Reprinted from the JOURNAL OF FORESTRY
Vol. 72, No. 10 Oct. 1974

Watershed Values

Important in Land Use Planning on Southern Forests

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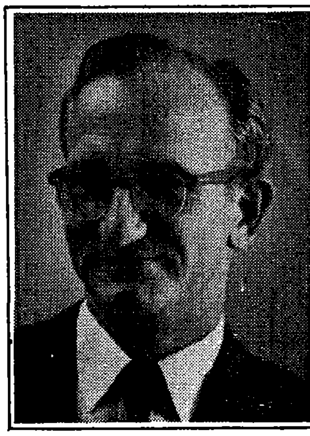

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ABSTRACT—Forests cover 20 to 65 percent of the land in the major water resource regions of the South, and forest management practices control or regulate the volume and timing of streamflow from these lands. Although water quality is emerging as the major water problem, quantity and timing of streamflow are also important and interrelated watershed values which should be considered in land use planning. Protection or improvement of hydrologic performance of forest soils will continue to be an important consideration in planning.

In discussing watershed values which are important in planning, one major idea should be emphasized. All forestry practices influence water resources. A major forestry operation may be detrimental or beneficial to the water resource. In either case, values may be such that the effect has very little practical significance. For too long, however, land-use planners in the South have assumed that changes in water yield and quality have no practical significance in their region.

Water Problems

A common misconception is that the South has a surplus of water and therefore has no serious problems. This is true only in a theoretical sense. In most parts of the South the total water supply is sufficient to meet expected demands for the next 50 years. In terms of quality, however, some parts are already experiencing problems.

In a recent survey of southern municipal watershed managers east of the Mississippi, 42 percent of the respondents listed water quality as a primary problem (*3*). A typical southern watershed is 65 percent forest or brushland, and only 27 percent of the total area is publicly owned. Twenty-two percent of the watersheds have management agreements with public, private, or industrial landowners. Pollution associated with agriculture and livestock is a major problem. Forestry-related problems other than recreation (i.e., logging, roads, and fire) comprised 17 percent of the quality problems.

In the same survey, 29 percent of the respondents listed seasonal distribution of flow and 21 percent listed water yield as problems. Seasonal distribution of water yield is a problem primarily for municipalities that draw water from streams rather than impoundments. As for management information needed, 33 percent wanted additional information on water quality, 26 percent wanted information on how to increase water yield, and 10 percent wanted information on how to regulate timing of the yields.

Although separation of water quality from water quantity is useful for analyzing problems, the two in practice are inseparable. Streams must supply needed water and they must transport accumulated waste to the sea. Although it is not fashionable today to speak of dilution as a means of regulating water quality, it is a fact of life. Were it not for the regulation of flow provided by reservoirs, the water quality problem would be considerably more acute. And the volume of high-quality water flowing from forest land is vital for diluting downstream waste loads. Since forest and brushland covers up to 65 percent of land in the South's major water resource regions, any change in the volume or distribution of flow from forest land will affect both quality and quantity.

Wollman and Bonem (*25*, p. 114) projected levels of water regulation and treatment required by 1980, 2000 and 2020. They considered three levels of demand (low, medium and high), three levels of water quality (6, 4, and 1 mg/1. of dissolved oxygen), and three management systems (minimum flow, minimum treatment and minimum cost). Table 1 shows the projections for minimum treatment levels which would be required to maintain an intermediate level of quality (5 mg/1. DO) for each water resource region (*Figure 1*).

In 1960, all regions of the South except the West Gulf required 70 percent treatment of municipal and 50 percent treatment of industrial waste to maintain a 4 mg/1. dissolved oxygen content; the West Gulf Region needed 93 percent treatment and maximum regulation of flow (maximum possible reservoir storage for regulation of flow). By 1980, only the Lower Mississippi

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and the Lower Arkansas, White and Red River Regions could get by with 70/50 percent waste treatment without maximum regulation of flow. It is unreasonable to expect that either maximum regulation or the high level of treatment projected for 1980 can be achieved for the other four regions. Clearly, water quality in those regions is already a problem. By the year 2020, only the Lower Arkansas, White and Red River Region could provide a water quality of 4 mg/1. of dissolved oxygen with the amount of existing regulation. All other regions would require something approaching tertiary treatment of all waste and maximum regulation of flow to maintain a 4 mg/1. dissolved oxygen level of quality. Thus, while the South is classified as a water-surplus area, we are faced with the problem of obtaining an adequate supply of water to maintain an acceptable level of water quality.

Although the water supply may be adequate for a region as a whole, acute water problems already exist in certain areas. Water is not always present in the volume and quality at the place and time needed. For example, the Water Resource Council (*24*) points to a shortage of water for irrigation in Louisiana; surface water shortages for cities and towns, overpumping, and contamination of ground-water supplies in the Lower Arkansas, White and Red River Region; overpumping of aquifers and increasingly high waste loads of streams in the West Gulf Region; and overpumping, overdrainage and salt water intrusion in the South Atlantic Gulf Region.

Water Yield

The preceding discussion has shown why water yield should be considered in land-use planning. By water yield, I mean the water which leaves the watershed as channel flow, enters ground-water supplies, or both.

Foresters are trained to think of planting, thinning and harvesting in terms of timber production. One hears that the silvicultural practices applied are for the production of timber, that the forest is not being managed for water yield. Manipulation of the forest cover changes evapotranspiration losses and thereby changes the water yielded from the land. Thus, intentionally or not, timber management is water management.

Consider what happens to water yield when Appalachian hardwood forests are managed. Cutting or deadening trees reduces the intercepting and transpiring surface, changing energy use on the site. Less water is evaporated than before, and more water is released to streams or ground water. The increase in streamflow the first year after cutting is dependent on the severity of the cut and on the energy received by the watershed, and clearcutting increases streamflow by from 8 to 18 inches the first year after cutting (*5, 6*). Cutting of conifers will produce even greater increases because conifers use more water than hardwoods.

Equations are available for predicting how long increases in streamflow will last and how much extra water can be produced. Assume that a hardwood forest is on an 80-year rotation with partial cuts to remove half the basal area at ages 40 and 60, and a regeneration clearcut at age 80. We would expect this managed forest to yield from 0.5 to over 2 inches more water per year than could be obtained from an undisturbed forest. These quantities may appear small, but they represent an increase of up to 25 percent in the total water supplied from the managed area, depending upon the existing flow. If valued at the cost of electricity required to pump this volume of water from wells, the increased water yield would be worth about $0.5 to $2 per acre per year.

The National Water Commission (*14*) pointed out that the annual increase in water supply possible from managing watersheds of the Southeast Atlantic and Gulf States might be 2.75 million acre-feet annually, at a cost of $.008/1,000 gallons. (The cost is much less than projected desalting costs in the year 2020 of $0.17 to $0.42/1,000 gallons and compares favorably to cloud-seeding costs of $0.003 to $0.007/1,000 gallons of rain produced.) This is enough extra water to supply about 10 million people. The Commission recommended that: "The Congress and the President should direct federal agencies having land-management responsibilities to give adequate consideration to water yield as an objective of multiobjective land-management plans."

The possibilities of decreasing water yield through forest management practices are even greater than for increasing water supplies. The *South's Third Forest* urged reforestation of 10 million acres with pine and conversion of 20 million acres of upland hardwoods to pine over a period of 17 years (*18*). This change in cover types would profoundly affect downstream water supplies, water quality and the ability to regulate minimum flows of streams. Conversion of Appalachian hardwoods to white pine (*Pinus strobus* L.) reduced annual water yield by 8 inches per year within only 15 years (*6*). Streamflow was reduced every month of the year but the largest reductions came in the dormant and early growing season (*Figure 2*). Reductions are attributable mainly to greater interception by pine than hardwoods (*19, 20*). The magnitude of the evaporation difference depends on the difference in needle leaf surface area between those forest types and on annual rainfall. Planting of 30 million southern acres of hardwoods to pine, as has been recommended, could reduce water yield by an amount of equal to the annual requirements of about 30 million people.

Water use as well as growth and yield of wood fiber should be considered when selecting the species to be grown. Even if pines are chosen, planners should consider the silvicultural practices and the sites which favor rapid fiber growth while minimizing evaporative losses. The equations presented by Douglas and Swank (*6*) show that conversion of sites with high potential solar energy loads, such as steep, south-facing slopes will reduce water yield the least. Thinnings and wide spacing reduce intercepting leaf surface area and significantly increase delivery of rain to the forest floor (*16*). However, even intensively managed pine will probably use more water than hardwoods.

Water Quality

Water flowing from pristine forests is usually higher in quality than from land in any other use. Some reduction in water quality is to be expected when forests are managed. Since criteria of acceptable quality depend upon needs within the forest and at points downstream, setting of water quality goals is a necessary part of comprehensive land-use planning.

An increase in siltation and turbidity of streams is the most visible change, and one of the most important which takes place after timber harvesting. Soil losses are small from undisturbed forest land primarily because of the protective litter layer and because infiltration rates usually exceed the maximum delivery rate of rainfall. Where litter is intact, soil losses of less than 200 pounds per acre annually are common (*9, 17*). Losses from previously abused soils are higher. Ursic (*23*) measured five times greater losses from depleted upland hardwoods and old fields and 100 times greater losses from the cultivated field and pastures than from pine plantations and mature pine-hardwoods in northern Mississippi.

Mechanical disturbance of surface soils can greatly increase erosion. Road building and logging bare and compact mineral soil, splash erosion dislodges soil particles and seals surface soils, and surface runoff transports the dislodged soil. Megahan (*13*) found that cutting and skidding increase erosion by a factor of 1.6, but that forest roads increased erosion by 220 times on the area disturbed.

The area disturbed by logging varies with the silvicultural system, layout and supervision, and type of equipment used. Dickerson (*2*) found that clearcutting exposed 55 percent more soil than selection cutting and that tree-length skidding with rubber-tired skidders disturbed more soil than log-length skidding with tractors. A study in the Atlantic Coastal Plain (*7*) showed ranges in the area disturbed of 3.2 to 22.8 percent for primary skidding trails, 8.8 to 42 percent for secondary skidding trails, 0.3 to 4.6 percent for log decks. In the Piedmont, Campbell et al. (*1*) estimated that 23 percent of a sale area was disturbed by rubber-tired skidders; both porosity and bulk density of surface soils were adversely affected. For a given size of disturbed area, erosion loss can vary greatly. At the Coweeta Hydrologic Laboratory in North Carolina (*8*) and the Fernow Experimental Forest in West Virginia (*15*), areas of about equal size were exposed by bulldozing roads. At Coweeta, roads were carefully designed and constructed and a combination clearcutting and thinning was made on 73 percent of the watershed area. At Fernow, roads were logger's choice and the entire watershed was commercially clearcut. Treatment increased maximum stream turbidity about 10-fold at Coweeta, compared to 3,700 fold at Fernow. Although these experiments were not comparable in all respects, the care exercised in road design and construction, soil stabilization, and logging supervision had more impact on turbidity than the amount of soil disturbed.

When they enter streams, eroded soil particles transport herbicides, pesticides, fertilizers, plant nutrients, and infectious organisms adhering to them. By minimizing erosion and by selecting chemicals which degrade rapidly, these sources of pollution can be minimized (*10*). Chemicals and infectious organisms also reach streams as drip from contaminated vegetation hanging over streams or as runoff from contaminated stream banks. Providing untreated buffer strips along streams is usually sufficient to prevent most chemicals from reaching streams, except where flooding is common as in swamps and flatwood conditions (*4*).

Recently, fear has been expressed that clearcutting causes excessive nutrient losses which may reduce water quality and lower site productivity (*12*). Nutrient export associated with all silvicultural practices and all southern conditions has not been thoroughly evaluated, but studies in the southern Appalachians indicate that carefully regulated clearcutting does not cause excessive losses of Ca, Mg, Na, K, Cl, SO_4 or PO_4. Cation losses from vigorous new stands appear

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to be lower than in old-growth biomass (*9*). Nitrate losses are increased (*6*), but not by the amount shown by Likens et al. (*12*). Maximum measured nitrate nitrogen concentration for any forest treatment was 1.23 ppm. This is considerably less than U.S. Public Health standards for nitrate nitrogen in drinking water (10 ppm).

Exposing the stream channel to solar heating can degrade water quality if maximum temperatures exceed the tolerance limits for fish (*22*). However, temperature increases are confined mostly to the exposed portions of the stream, and water temperatures drop back to normal shortly after the stream enters shaded areas or is diluted by joining cooler water flowing from uncut areas (*21*). By modifying logging practices to provide shade strips along streams, the temperature increases as a water-quality problem can be virtually eliminated.

In most cases, water quality can be protected by following known practices that minimize erosion and the likelihood of transport of chemicals or other pollutants to the stream (*8, 11*). Problem areas such as depleted Piedmont and loessial soils may require special care during timber cutting and site preparation to prevent accelerated erosion or reestablishment of gullies on depleted soils, but research results are sometimes conflicting. For example, repeated prescribed burning has been reported not to significantly change the hydrologic properties of soils or increase soil movement in established gullies, but most workers report that burning reduced infiltration rates, increased sediment yields, and, in at least one case, reactivated a gully.

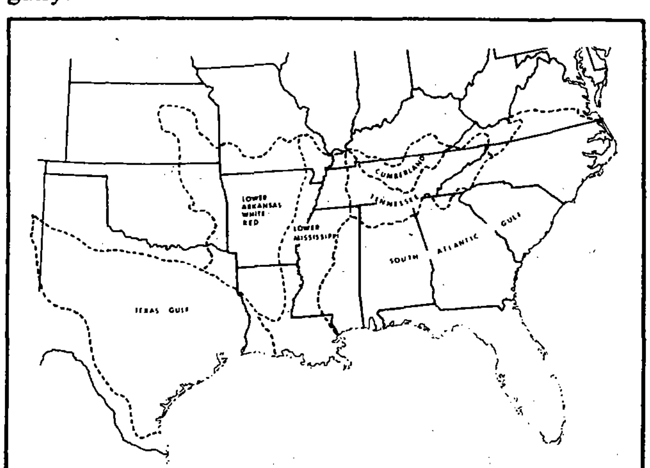

Figure 1.—Water resource regions of the South.

Hydrologic Characteristics of Soils

Watersheds have not generally been managed to increase or decrease water supplies. The traditional role of watershed management has been to preserve and ameliorate the soil resource rather than to enhance water yields. Although this role ignores opportunities to enhance water supplies, hydrologic characteristics of soil are important for they determine in part the pathways water follows and the quality of streamflow leaving the forest.

Southern forest soils that have not been abused have nearly optimum hydrologic characteristics, and very little can be done to improve their hydrologic functioning. Virtually all management except as wilderness tends to degrade rather than improve properties of virgin forest soils. Practices that reduce infiltration capacity and cause water to begin moving over the soil surface are of greatest concern. Special care is warranted on shallow soils and those that have low infiltration rates. Soils that are wet because of perched water tables or because of their position along drainages (coves, swamps and stream channels) are particularly susceptible to reduction in porosity and permeability by compaction.

The hydrologic function of many Piedmont and loessial soils has been impaired by past practices. The rehabilitation of these soils is a realistic objective of watershed management. Pines quickly stabilize eroding soils, but many years are required to significantly improve hydrologic properties such as permeability and porosity.

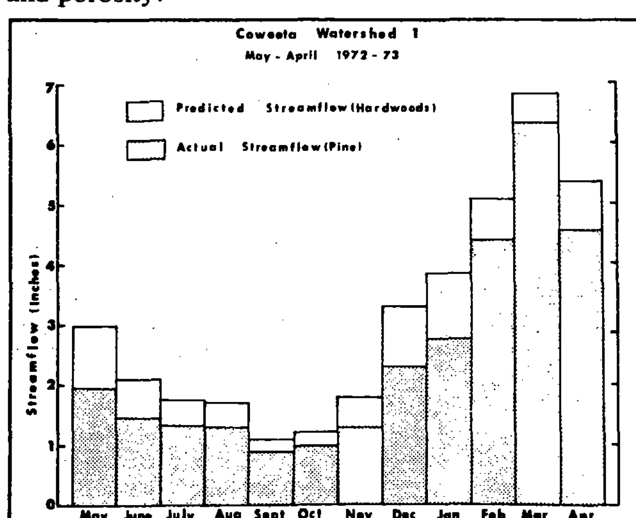

Figure 2.—Predicted streamflow for a mature Appalachian hardwood forest and measured streamflow from the watershed supporting a 16-year-old white pine plantation.

Planning Ahead

I mentioned some current and projected water problems facing the South, and urged that watershed values be considered in land use planning. To be effective, this planning must be properly timed.

There is a tendency to be most responsive to current problems and needs. Often, insufficient thought is given to the consequences today's decisions have on goods and services supplied from the forest some years hence when pressures, problems and needs will be different. Foresters understand that a sustained outflow of timber products requires a full rotation and that today's decisions have both immediate and long-term effects on wood-fiber production. The same applies to water production since water management is achieved through management of the forest. Production goals, therefore, should be set for times corresponding to the rotation age of the forest.

The years 1980, 2000 and 2020 are most often selected for projections of supplies and demands for both timber and water resources because they provide reasonable time frames for most planning. Timber rotations often match such intervals and can be 80 years or more. In some cases, then, planning for resource needs 50 years ahead can be considered relatively short term. Since planning 50 years ahead is rather tenuous because of rapidly changing needs, provision must also be made for periodic reevaluation and modification of long-range goals. I submit, however, that the only substitute for long-range planning is a continuation of the crisis-to-crisis planning that is so prevalent today. If we are to truly manage forest land resources to meet future needs, long-range planning must begin immediately.

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Table 1. Treatment levels and the increase in regulated flow needed to maintain a 4 mg/1. dissolved oxygen content for a minimum treatment program for medium projections, by regions.

Region	Regulated flow (98%)		Projections for—					
			1980		2000		2020	
	In 1971	Maximum possible	Treatment level[1]	Increase in regulated flow[2]	Treatment level	Increase in regulated flow	Treatment level	Increase in regulated flow
	bgd	bgd		Pct.		Pct.		Pct.
Southeast	95	186	78	196	89	196	94	196
Cumberlands	11.1	14.6	78	132	91.7	132	96	132
Tennessee	20.8	40.4	70/59	194	79	194	88.9	194
Lower Mississippi	1.5	35.2	70/50	0	70/50	0	77.5	2,347
Lower Arkansas, White, Red	23.9	57.7	70/50	0	70/50	0	70/50	0
West Gulf	15.4	25.6	96.4	168	97.5	168	97.5	168

[1] A 70/50 level means 70 percent biochemical oxygen demand (BOD) removed from municipal wastes and 50-percent removal from industrial wastes. A single feature figure is the percent BOD removal from both municipal and industrial wastes.

[2] The increase in regulated flow over that available in 1971 for the level of waste treatment shown.