Southern Coastal Plain

"Forest Harvesting and Site Preparation Impacts on Stormflow and Water Quality in East Texas" by W. Blackburn, J. Wood and M.DeHaven in Forestry and Water Quality: a mid-South Symposium, Little Rock, AR, 1985, p 74-93.

Nine small (6.4-6.8 ac) forested watersheds in East Texas instrumented 1979 with 3 replications of 3 treatments:

1. Clearcutting, 6-9/1980, then shearing, windrowing and w. burning, hand plant 2/81 of shortleaf pine and mixed hardwoods, 4-25% slopes.
2. Clearcutting, 6-9/1980 then roller chopping and broadcast burning, hand planted 2/81.
3. Undisturbed control.

Buffer strip of undisturbed vegetation of 20 to 60 ft. wide was left along each side of channels as a BMP.

Results

1. Ground Cover: Bare soil 58% on sheared watersheds; 15% chopped; 4% control.
2. Stormflow: 1st year up 5.8" on sheared watersheds, 3.3" chopped; 1.0" on the control watersheds. It declined to less than half of the first year in years 2-4.

3. Sediment losses from pre-sheared watersheds: 305 lb/ac; from pre-chopped 77 lb/ac, mostly (98%) from channel erosion during an intense rainstorm on 5/15/80. After treatment: 18 events resulted in 2,620 lb/ac yield from sheared watersheds, 22 lb/ac from chopped and 29 lb/ac from controls in 1981. Sediment sources were sheet erosion and channel scouring, scalping of surface soil on some steeper slopes exposed clay-textured B horizon which then eroded severely.

4. Sediment losses in 1982 (yr. 2) were 71.3 lb/ac for sheared, 4.9 lb/ac for chopped and 4.5 lb/ac for control, declines due to low runoff and revegetation. Sheared watersheds sedimentation was much less in 2, 3, and 4th years, but still higher than chopped or undisturbed watersheds, because of less exposed mineral soil.

5. Nutrient Losses, lb/acre:

	Nitrates				Tot. Nitrogen				Ortho-Phos				Tot. Phos		
	Pre	Yr 1	Yr 2	Yr3	Pre	Yr 1	Yr 2	Yr3	Pre	Yr 1	Yr 2	Yr 3	Pre	Yr1	By Yr 4
Shear	.007	.267	.035	.033	.23	.86	.3	.3		.0348	Low			.2967	Close
Chop	.007	.071	.005	.006	.29	.60	.12	.18		.0130	and			.0346	to the
Con-trol	.007	.003	.002	.002	.24	.16	.05	.07	.005	.003	Similar		.0245	.0137	Control Level

6. Sediment losses in 1983 (Yr 3) were 30.9 lb/ac for sheared and remained about the same on the chopped and control sites.

"Prescribed Fire Effects on Water Quality and Forest Nutrient Cycling" by D. Richter; C. Ralston and W. Harms in Science (Wash D.C.), 215 (4533). 1982, p.661-663.

Prescribed fire, a practice applied annually to 250,000 acres of forests in the southeastern USA, had limited effects on soils, nutrient cycling and hydrologic systems of a coastal plain pine forest. Hydrologic fluxes of N, P, S and basic cations, from burned pine litter to ground and stream waters, are not likely to have appreciable impacts on water quality in the Coastal Plain.

"Determining the Effects of Forest Management on Water Quality, Quantity, and Timing" by J. Hewlett, Research Progress Report, Univ of Georgia, Athens, for period FY 84.

OBJECTIVES: Complete the objectives of the project now titled "Impacts of forest land management on water quality in the southeast." Publish analyses of the effects of clear-cutting, site preparation and planting on dissolved and

suspended mineral load, stormflow and water temperature. Assist in the establishment of an extension of the project into neighboring State of Florida, where data on sediment deliveries under forest management will represent the Coastal Plains of South Georgia.

APPROACH: Accumulated data on water quality, stormflows and temperature from the Grant Memorial Forest will continue to be analyzed by regression methods to quantify the effects. Additional observations will be made on water quality within the Grant Forest to assess the temporal variance and spatial behaviour of these parameters. Firm conclusions will be drawn concerning the practical significance of hydrological impacts of forest management in Georgia and adjoining states. Further demonstration of proper logging road layout and construction will be made on private or public land as a practical remedy for the most serious impacts (sediment from roads) reported earlier from this experiment.

PROGRESS: 84/01 - 84/03

Since the last report, all papers so far prepared under this project have been published. Progress this period includes consolidation and storage of basic hydrological and chemical data collected for the entire period of the active experiment. About two dozen papers and documents were produced, but more importantly the project remains the single most important experiment conducted in the East on the effects of clearcutting on water quality, quantity and timing. The results are already incorporated into the planning and practice of silviculture, including scheduling, patterning and execution of clearcuts, as well as in road design, location and construction to avoid sediment exports.

PUBLICATIONS: 84/01 84/03

HEWLETT, J.D., POST, H.E. and DOSS, R. 1984. Effect of clear-cut silviculture on dissolved ion export and water yield in the Piedmont. Water Resources Research. Vol. 20, No. 7. pp. 1030-1038.

HEWLETT, J.D. and DOSS, R. 1984. Forest, floods, and erosion: a watershed experiment in the southeastern Piedmont. Forest Science, Vol. 30, No.2, pp. 424-434.

HEWLETT, J.D., FORTSON, J.C. and CUNNINGHAM, G.B. 1984. Additional tests on the effect of rainfall intensity on storm flow and peak flow from wild-land basins. Water Resources Research, Vol. 20, No. 7, pp. 985-989.

"Prescribed Fire: Effects on Water Quality and Forest Nutrient Cycle" by Richter, D. D.; Ralston, C. W.; Harms, W. R. in Science, Vol 215, No 4533, pp. 661-663, February 5, 1982.

This report examines both off-site and on-site effects of a series of prescribed fires on experimental watersheds in the lower Coastal Plain of South Carolina. Studies of off-site effects were concerned with fire caused exports of materials from a pine forest ecosystem to drainage waters and the atmosphere, while on-site effects focused on the magnitude and extent of hydrologic fluxes of nutrients from burned litter to mineral soils and ground waters. Hydrologic nutrient fluxes from burned forest floors were evaluated from the nutrient contents of litter samples collected immediately after the fire and again after postburn rainfall of about 15 cm.

The contents of total nitrogen, phosphorus and sulfur in burned forest floors were not significantly changed by the initial rainfall. Analysis of

mineral soil collections before fire and after fire and rain indicated minor effects of fires on mineral soil chemical properties, despite variations in fire intensities and in postburn leaching conditions. The changes in total mineral soil carbon, nitrogen and phosphorus were small.

No fire effects were observed on specific conductance, pH, or dissolved concentrations of ammonium, nitrates, phosphates, sulfates, chlorides, calcium, magnesium, potassium or sodium in ground waters collected from surface soil and subsoil horizons. No changes were noted in the chemical constituents of streams which could be attributed to the fire treatment.

"Intensive Site preparation and Sediment Losses on Steep Watersheds in the Gulf Coastal Plain" by Beasley, R. S. in Soil Science Society of America Journal, Vol. 43, No. 2, p 412-417, March-April 1979.

The hydrologic effects of 3 methods of intensive site preparation, brush chopping, shearing and windrowing, and bedding on contour were measured during the 1976 and 1977 water-years on 3 small watersheds on steep terrain in northern Mississippi. After site preparation, the treated watersheds were fertilized, limed, sown with clover, and planted with loblolly pine seedlings. An undisturbed watershed served as a control. Site preparation exposed soil on 37% of the chopped watershed, on 53% of the sheared and windrowed watershed, and on 69% of the bedded watershed.

First-year sediment losses for the chopped, sheared, bedded, and control watersheds were 12.5, 12.8, 14.2, and 0.6 metric tons/ha, respectively. Sediment concentrations for the 4 watersheds were 2,471; 2,837; 2,127 mg/liter of stormflow. Most of the first-year sediment losses occurred during months of highest stormflows, November, January, February, and March. Stream channel scouring was a major source of sediment on the site prepared watersheds.

Second-year sediment yields from the chopped, sheared, and bedded watersheds decreased to 2.3, 2.2, and 5.5 metric tons/ha, while sediment from the control watershed decreased to 0.1 tons/ha. Sediment concentrations were 670, 794, 2,346, and 393 mg/liter for the 4 watersheds. In relation to annual precipitation, total stormflow decreased on all treated watersheds the second year.

"Water quality effects of clearcutting upper coastal plain loblolly pine plantations" by McClurkin, D.; Duffy, P.; Ursic, S.; Nelson, N. in Journal of Environmental Quality 1985. 14 (3): 329-332.

The effect of clearcutting loblolly pine (Pinus taeda) on concentrations of sediment and nutrients in stormflows was studied on small catchments near Lexington, Tennessee. The plantations were established on eroded and abandoned agricultural lands with fragile soils. Soil series on the catchments include Lexington silt loam, Providence silt loam and Ruston sandy loam. On eight catchments (0.17-0.56 ha) stormflow was measured and integrated samples of the flow were obtained. Plantations on four catchments were clearcut; the other four were left as uncut controls. Stormflow samples were analyzed for sediment-phase total Kjeldahl nitrogen (TKN), total phosphorus (TP) and solution-phase TKN, TP, and potassium (K).

Rainfall inputs of TKN, TP, and K were found to exceed losses in stormflows. The study demonstrated that pine plantations on some of the most fragile soils in the upper Coastal Plain could be clearcut without significant impact on water quality if recommended harvesting practices were observed.

However, it was clearly beneficial to minimize erosion losses as one-third or more of the TKN and two-thirds or more of the TP exported from all sites in stormflows was via the sediment.

"Forest site preparation and water quality in Texas" by Blackburn, W.; DeHaven, M.; Knight, R. W. in Proceedings of the Specialty Conference on Environmentally Sound Water and Soil Management [edited by Kruse, E.G.; Burdick, C.R.; Yousef, Y.A.], American Society of Civil Engineers, 1982. pp 57-66.

Nine small watersheds were instrumented in East Texas to determine the effect of site preparation practices applied in 1980 on water quality and yield. Following treatment, during the first 8 months of 1981, stormflow volumes increased with the intensity of the site disturbance. Watersheds sheared and windrowed produced the greatest amount of stormflow (7.77 cm), followed by roller chopping (4.04 cm) and the undisturbed watersheds (0.78 cm). The shearing and windrowing treatment exposed 59% of the mineral soil as compared to 16% on the chopped watersheds.

Sediment losses were significantly greater from the sheared (2201 kg/ha) than from the chopped (13 kg/ha) or undisturbed watersheds (3 kg/ha). Total nitrogen losses were nearly 20 times greater from sheared (2.14 kg/ha) than from undisturbed (0.12 kg/h) watersheds, and three times greater than from chopped or undisturbed watersheds. Potassium, magnesium and sodium export was highest on the sheared watersheds; however, calcium export was greater from the chopped watersheds.

"Multi-resource effects of harvest, site preparation, and planting in pine flatwoods" by Swindel, B.; Marion, W.; Harris, L.; Morris, L.; Pritchett, W. Conde, L.; Riekerk, H.; Sullivan, E. in Southern Journal of Applied Forestry 1983. 7 (1): 6-15.

A report, incorporating published results and results in press, of studies of three catchment areas (a= 165 ac., b= 120 ac, c= 345 ac.) in naturally regenerated, 40-yr-old slash/longleaf pine forest in the lower Coastal Plain, N. central Florida. Areas (a) and (b) were harvested, prepared and replanted over the period Nov. 1978 to Nov. 1979 with (a) less ecologically disruptive and (b) more disruptive management regimes than those typical in the area. Treatment for (b) included burning, windrowing and harrowing and bedding. Site (a) was prepared only by chopping and bedding and (c), the control, was not treated.

Effects on sediment production, water quality and yield, flora and small mammal populations were monitored. Water yield increased during treatment. This increase was substantially greater when more of the area was harvested and intensively prepared as in (b). Treatment increased stormflow, especially for medium-sized storms. Peak flowrates increased only when the stream channel was exposed to more intensive site preparation in area (b).

Changes in water quality were small and transient: concentration of K, Ca and suspended sediment increased in (a) and (b) relative to the control (c). There was substantial soil and nutrient relocation with windrowing. Floral composition was altered by both types of site preparation, the frequency of herbaceous species increasing while that of woody species decreased. Plant species diversity was initially increased by less intensive practices. Winter bird densities increased.

Group G Silty Uplands & Blackland Prairie
LRA 134, 135

LRA 134

"Hydrologic Effects of Prescribed Burning and Deadening Upland Hardwoods in Northern Mississippi" by S. Ursic, 1970. Res. Paper SO-54

Rainfall, runoff and sediment were recorded on 3 small (2-3 ac) watersheds from 1958-1963 on very erosive sandy and loessial soils (silt loams). Two watersheds were burned, hardwoods (oak and hickory) deadened and loblolly planted, a third watershed was the control. The area is in the Upper Coastal Plain, 53" mean annual precipitation, with a land use history of grazing and burning abuse with sheet erosion, but no gully erosion. Slopes 10% on ridges to 45% on hillsides. Burned 12/19/1963 with slow backfire that consumed the L layer, but not F layer of A horizon. Sprayed with 2,4-D amine and 2,4,5-T in May and June 1964.

Results

I. Runoff

1. Stormflow volumes up significantly all 3 years after treatment by 26-30% (range 16-54%), mostly from a few large storms.

2. Overland flow volumes up all 3 years on watersheds lb2 and two of three years on watershed lb3 by 22-27%.

3. Peak discharges up by 28-36% from 24% of the storm events.

II. Sediment

Pretreatment: watershed II produced twice yields of watershed I (control) or watershed III.

1st year after treatment sandy watershed II increased sediment by 385 lb/ac (48%) over the control watershed. The loess watershed III increased sediment yield by 471 lb/ac (119%) over the control.

2nd year after treatment watershed II increase of 30 lb/ac (8%) over control watershed. Watershed III increased 228 lb/ac (127%) over control.

3rd year after treatment watershed II decreased sediment 32 lb/ac compared to the control while watershed III increased yield by 70 lb/ac (121%).

LRA 133A, 134

"Hydrologic Effects of Forestry Practices in (N.) Mississippi" by S. Ursic and P. Duffy in Proceedings, Mississippi Water Resource Conf., 1986, p. 85-88.

I. Undisturbed loblolly pine forests of N. Mississippi: A typical hydrologic cycle consists of 53 inches of annual rainfall, 10 inches of interception by the forest canopy and floor, 25 inches of transpiration and evaporation by the forest and soil, leaving about 18 inches of annual stream runoff.

Storm runoff as a percentage of precipitation ranges from 0.1 to 16%, with the higher end from watersheds with restricted soil drainage or high drainage densities.

Average annual base rate for sediment yields from undistrubed pine types was .007 ton/acre-inch of stormflow. The average rate for 14 data sets on 12 studies ranged from .002 to .012 t/ai and averaged .006 t/ai from 37 watersheds in 8 Southern States with 189 years of record. Concentrations from single large storms may be 10 times this average or more because of sediment flushing on these intermittent channels.

Sediment particles carry twice the phosphorus and the same nitrogen loads as the dissolved forms of both these nutrients.

II Effects of Management Practices:

a. Planting pine on abandoned farmland cuts storm runoff by 50% in less than 10 years.

b. Replacing poor quality hardwoods with pine decreases stormflows 80% in 12-13 years, with amount of effect proportional to rainfall. Largest reductions in stormflows occurred on moderately eroded, silt-loam soils, compared to areas with similar but more severely eroded soils.

c. Harvesting did not significantly change soil solution concentration of total Kjeldahl nitrogen, total phosphorous or potassium. Averaging all watersheds before and after treatment for the 4.5 years of sampling, about 75% of the TKN and T.P. losses in stormflows were via sediment.

"Changes in Forest Floor and Water Quality Following Thinning and Clearcutting of 20-year Old Pine" by D. McClurkin, P. Duffy and N. Nelson in Journal of Environmental Quality, 1987, 16(3): p. 237-241.

Effects of timber cutting on the forest floor, sediment movement and chemical quality of percolating water and of plot runoff are reported for pole sized loblolly pine plantations on fragile soils of Mississippi. Treatments were clearcut, thin and undisturbed controls. Water quality measurements were made on runoff samples from 0.002-ha plots and for percolating water from zero-tension lysimeters at 6 inch depth. Forest floor on clearcut plots was reduced to near the minimum regarded as necessary for site protection within two years.

Regardless of cutting treatment, more N and P were coming into the plots via rainfall than were leaving via plot runoff and percolation combined. More K appeared to be leaving the sites than was coming in via rainfall. Sediment concentrations in plot runoff tended to be proportional to cutting intensity, whereas nutrient content in percolation was not related to the intensity. Nutrient content in plot runoff was high compared to concentrations reported in

stormflows from local, small catchments with similar characteristics. Plot runoff was only 3% of annual rainfall.

Group H Southern Piedmont
(LRA 136)

"Man-Induced Soil Erosion on the Southern Piedmont, 1700-1970" by S. Trimble, 1974, Soil Conservation Society of America, 180 pp.

The Southern Piedmont has lost an average of 7" depth of topsoil since European settlement, some 6 cubic miles. Alabama Piedmont lost 7", GA 7.5", SC 9.5", NC & VA 5.5". Maximum loss was in lower (SE) Piedmont of SC and Georgia, and minimum loss was in eastern Piedmont of North Carolina.

Aboriginal erosion was present from mass failures in mountains, stream erosion, Indian farming, forest fires and animal trails, but was very low. Almost all streams/rivers were crystal clear, bottomland soils were dark, rich and mature, and archeological sites along Savannah River show "no evidence of silt deposition during prehistoric times."

As whites and slaves moved in, lands were farmed until depleted when they moved on and repeated this erosion process - more inland and southwesterly across the Piedmont, from 1700 to about 1920.

The Piedmont is quite erosive due to natural conditions:

1. Moderate-highly erosive soils derived from acid igneous rocks, basic igneous rocks, Carolina slate, shale and sandstone, micaceous crystalline rocks. For this area, the "K" factor varies .24 to .43, with .32-.33 average.

2. Mantle of weathered material (saprolite) is usually 25-50 feet thick; and easily gullied.

3. High erosive energy of rainfall with "R" factor of <200 in. VA to >350 in. southwest Alabama.

4. Greatest amount of erosion occurred generally 1860-1920. As farm tenancy has declined from 56% in 1920 to 8% in 1970, erosive land use has declined. However, present stream sedimentation still reflects past upland losses. Suspended sediment of Chattahoochee River in Atlanta during month of August has declined from 800+ ppm in 1931 to <100 ppm in 1952. The Dan River at Danville, VA averaged 1314 ppm between 1925-30; 268 ppm for 1930-39, 134 ppm for 1940-49; 129 ppm for 1950-59 and 63 ppm for 1960-70. Declines in stream turbity in much of Georgia and South Carolina has been pronounced: annual rates of 300-400 ppm in early 1930's declined to well below 100 ppm by early 1950's.

Present (1974) average turbidity or suspended sediment for entire Piedmont is about 35 ppm, based on city water treatment plan records.

Pee Dee R., N.C., was transporting 154 tons/sq.mi of sediment in 1909. By 1950-69, this rate was only 50 tons/mi^2/yr. The Ogeechee R. at Eden, Ga.,

dropped from 225 tons/mi^2/yr in 1909 to 23 tons/mi^2/yr in 1950-69. In many cases, large upstream reservoirs are responsible for these declines.

Old sediment deposits are now being dissected and eroded away by the cleaner water, rivers are lowering their beds - as much as 12 ft. - and friable stream banks are being eroded. The sediment is transported farther downstream where it is re-deposited in stream channels and on floodplains. Some presently aggrading areas have already undergone heavy sedimentation, while others little. In the former, stream channels are aggraded further, more overbank deposition occurs and the amount of wetland increases, even to perennial ponds and lakes.

Where minor sedimentation took place, sediment migration is now occurring with channel-filling, overbank deposition and formation of new wetlands.

It is likely these fluvial processes are present throughout the Piedmont now - it has been shown to be widespread on the middle Georgia Piedmont in Regions III and IV because of the decline in agricultural row crops, the transition of farmer cropland to forest and pasture, and widespread use of soil conservation practices. Region III is Cotton Plantation Area. Region IV is Cotton & General Farming Area.

"Stream Protection During Forest Road Construction" by R. Lafayette and M. Callaham in Symposium on Watershed Management, 1980, American Society Civil Engineers, Boise, ID.

A sediment barrier of 6'x6' piled brush faced with 8000 sq ft polypropylene filter fabric (Bidum C-22) was used to prevent soil eroded during logging road construction and use from entering Wildhog Creek.

Other BMP measures: 8 culverts per 1000 ft. of road instead of three, road banks were seeded, fertilized, limed and asphalt-mulched. Over a 15-month period in 1978-79, water samplers above and below road project pumped samples every 3 hrs. for turbidity, conductivity and suspended sediment; benthic macroinvertebrates were sampled six times and channel stability was evaluated.

Results:

1. Overall, turbidity generally declined from pre-to-post project. It increased slightly while road was in use during 1" rainstorms.

2. Specific conductance declined overall after peaking during road construction - probably from lime and fertilizer applied to road banks.

3. Suspended sediment increased about 50% from pre-project during road construction then declined to baseline condition - probably due to blow-out of a silt fence at three culverts during a heavy rainstorm in 8/78.

4. No change in benthic invertebrates nor channel stability from project.

5. Silt fence/brush barrier trapped 80-90 yd^3 (about 100 tons/ac/yr) of soil. Stream was 30 to 300 feet away, with 90 feet being average. Roughly 40-60% of trapped soil would have become stream sediment.

"Forest Water Quality: An Experiment in Harvesting and Regenerating Piedmont Forest" by J. Hewlett, 1978, A Georgia Forest Research Paper, School of Forest Resources, Univ. of Georgia, Athens, GA., 22 p.

Two 1st order streams in 80 ac and 105 ac watersheds in Putnam County, GA, were selected in 1973 to determine effects of forest harvest and regeneration on water quality, quantity and regime.

The 105 ac watershed was the control. The 80 ac watershed was clearcut winter '74-75, roller chopped twice (spring and fall '75) and machine planted (spring '76). 60% of area had been severely eroded by cotton farming from 1880-1920. Soils are all in A or B hydrologic group and have K factor of .24. 12 sub-basins were instrumented: 8 in clearcut and 4 in control basin; each sub-basin ranged from 0.5-4 acres with small H-flume, recorder and Coshocton wheel samplers. Coarse sediments were trapped and measured in rubber-lined box above the flume after each storm, recording water thermometers and weekly grab samples, 2 weighing bucket and 4 non-recording raingages were operated.

The 80 ac basin was planted to loblolly with a 6 ft. V blade pulled by a TD 257 dozer w/blade pushed to average depth of 4-6", exposing B-horizon soils over 45-50% of the watershed. About 5-10% of area produced coarse sediment delivery to 1st order channels from accidental or purposeful blading of old gullies during roller chopping and planting, while fine sediments came from same areas as coarser material during chopping plus a much larger area after machine planting. Road and channel damage from 4 years of operation.

Results:

1. Average annual sediment export was 157 pounds/ac/yr of which 82 lb/ac will be normal yield from uncut forest. Actual export following machine planting reached 3568 lb/ac in this experiment. The entire 2nd year produced 2140 lbs/ac. Return to geologic rate in year six. Peak increase was 7140 lb/ac/yr after road construction and planting.

2. Geologic erosion rate in area is 82 lb/ac/yr.

3. 90% of sediment increase of 728 lb/ac/yr came from bad roading and channel damage by logging equipment operating inside streamside management zones.

4. Total accelerated sediment export was about 800 lb/ac/yr, of which silviculture accounts for 75 lb/ac/yr and roads/channels accounts for 728 lb/ac/yr.

5. Two stream crossings with "soil and brush bridges [used] during 2 rainy weeks in January with no effort to repair the damage will in the long run have caused 90% of all damage to water quality by sediment during the harvest."

6. Water temperature: Midsummer daytime average increases of $6^{O}C$ ($11^{O}F$) from $68^{O}F$ to $79^{O}F$, have persisted for all 3 years since cutting despite leaving a thin uncut buffer strip of about 20 feet. Winter minimum temperatures decreased 6 degrees C the first year, but had recovered by year 3.

7. Water yield increased 10 area-inches the 1st year after logging, and is retreating toward normal as reforestation occurs. Soil moisture increased and in some low spots growth of sedges and other water-loving plants increased.

Stormflow volume increased by 27% from 1" runoff events, but by only 10% where stormflow runoff exceeded 2 inches. Roller chopping and machine planting doubled peak flows when peaks were under 100 cfs/sq.mi. This increase declined at higher peaks. Likely causes of increased discharge rates and volumes were reactivation of old gullies, exposure and compaction of soils from road and planting operations and increases in near-channel soil moisture after clearcutting.

8. Forest operations did not significantly affect baseflow concentrations of nitrate, TKN, total phosphorus, K, Na, Ca, Mg, EC or pH, but because water yield was increased, short-term increases (<1 kg/ha/mo) occurred in the export of some dissolved minerals. All levels returned to normal after 3 years.

Recommended BMP's:

1. Advanced layout of roads
2. Contract supervision
3. Wider buffer strips

"Runoff and Soil Erosion from Forest Site Preparation Practices" 1980, by J. Douglass and O. Goodwin <u>in</u> U.S. Forestry and Water Quality: What Course in the 80's?, Proceedings of Water Pollution Control Federation Conference, June 19-20, 1980, Richmond, Va., pp 50-74.

Soil losses in runoff were measured for 3 years after mechanical site preparation treatments were applied on 16 small (.5-2 acres) watersheds in the North Carolina Piedmont. Treatments were: KG only, KG and disk; KG, disk and plant grass, and undisturbed control, replicated at 4 locations. Percent ground cover and runoff account for soil loss variability.

Erosion varied from 1.0 to 14,000 pounds/acre, depending on cover percent and ephemeral channel lengths. Windrowing and burning were done on all treatments except control. Study ran 1/76-1/79; 8-14% slopes on watersheds.

<u>Results</u>

1.

	1976		1977		1978	
Treatment	Erosion lb/ac	Runoff in.	Erosion lb/ac	Runoff in.	Erosion lb/ac	Runoff in.
Mean Control	31	1.61	10	0.92	20	1.84
Mean KG & Disk	8680	15.19	6233	10.45	4495	10.62
Mean KG only	3123	4.38	1173	6.50	562	4.65
Mean KG, Disk, Seed	642	3.44	118	2.47	71	3.24

2. Data from severe gully erosion on two watersheds after treatment and the first year results on watersheds 14 and 18 were omitted from this table because

slash and soil piled in the channels of these watersheds produced excessively high rates of soil loss when burned.

3. A regression equation for predicting annual soil loss from percent ground cover and length of ephemeral channels developed from this study is:

$\log_e$ (Annual soil loss lb/ac)= 4.898 - 0.0657 (% ground cov.) + 0.963 $\log_e$ (ephemeral channel length); r = .86

4. Soil loss increased sharply as ground cover dropped below 40%. Ground cover is litter, wood, stone, herbaceous material, grass.

"Sediment Source Areas, Delivery Ratios and Influencing Morphological Factors" by J. Roehl in I.A.S.H. Commission of Land Erosion Publication 59, pp 202-213, 1962.

1. Design studies for 371 floodwater retarding structures throughout SE USA on 1-4 sq.mi drainages quantified sheet and channel erosion, with sheet dominating by far. Relative differences in erosion by physiographic province were:

Province	% Sheet Erosion	% Channel Erosion
So. Coastal Plain	100-69	0-31
So. Piedmont	100-66	0-34
So. Miss. Valley Loess	84-77	16-23
Blackland Prairie	100-77	0-23
Sand Mtn. Area	100	0
So. Appalachian Ridge/Valley	100-99	0-1
Blue Ridge	99-86	1-14

2. Sediment delivery ratio varies inversely with size of watershed, from about 65% @ .01 mi^2, 30% @ 1.0 mi^2, 20% @ 10 mi^2, 10% @ 100 mi^2.

3. Sediment delivery ratio varies with relief to length ratio of basin as follows:

Log SDR = 2.94259 - .82362 colog R/L; where R/L is relief-length ratio defined as: Relief in ft., the average elevation of watershed divide at headwaters of the main channel minus the elevation of stream bed at point of sediment yield measurement. Length, in feet, is distance measured parallel to the main stem from point of sediment yield measurement to watershed divide.

4. In the Piedmont Area alone, Log SDR = 2.88753 - 0.83291 colog R/L.

"Prescribed Fire on Water Quality and its Potential as a Site preparation Treatment for Natural Regeneration" by D. Van Lear and J. Douglass. Unpublished research progress report for FY 85, Clemson Univ., Clemson, SC.

OBJECTIVES: Determine the effects of prescribed fire on water quality of ephemeral streams. Secondly, to evaluate the feasibility of using prescribed

fire with seed-tree cutting to naturally regenerate loblolly pine in the Piedmont.

APPROACH: Instrument small watersheds with H-flumes and Coshocton samplers and monitor water quality for one year. At the end of this period, half the watersheds will be burned, and water quality will be monitored for an additional year. Then a seed-tree cut will be made, and water quality and natural regeneration of loblolly will be evaluated over a two-year period.

PROGRESS: 75/06 - 85/12
Low intensity prescribed fire in mature loblolly pine stands in the Piedmont of South Carolina had no adverse effects on water quality of ephermeral streams. Neither suspended sediment levels nor nutrient concentrations in storm runoff were significantly affected by two prescribed fires. The presence of residual forest floor materials after burning and the rapid infiltration rates of these soils account for the lack of overland flow and low erosion rates. Nutrients in the ash were apparently immobilized or absorbed on the exchange complex of the soil after burning. Results of this study indicate that moderate to steep slopes in the Piedmont can be burned with low intensity fires prior to harvest to control hardwood understories and prepared seedbeds with no significant impact on water quality.

PUBLICATIONS: 75/06 85/12
VAN LEAR, D.H. and WALDROP, T.A. 1986. Current practices and recent advances in prescribed burning. Southern Forestry Symposium, Atlanta, GA. Nov. 18-21, 1985.

"Water Quality of Ephemeral Forest Streams After Site Preparation with the Herbicide Hexazinone" by Neary D.G; Bush P B; Grant M.A. in For Ecol Manage 14 (1). 1986, pp 23-40.

Four small watersheds (1 ha) in the upper Piedmont of north Georgia were treated with 1.68 kg/ha active ingredient of hexazinone pellets. Residues in stormflow peaked in the first storm (442 mg m-3), declined rapidly thereafter, and disappeared within 7 months. Loss of hexazinone in stormflow averaged 0.53% of the applied herbicide.

Suspended solids concentrations in runoff from the treated watersheds averaged 50.4 +/- 7.9 g m-3 and were slightly more than those of the control (36.4 +/- 5.4 g m-3). Total sediment yields were increased by a factor of 2.5 due to increased runoff associated with site preparation using herbicide and salvage logging. However, sediment loadings remained below those produced by mechanical techniques and well within levels common in relatively undisturbed forests.

Hexazinone treatment produced a large increase in NO3-N concentrations (peak of 5328 mg m-3), but NO3-N levels returned to normal within 2 years. Data indicate that hexazinone may have produced some stimulation of nitrifying bacteria. Cation concentrations increased 30-100% as a result of hexazinone application, but these increases were also transient. Overall, water quality changes were small and short-lived.

"Sediment and Nutrient Export in Runoff from Burned and Harvested Pine Watersheds in the South Carolina Piedmont" by D. H. Van Lear, J. Douglass, S. Cox and M. Augspurger, in J. of Environmental Quality, 1985, 14 (2): 169-174.

Soil and nutrient export in ephemeral flow were studied over a 3-yr period following clearcutting three loblolly pine (Pinus taeda) watersheds (0.60-1.24 ha). Two preharvest, low-intensity prescribed fires had no effect on flow or water quality. Harvesting after the third prescribed fire significantly increased sediment concentration and export, but increases were minor compared with sediment export reported for mechanical site preparation.

Nutrient concentrations varied among watershed locations because of differences in surface soil depth, but were generally unaffected by harvest. Because harvest increased runoff, nutrient export (concentration X flow) was generally increased. Results of this study show that loblolly pine stands in the erosive Piedmont physiographic region can be harvested following a series of low-intensity prescribed fires with minimal soil loss or degradation of water quality.

"A Decision Model to Predict Sediment Yield from Forest Practices" by Burns, R. G. and Hewlett, J. D. in Water Resources Bulletin 1983. 19 (1): 9-14.

For selecting best management practices, the prediction of sediment yield to perennial streams following various forest land operations is necessary. The Universal soil loss equation (USLE) is not directly applicable to forest operations because of the heterogeneous soil surface conditions left by harvesting, site preparation, and planting. A sediment hazard index (W) is proposed, to be based on the amount of exposed mineral soil and its proximity to streams. A model is presented which includes rainfall erosivity, soil erodibility and average land slope, together with the index W.

A paired watershed experiment in the central Georgia Piedmont was used to estimate parameters in the model. The experimental basin (80 acres) was clearcut, drum roller chopped twice, and planted by machine. The standard error of estimate of sediment yield was computed to be about 50 lbs/ac per sampling period (four months). Use of William's erosivity index (storm flow times peak flow) reduced the standard error to 33 lbs/ac.

"Prescribed Burning and Water Quality of Ephemeral Streams in the Piedmont of South Carolina" by Douglass, J. E.and D. H. Van Lear in Forest Science 1983, 29 (1): 181-189.

Soil and nutrient export were monitored in 4 pairs of adjacent catchments planted with 36-37 yr old loblolly pine, before and after two prescribed burns 18 months apart (1977-78) carried out in one of each pair and designed to prepare the stands for regeneration. The burns did not significantly affect storm runoff, sediment concentrations, or sediment export from the catchment areas. Both runoff and sediment export increased from one area, but this was due to an outbreak of Dendroctonus frontalis rather than burning. There were no significant changes in NO3-N, NH4-N, Ca, Mg or K concentrations or export after either burn.

"Impact of Hexazinone on Invertebrates After Application to Forested Watersheds" by D. Mayack; P. Bush; D. Neary; J. Douglass in Archives of Environmental Contamination and Toxicology, Vol 11, No 2, pp. 209-217, 1982.

The effect of the herbicide hexazinone (useful in reforestation) on aquatic macrophytes, aquatic and terrestrial invertebrates was assessed in the Chattahoochee National Forest, Georgia. Pelletized hexazinone was applied at the rate of 16.8 kg per ha to four small watersheds in the forest on April 23, 1979. One untreated watershed served as a control.

During the 8-month monitoring period hexazinone levels in samples of stream water were generally below the 1 ppb detection limit except for three peaks of 10 to 40 ppb in July-August and three very minor peaks at other times. The peaks did not appear to be correlated with storms. Traces of hexazinone or metabolites were found in aquatic macrophytes on a few occasions. The forest floor litter contained residues of hexazinone and metabolites for about 90 days after application. The highest levels were 0.18 +/- 0.19 ppm hexazinone (dry weight basis) and 0.10 +/- 0.17 ppm metabolite 5 days after the first rainfall. No major changes in species composition or diversity were detected in aquatic or terrestrial invertebrates. Most samples of aquatic and terrestrial invertebrates contained no detectable herbicide residues. On a few occasions there were detectable hexazinone and/or metabolites at average levels of less than 2 ppm (wet weight basis).

Group I Sand Hills and Florida Ridges (LRA 137, 138)

No reports were found for this area.

Group J Northern Piedmont (LRA 148)

"Movement and Persistence of 2,4,5-Trichlorophenoxyacetic Acid in a Forest Watershed in the Eastern United States" by L. Norris; M. Montgomery; B. Loper and J. Kochenderfer in Environmental Toxicology and Chemistry, 1984, 3, pp. 535-549.

About 98% of a 22-ha catchment area in West Virginia was aerially sprayed with 2.24 kg/ha of 2,4,5-T in August 1975. Samples of vegetation, forest floor, stream water and soil were collected before and immediately after treatment and 1 wk, 1, 3, 6, 12 and 24 months later. Mean herbicide residue in the foliage and shoot tips of 4 vegetation types used as browse was 151 mg/kg, immediately after application, declining to 0.07 and 0.01 mg/kg after 12 and 24 months. Residues in the forest floor decreased from 31 mg/m2 (0.31 kg/ha) immediately after application to 2 mg/sq.m after 12 months and 1.6 mg/sq.m after 24 months. The concentration in top soil (0-15 cm) decreased by 90% in 1 month and then remained relatively constant. Less than 0.01 mg/kg was found deeper than 15 cm after 3 months.

Throughfall transferred 34 mg/sq.m to the forest floor with 79% occurring during the first 2 wk, during which time there was 16.9 cm precipitation. About 6 mg/sq.m was transferred to the forest floor in freshly-fallen litter. The highest concn. of 2,4,5-T in stream water during application was 0.012 mg/liter. The highest concentration measured (0.05 mg/liter) occurred 4.5 hr

after the start of application, presumably the result of 0.38 cm of rain that fell 2.5-6.0 h after beginning application. None was found 13 days after application. A total of 8.4 gm (0.017% of the amount applied) was discharged from the catchment area in streamflow. It was concluded that the 2,4,5-T concentration detected were substantially below those likely to cause toxic effects in animals.

Group K Coastal Flatwoods
(LRA 152, 153)

LRA 153-A Atlantic Coast Flatwoods

"Effects of Clearcutting and Site preparation on Water Yields From Slash Pine Forests" by B. Swindel, C. Lassiter and H. Riekerk, 1982, in Forest Ecology and Management, 4 (1982) 101-113.

Three contiguous watersheds of 67,49 and 140 ha. (watersheds 1,2,3) on a flatwood landscape near Starke, Florida were formed by building up existing roads and constructing new roads to form artificial dikes that obstructed surface and lateral groundwater movement. Monitored for more than three years with flumes, including one year of calibration (10/17/77 - 10/31/78).

Treatments (Nov. 78 thru Nov. 79):

Watershed 1: Manual clearcut harvest merchantable (4" dbh) pine on 59% of watershed area, delimb and buck into 4' bolts, stacked by hand and removed by small pre-handler. Debris and residual understory were double chopped with roller drum chopper. Bedding and machine planted. Main drainageway lies within pond cypress and hardwood stands that comprise 41% of watershed and were undisturbed. Most green vegetation remained.

Watershed 2: Merchantable (5" dbh) pine were felled and stacked with tops left by feller-bencher shear machine, skidded to delimbing gates, delimbed, and loaded tree length on tractor trailers. Lightwood stumps, extracted by dozers, were harvested. Debris and residual vegetation were burned and pushed into windrows. Area between windrows were harrowed, bedded and machine planted. Little green vegetation remained.

Watershed 3: Undisturbed control; pond storage capacity exceeded watersheds 1, and 2.

Results

Watershed 1: Water yield increase was intermittent and very dependent on season, weather and post-harvest practices. The only monthly increase was the September after double chopping when 10+" of rain fell. Yields returned to pre-treatment in less than one year.

Watershed 2: Consistent and persistent water yield increase for at least two years after treatment: about five inches first year and 0.25 inch second year.

No sediment or other water quality variables were monitored.

"Sediment Concentrations from Intensively Prepared Wetland Sites" by Askew, G. R. and Williams, T. M. in Southern Journal of Applied Forestry 1984. 8 (3): pp. 152-157.

Suspended sediment concentration was measured in water draining from a 5900-acre 'bay' in South Carolina. Samples were collected during the first stormflow of each month between Jan. 1981 and Dec. 1982 from subcatchments involved in different phases and combinations of phases of conversion to loblolly pine plantations. Suspended sediment concentration varied from 0 mg/liter in samples from an undisturbed broadleaved area to 428.7 mg/liter in a new ditch and logging area. Suspended sediment concentration in water leaving the bay averaged only 16 mg/liter for 13 storms. Road erosion and ditch installation produced the highest concentration. Suspended sediment concentration decreased with increasing distance from the sediment source. Logging and site preparation did not increase suspended sediment appreciably as long as equipment did not operate in the drainage ditches.

"Water Quality Effects of Pine Flatwoods Silviculture" by Riekerk, H. in Journal of Soil and Water Conservation 1985. 40 (3): 306-309.

Three watersheds in the poorly drained pine flatwoods region of north central Florida were monitored for 6 years. Three silvicultural treatments were imposed during the second year: harvest with minimum disturbance and site preparation, harvest with maximum disturbance and site preparation, and an undisturbed control. The minimum treatment included manual shortwood harvesting, slash chopping, soil bedding, and machine planting. The maximum treatment included machine tree-length harvesting, slash burning, windrowing, soil bedding, and machine planting.

There were small but significant increases in pH, suspended sediment, Ca and K proportional to the degree of disturbance during the treatment year. Only K and Ca levels remained significant during the first post-treatment year. Minimum disturbance practices with protective stream management zones will minimize nonpoint-source pollution.

"Effects of Prescribed Fire on Water Quality at the Santee Experimental Watersheds in South Carolina" by Richter, D. D. ; Ralston, C. W. ; Harms, W. R. and Gilliam, F. S. in Southern Regional Meeting of National Council of the Paper Industry for Air and Stream Improvement, Atlanta, GA, 30 May 1984, Environmental Sciences Div. Publication No. 2379, 19 pp.

Prescribed fire is an important practice in the multiresource management of forests, and controlled burning is now applied annually to about 1 million hectares (2.4 million acres) of forest in the southeastern United States. Experiments at the Santee Experimental Forest in the Francis Marion National Forest in South Carolina, a site of long-term watershed research by the US Forest Service and Duke University, were designed so that treatment effects would simulate responses of an operational southern pine forest.

Prescribed fires had few detectable effects on forest soils, nutrient cycling, and hydrologic systems of a pine-flatwoods watershed. It was concluded that nutrient fluxes from burned pine litter to ground and stream waters are

not likely to have appreciable effects on the quality of waters that drain southern pine watersheds, especially those with fine-textured soil.

"Changes in Water Quality Associated with Lowland Forest Site Conversion" by T.M. Williams and G. R. Askew. Unpublished research progress report for FY 87, Clemson Univ., Clemson, S. C.

OBJECTIVES: Evaluate changes in water quality on wet sites which have received combinations of logging, logging and site preparation, and pine planting.

APPROACH: Kilsock Bay, a Carolina bay owned by International Paper Company, has already been divided into subwatersheds by draining and ditching. Stand conditions which will be monitored are natural hardwoods, active logging, completed logging, site preparation areas, young pine plantations and older pine plantations. One storm flow sequence will be collected at 20 points once per month. The following variables will be measured: Temperature, dissolved oxygen, pH, flow, dissolved phosphate, nitrate and ammonia, suspended sediment, total P and N in water and sediment and Ca, K, and Mg using standard methods.

PROGRESS (87/01 - 87/12): Analysis of present results of Kilsock Bay study confirmed earlier conclusions that logging decreased concentration of NO3-N, SO4-S, Ca, Mg and increased pH and K concentration. This experiment did not show the consistent increase in sulfate and nitrate concentrations of earlier experiments. Nitrate nitrogen concentration was sensitive to soil drying and elevated NO3-N was absent during the relatively wet period of this experiment. Sulfate concentration varied from one replication to another.

PUBLICATIONS:

Williams, T.M. and G.R. Askew. 1988. Impact of drainage and site conversion of pocosins on water quality. In Hook, D.D. et al. eds. "The Ecology and Management of Wetlands," Vol. 2, Ch. 23, Timber Press, Portland, OR.

Williams, T.M. and G.R. Askew. 1988. Nutrient movement following natural and with no pogenic disturbance of a coastal pocosin. In Freshwater Wetlands and Wildlife: Managed and Degraded Ecosystems, POE Symposium Series.

All Groups of LRA's
Woodland Grazing

"Forests and Water: Effects of Forest Management on Floods, Sedimentation and Water Supply" by H. Anderson, M. Hoover and K. Reinhart. USDA Forest Service Gen. Tech. Rep. PSW-18, 1976, p. 57.

A 1972 USFS Forest-Range Task Force Report estimated that in 1970, 40% of Eastern forest land was grazed and some 72 million acres was at exploitive intensity.

At Coweeta a 145 acre forested watershed was grazed from May-September for nine years by average of six head of cattle. By the end of the first season, all herb forage and much of hardwood understory had been consumed and supplemental feeding begun. By the end of eighth season, overland flow moved directly into streams and the frequency and size of peak flows increased sharply.

Before grazing, 2" of rain (between start of flow and peak flow) would cause peak flows of 18 cfs/sq.mi., but after nine years they were 32 csm. For a 4" rainfall, peaks went from 32 csm to 120 csm after nine years of grazing.

Sediment yields increased only when overland flow started to reach stream as forest-litter plugs in natural drainage ways were washed out by the overland flow. In one storm, turbidity peaked at 108 ppm while ungrazed forest control remained at 30 ppm.

Wood and others (1987) evaluated the impacts of seedtree harvesting, thinning of longleaf pine stands, moderate continuous cattle grazing and no grazing on infiltration and runoff water quality (sediment, nitrogen and phosphate) in the Western Coastal Plain (MLRA 133B, Group F in this report). Plots of 11 sq.ft., rainfall simulators and non-standard water sampling procedures were used in the study. Stocking rates were 3.5-4.0 ac/AUM on the 6 study sites. Soils are of the Malbis series, deep, moderately well drained, fine-loamy, silicous, thermic Plinthic Paleudult. Vegetation is a longleaf pine overstory and a bluestem and panicum grass understory on gentle rolling topography.

Results show 25% decreases in infiltration rates from livestock grazing and seedtree harvesting, approximately 40% increases in sediment production from both grazing and timber harvest (statistically nonsignificant, $P<.05$). The increases in total nitrogen and phosphate from both grazing and seedtree harvesting were small and statistically nonsignificant. Overall, the decreased infiltration and runoff water quality resulting from cattle grazing were due to the removal of protective plant cover and to surface soil trampling.

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Patric, J.H., Evans, J.O., and Helvey, J.D. 1984. Summary of Sediment Yield Data in the United States. J. Forestry, Vol 82, No. 2, p. 101-103.

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Wood, J.C., W.H. Blackburn, H.A. Pearson, T.K. Hunter and R.W. Knight. 1987 Assessment of Silvicultural and Grazing Treatment Impacts on Infiltration and Runoff Water Quality of Longleaf-Slash Pine Forest, Kisatchie NF, Louisiana, in Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests, Proceeding of the Southern Evaluation Project Workshop, Long Beach, MS. Southern Forest Experiment Station Gen Tech. Rep. SO-68, p. 245-249.

APPENDIX A

Based upon 2800 sample plots on about 800 forested tracts across Virginia measured over a period of years, a modified Musgrave equation and a series of assumptions, Austin (1989) calculated regional average erosion and sedimentation rates for logging and road or trail construction by physiographic province as follows:

Province	LRA Group	Regional Erosion		Regional Sediment Rate	
		Logging	Roading	Logging	Roading
		- Average over 5 years, tons/acre/year----			
Mountains	D	8.07	20.5	0.09	0.99
No. Piedmont	J	5.94	22.6	0.56	3.16
SO. Piedmont	H	5.73	14.7	0.19	1.05
N. Coast Plain	F	4.92	5.56	0.17	1.11
S. Coast Plain	F	1.21	3.73	0.05	0.01
All Coast Plain	F	3.06	4.64	0.11	0.01

A more detailed table in Austin's report shows the values for each of the five years, as well as more predicted values. Overall, he predicts a 42 percent decline in erosion rates between 1988 and 2000 and a similar 48 percent decline in stream sedimentation with adoption of BMPs on all areas being harvested.

End of Document

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

LEGEND

A	PLAINS AND PRAIRIES 78,80A,80B,84A,84B,84C,85,86,87,1504,1508
B	ARK. MTNS. RIDGE AND VALLEY 116A,117,118,119
C	KENT. HILLS AND VALLEYS 120,121
D	BASINS. SO. AP. RIDGE AND VALLEY 122,123,125,128,129,130
E	SD. MISS. VALLEY ALLUVIUM 131
F	SD. CDASTAL PLAIN 133A,133B
G	SILTY UPLANDS AND BLACKLAND PRAIRIE 134,135
H	SD. PIEDMONT 136
I	SANDHILLS AND FLDRIDA RIDGE 137,138
J	ND. PIEDMDNT 148
K	CDASTAL FLATWDODS 152A,152B,153A,153B,153C
L	NO OATA AVAILABLE 77,81,62,83A,83B,83C,83D,112 147,151,154,155,156A,156B,42,76

MAJOR LAND RESOURCE AREA GROUPINGS FOR FOREST PRACTICE EFFECTS ON WATER QUALITY

AL, AR, GA, FL, KY, LA, MS, NC, OK, SC, TN, TX AND VA

0 100 200 300 400 MILES

SOURCE:

OIGITIZEO FROM SCS BASE 1000303-05 DATEO SEPTEMBER 1988
MAP COMPILEO USING AUTOMATEO MAP CONSTRUCTION WITH THE
FOCAS EQUIPMENT. NATIONAL CARTOGRAPHIC CENTER
FORT WORTH, TEXAS 1989

OCTOBER 1989 1005103