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STATE OF THE ART IN MANAGING WATER RESOURCES ON FOREST LAND

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The southern Appalachian Mountains of North Carolina produce a surplus of water; they have the highest rainfall and runoff in the East. Annual rainfall varies from nearly 50 inches in the foothills east of Asheville to almost 100 inches at higher elevations in the central core of the Blue Ridge Mountains; annual runoff varies from over 30 inches in the foothills to over 50 inches at the higher elevations. The surplus water is both a bane and a blessing. Floods occur periodically, destroying property and sometimes people, but water shortages are rare.

Water in the Appalachians is among the purest in the South, but to maintain water quality in the future, levels of waste water treatment and regulation of flow must both increase. By the year 2020, the volume of regulated flow must be nearly doubled, and greater than secondary treatment must be provided for all municipal and industrial waste to maintain a dissolved oxygen level of 4 mg/l (Douglass, 1974).

In addition to the surplus of water, we are blessed with a wealth of information on management of this resource. While my discussions are restricted to management of forest land, comparable information and technical services also exist for agriculture and for industrial and municipal waste treatment. My purpose is to review the state of the art of managing water resources from forest lands and to discuss some of the research needs of the future.

FORESTED WATERSHEDS

Forests occupy 80 percent of the land in the Appalachian Mountains of North Carolina (Cost, 1974). In its pristine state, the forest produces water of the highest purity. With management, roads are constructed to get people into and products out of the woods. Litter, soil, and intercepting and transpiring surfaces are changed, and the volume, timing, and quality of the water production are altered.

Quantity of water is affected by changing the transpiring surface. Flow increases when a hardwood forest is thinned or completely harvested and allowed to regrow. The increase is directly proportional to the severity of the cut and inversely proportional to the solar energy load received by the vegetated surface of the watershed (Douglass and Swank, 1975). The energy load varies with aspect and slope of the land, being greatest on steeply sloping south-facing watersheds and least on comparable, north-facing watersheds. Under southern Appalachian conditions, the extreme of harvesting all hardwood timber and felling all residual stems, as is commonly done to reproduce desirable hardwood species, increases streamflow from the cutover land by 8 to 18 area inches or from a quarter million to over a half million gallons per acre per year.

As the forest regrows, the transpiring surface area increases, evapotranspiration increases, and streamflow declines to the normal flow for a mature forest. The decline is predictable, with increases in flow for complete clearcutting lasting from 12 to about 30 years. Thus, the amount of extra water that can be produced from the forest can be estimated if one knows a few basic facts about the watershed and the level of cutting applied.

Some individuals question whether vegtative management significantly influences water supplies. It does. For example, if Appalachian hardwood forests in North Carolina are under even-aged management with a rotation of 100 years and two intermediate cuts, approximately 1 extra inch of water can be obtained over that which is available under wilderness conditions. The 1 inch sounds insignificant, but it represents 1.25 billion cubic feet of water annually, or the equivalent of the annual flow from a 185-square-mile watershed. Thus, man's choice to manage, or even not to manage, does affect the water supplied from forests.

Harvesting pine forests will produce more water initially than harvesting hardwoods. However, if hardwood stands are converted to pine, the pine will use more water than hardwoods after the pine reaches about 10 years of age (Swank and Douglass, 1974). The result is that less water will appear as streamflow from pine than from hardwood culture over the rotation. Available models simulate the consequences on streamflow of managing different forest cover types (Swift *et al.*, 1975).

Timing of streamflow is also changed by the level of forest management. Flow rates are greatest in February, March, and April and lowest in September, October, and November. Any management practice that increases total annual flow tends to increase flow in the late summer and fall when flows are least and needs are greatest, but has little effect on high flows in the spring. Practices which decrease flow, such as hardwood to pine conversions, tend to reduce flow, particularly in the dormant season.

During individual storm periods, practices which increase total flow also tend to increase peak flow, stormflow volume, level of flow at the beginning of the storm, and duration of stormflow (Hewlett and Helvey, 1970). Practices that reduce total flow have the opposite effect (Helvey and Douglass, 1971). Initially, peak flow may be increased by 30 percent or more through heavy harvesting (Douglass and Swank, 1976), but peaks decline to near normal within about 10 years, assuming road construction and logging methods are proper. Because a relatively small proportion of a forest is heavily cutover at any one time, increases in peaks and stormflow volumes are small when viewed on 50-square-mile or larger watersheds.

WATER QUALITY

The purity of water from undisturbed forests is unsurpassed. At the Coweeta Hydrologic Laboratory, the dissolved load of chemicals is low, averaging about 100 pounds per acre per year. Suspended sediments add another 45 to 90 pounds per acre, and bedloads of streams range from 50 to 150 pounds per acre per year. The dissolved, suspended, and bedloads of such streams reflect geologic weathering and natural erosion, mostly erosion of the stream channel itself. Management normally increases the solution loss slightly. Although a statistically significant increase in nitrate nitrogen outflow is found (Johnson and Swank, 1973; Swank and Douglass, 1975), the increase in total solution loss is only in the order of 5 to 10 pounds per acre. This change is insignificant in drinking water.

Changes in suspended and bedload are of greater importance. When roads are built to manage the resources and when timber is harvested, the hydrologic characteristics of portions of the watershed are affected. Soil is bared, compacted, and surfaced for roads. Reduced infiltration may cause runoff over the soil surface (surface runoff is virtually nonexistent in undisturbed forests). Similarly, soil is compacted and exposed on trails, and some soil is exposed during skidding operations. Practices such as prescribed burning trail hiking, picnicing, and camping all compact soil and reduce infiltration. Increased erosion and bacterial contamination are the consequences of such activity.

How much change in suspended and bedload occurs under management? This is virtually impossible to answer because of differences in supervision and care exercised during management, storm characteristics and timing, and topography. Change can be small when management is intensive and follows recommended practices (Hewlett and Douglass, 1968), or it may be quite large, even with good management, if activities coincide with extreme storms.

A case in point is a study of erosion losses from a high-quality road system that was under construction during two floods of magnitudes which are expected to recur less frequently than once in 20 and once in 50 years. Results represent an extreme situation under proper management. Sediment trapped in a ponding basin and in water flowing over a weir blade indicate that the road caused about fivefold and elevenfold increases in erosion losses from the two storms. The probabilities are remote that storms of this magnitude will coincide with road construction. Under less rigorous construction standards, one would expect erosion to be much greater for storms of this severity.

Research on contamination of forest streams from use of pesticides and herbicides (Douglass et al., 1969; Grzenda et al., 1964) has also shown that when reasonable care is exercised, little or no contamination can be expected. Elevation of water temperature can also be a problem when streamside vegetation is removed. Here too, we have information on the amount of increase in temperature that can be expected from management practices and on how management practices can be modified to minimize or eliminate temperature problems (Swift and Baker, 1973; Swift and Messer, 1971).

DISCUSSION

It is doubtful that any region in the nation has better hydrologic information for land use planners and land managers than exists in western North Carolina. If existing technology were fully utilized in all levels of management, problem symptoms related to water from forest land would not appear as priority items in the SARRMC analysis, at least in the immediate future. However in the discussion of probable research impact, this report commented that the best of research is without value unless findings are put into practice, and that "the opinion of the extension specialists was that there is only a fifty-

fifty chance that high quality research results would be used to the extent necessary to eliminate individual problems" (The Southern Appalachian Research/ Resource Management Cooperative, 1977). If true, the overriding water problem in western North Carolina is that "current technology is not being applied to the extent necessary to protect water resource values."

Technology transfer or a communication gap is often cited as a major factor that limits application of research results. It is one factor. Lack of motivation is often the major factor, particularly in protecting water quality. In building roads, for example, a timber or pulp and paper company is extremely reluctant to apply the best known technology to protect water quality if application doubles or triples costs. In steep terrain, high-quality roads can cost more than the value of the timber removed. Neither will landowners require best management practices to be applied if they must bear all the additional costs. Limitations imposed by economics are readily understandable and unless rather drastic measures are taken to insure application of best management practices, the gap between what we preach and what we practice will remain.

Despite what is already known, additional research is needed. The major emerging water problem for western North Carolina is water quality. In the future, additional regulation of flow and greater control of point- and nonpoint-source pollution will be required to provide a quality of water which will support swimming and fisheries. Although technology is available to minimize nonpoint-source pollution (NPSP), a predictive model is needed to estimate the quantities of pollutants produced from alternative management practices. For example, sites can be prepared for regeneration of forests with fire, herbicides, or heavy mechanical equipment. Amount and type of pollution, biological effects, effectiveness, and costs of alternative methods should all be considered in selecting the best method, yet we have no way of doing this today. Also, cold water fisheries are an extremely valuable mountain resource; we need information on threshold values where various pollutants impinge on trout productivity in order to guide land management and thus protect this limited resource. While technology is available for a much higher quality of management than exists today, information is still needed to determine the most effective, lowest cost alternatives for managing our timber, water, and aquatic resources.

LITERATURE CITED

Cost, N. D. 1974. Forest Statistics for the Mountain Region of North Carolina, 1974. USDA Forest Serv. Res. Bull. SE-31, 33 p. Southeast. Forest Exp. Stn., Asheville, N.C.

Douglass, J. E. 1974. Watershed values important in land use planning on southern forests. J. For. 72: 617-621.

Douglass, J.E. and W. T. Swank. 1975. Effects of management practices on water quality and quantity: Coweeta Hydrologic Laboratory, North Carolina. Proc. Municipal Watershed Management Symp., USDA Forest Serv. Gen. Tech. Rep. NE-13, Northeast. Forest Exp. Stn., Upper Darby, Pa.

Douglass, J. E. and W. T. Swank. 1976. Multiple use in southern Appalachian hardwoods--a 10-year history. XVI IUFRO World Congress Div. 1 Proc. 1976: 425-436.

Douglass, J. E., D. R. Cochrane, G. W. Bailey, J. I. Teasley, and D. W. Hill. 1969. Low herbicide concentrations found in streamflow after a grass cover is killed. USDA Forest Serv. Res. Note SE-108, 3 p. Southeast. Forest Exp. Stn., Asheville, N.C.

Grzenda, A. R., H. P. Nicholson, J. I. Teasley, and J. H. Patric. 1964. DDT residues in mountain stream water as influenced by treatment practices. J. Econ. Entomol. 57: 615-618.

Helvey, J. D. and J. E. Douglass. 1971. Effects of some forest resources management alternatives on storm hydrograph characteristics in the southern Appalachians. Paper presented at International Union of Forestry Research Organizations Congress, Gainesville, Fla., March 14-20.

Hewlett, J. D. and J. E. Douglass. 1968. Blending forest uses. USDA Forest Serv. Res. Pap. SE-37, 15 p. Southeast. Forest Exp. Stn., Asheville, N.C.

Hewlett, J. D. and J. D. Helvey. 1970. Effects of forest clear-felling on the storm hydrograph. Water Resour. Res. 6: 768-782.

Johnson, P. L. and W. T. Swank. 1973. Studies of cation budgets in the southern Appalachains on four experimental watersheds with contrasting vegetation. Ecology 54: 70-80.

Southern Appalachian Research/Resource Management Cooperative. 1977. Western North Carolina Priorities for Natural Resources Research: A system analysis of problems, opportunities and information needs for management and research, 17 p., SARRMC, Raleigh, N.C.

Swank, W. T. and J. E. Douglass. 1974. Streamflow greatly reduced by converting deciduous hardwood stands to pine. Science 185: 857-859.

Swank, W. T. and J. E. Douglass. 1975. Nutrient flux in undisturbed and manipulated forest ecosystems in the southern Appalachian Mountains. Proceedings of the Tokyo Symposium on the Hydrological Characteristics of River Basins and the Effects on These Characteristics of Better Water Management 1975: 445-456.

Swift, L. W., Jr. and S. E. Baker. 1973. Lower water temperatures within a streamside buffer strip. USDA Forest Serv. Res. Note SE-193, 7 p. Southeast. Forest Exp. Stn., Asheville, N.C.

Swift, L. W., Jr. and J. B. Messer. 1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. J. Soil Water Conserv. 26: 111-116.

Swift, L. W., Jr., W. T. Swank, J. B. Mankin, R. J. Luxmoore and R. A. Goldstein. 1975. Simulation of evapotranspiration and drainage from mature and clearcut deciduous forests and young pine plantation. Water Resour. Res. 11: 667-673.