Forest Hydrology in the Appalachians

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"The lumberman, the forest fire, and the farmer cooperate in the work of forest destruction and the consequent disturbance of the regularity of the flow of the streams. This increases the floods which destroy the valley lands below, and as the irregularity of their flow increases, the streams lose their value for water power during the dry season, and during the season of rain the floods wash away the farming lands in the valleys and carry destruction along their course to the lowlands. As the rains wash away the cleared fields on the mountain slopes and the farming lands in the valleys, these soils on their way toward the sea incidentally silt up the river channels and the harbors. Hence it is strictly true that in destroying forests these agencies are removing the soils, ruining the rivers, and destroying the mountains themselves; and along the lower courses of these streams they are thus destroying agricultural and manufacturing interests, and incidentally seriously affecting important navigation facilities." (1)

THE WATER problem of the Appalachian region is primarily a forest problem. This dependent relation was recognized as clearly by the geologists, hydrologists, and foresters of nearly 50 years ago as it is acknowledged by conservationists today. Both problems are well on their way to solution.

Great progress has been made in solving the southeastern forestry problem during the past half-century. Much steep land has been publicly acquired, automatically retiring from further abuse many thousand acres of "worn-out agricultural land." Forest fire control has been applied in varying degree to nearly all woodland. Logging practices that result in denudation over large areas of mountain land are seldom seen. Many denuded and open lands have been reforested. Woods grazing is less widespread. Roads and highways are more carefully located and many roadsides are being revegetated. (2) Many sore spots still exist, but they are not as extensive as before. Although conservation measures are not as widely applied as they should be, they are generally accepted and cover conditions on many forest lands show marked improvement over the earlier conditions.

Water Resources Are Improved

Improvement in water has gone hand in hand with the adoption of these forestry measures. Streams that once were heavily discolored by their loads of soil, now flow clear. Stream channels, once lined with great banks of loose sand and gravel lying naked in the sun, are now shaded and tree-clothed and the debris is anchored in place by myriads of tree roots. Flood peaks have been reduced as rapid surface runoff has been checked and in consequence a greater regularity in flow has been achieved. However, floods, irregular flows, water shortages, and other less important water problems remain with us in varying degree. Although advancement in the solution of the over-all water problems has been achieved by the general adoption of forestry practices, what further is needed? One answer is the adoption of that type of forest management which will adequately take water values into account.

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The idea of intensive forest management in the interest of the water resource is startlingly new. It came about with the realization that geology, soils, topography, precipitation, climate, forest types and the uses of the forest land all affected water in some way. It also resulted from the growing realization that to achieve a reduction in floods, practices different from those used to obtain maximum yields of domestic water must be followed. As facts to substantiate the idea were lacking and in order to understand how the various factors could be integrated, to discover their values in relation to water flow, and to develop methods applicable in forestry, research was needed.

Research was especially needed in the Appalachian forest area from the Potomac to the Coosa. Water values in this area were increasing. Available supplies were dwindling. Industrial, municipal and domestic demands were growing. Abundant water was needed for recreation. Cheap hydroelectric power was attracting new industries and people. Damages per unit of flood discharge were increasing. Forests were recovering from heavy exploitation. Accordingly, studies of forest and water relations hydrology were included in the research program of the Southeastern Forest Experiment Station at Asheville, N. C., in the late 20's.

SOIL AND WATER PROBLEMS WERE INVESTIGATED

Early investigations here were directed to an understanding of some of the basic soil and water problems. Among the first were those to determine the amount of precipitation which reached the ground with storms of different characteristics and intensities, and under various types, densities and ages of forest cover. Studies of the litter were made. Some of the early ones revealed that even the gentle removal of the forest litter by whatever means as by raking and without disturbance to the soil resulted in markedly reduced infiltration and increased surface run-off. (3) For example, a 10-minute quarter-inch rain with intensities of 3 inches per hour produced 20 times the volume of run-off from the raked plot as the natural plot, the rates being also in the ratio of 10 to one.

Other studies revealed that agricultural soil resembles an unorganized mass of building materials whereas the natural forest soil with its stable organization is more like a house built from this material. Primary aids in this building are the inhabitants of the soil—the myriads of microarthropods which digest the litter and incorporate it as humus in the soil. (4) The number of these microorganisms varies greatly with moisture and plant food, from one square inch to another, and diminishes with increasing soil depth from 1,800 at one- or two-inch depths to 130 at a foot depth per square foot of surface. These and other small animals according to their diminishing abundance are mites, springtails, ants, hemiptera, myriapods, thrips, beetles, and a miscellany of others. Earthworms (not microarthropods) are found in abundance, but some species of worms are so exceedingly minute as not often to be discovered. The larger species are usually found in mull soils. Loss of surface litter and exposure of the mineral soil as by fire, grazing or logging, and the slight erosion of the top soil eliminates many of these soil makers.

PROBLEMS ARE RELATED TO WATERSHEDS

Associated with these basic studies were others of small watersheds on the Bent Creek Experimental Forest near Asheville. One comparative study over an 8-year period revealed that the peak discharge from a wooded area for storms with a maximum intensity of 1 inch in 20 minutes did not exceed 25 c.f.s. per square mile. The comparable peak discharge over a two-year period for a nearby area in weeds was 275 c.f.s.; in the next two-years when the area was lightly grazed, the discharge was 615 c.f.s.; in the next two-year period with added grazing use, the discharge soared to 1,000 c.f.s. An application of lime and phosphate was given the area which was put into lespedeza. The discharge rate for the next two-year period dropped to 150 c.f.s. These comparative studies revealed the need for more detailed forestry investigations. (5) Accordingly a new area was sought where

Figure 1.—Not all rain and snow falls directly to the ground; some of it is held temporarily on the branches before dripping to the ground; some runs down the trunk. Foresters must determine the amount of this stem flow to account for all the precipitation which reaches the ground.

the whole gamut of forest conditions could be studied. A suitable area of 5,000 acres was found in the drainage of Coweeta Creek near Franklin in southwestern North Carolina.

The Coweeta Experimental Forest is high in the mountains of North Carolina and only a stone's throw from Georgia and Tennessee. Physical conditions appear virtually perfect for hydrologic studies. It has some 50 storms per year producing an annual rainfall of around 80 inches, deep (up to 30 feet) well drained granitic soils on unstratified rocks with well stocked, unburned and ungrazed forests at elevations between 2,000 and 5,500 feet, and a topography that produces many small individual drainages each with its own living stream. And, not far away are the smelter-denuded Copper Basin and the Bent Creek and Enoree Experimental Forests, each affording other opportunities for supplemental investigations with different soils, geology, rainfall, and forest conditions.

In making Coweeta into an outstanding hydrologic laboratory, the first step was to learn as much as possible about hydrologic conditions. A complete set of 67 precipitation stations was installed along trails constructed throughout the main area. Precipitation caught in the standard cans was measured after every storm and checked with 12 intensity gages. Coincidentally, 27 stream-gaging stations were installed, 21 on small independent watersheds, and the balance on reaches of the two main forks. The main gages are supplemented by shallow wells at which the fluctuations in depth and flow of ground water can be determined. Ground water wells and meteorologic stations were also installed at the headquarters station and within some of the smaller watersheds. Other hydrologic data relate to water quality, frost, snow, evaporation, etc. An inventory of soil and forest conditions was also made.*

Original plans provided for a standardization period of 10 or more years before any treatment was accorded a watershed. The gages had been in operation only a short time when it was discovered that because of the uniformity and number of storms per year, the stream behavior was rather uniform basin by basin, storm by storm, and season by season. This permitted each stream to be compared with itself, and shortened the time required for standardization to around 5 years.

The scheduled treatments were designed to furnish information on how the forest cover affects water production, behavior and rate of discharge. With information on these matters available, specific forestry practices could be developed for drainages where flood control is the objective, for those where water yield is important, or for those where regularity of flow is desirable. It will also be possible to determine how, when and under what conditions the forest can be harvested or the land utilized to pro-

*Dryman's Fork drainage of 1,500 acres has not yet been developed.

duce desired streamflow.

The forest treatments included such practices as the continual removal of all timber growth from one watershed without soil disturbance; maintaining a "brush" cover on another clear-cut area; cutting as done by local loggers; cutting and logging according to silvicultural needs and according to watershed considerations; cutting of riparian vegetation; mountain grazing; forest burning; changing forest to agriculture; etc. (6) Several of these treatments were put into effect prior to World War II.

Watersheds Are Selected for Treatment

Two small watersheds (33 and 40 acres) have been cut clean. All vegetation down to broom-stick size was cut to the ground with none of the wood material salvaged. Care was taken not to disturb the litter or the soil. The effect on streamflow was electrifying: the run-off the first year was increased by 17 area inches or 65 percent. During the summer the low water flow was increased from a calculated 3 inches to over 7. At no time during the year was there a significant increase in storm flow or a change in water quality. On the one watershed where a new sprout forest is developing, a gradual reduction in the water yield is noticeable.

Cutting in another small basin (22 acres) was confined to the riparian forest. Again no logging or other disturbance of the forest soil was permitted. Although the cutting was limited to the small area closely adjacent to the stream and amounted to only 12 percent of the drainage, the increase in stream flow was about 20 percent. Again, water quality was unaffected.

A 212-acre watershed is being logged. Cutting and logging are being carried out according to the ideas of the mountain operator. He cuts what trees he wants and gets the logs out in any fashion that appeals to him. As soon as the area can no longer be logged profitably for lumber, cutting for other products such as posts, pulp and fuel will be permitted. The cutting and

Figure 2.—Within the Coweeta Forest, one experimental watershed was cleared of all of its timber, and was plowed and grazed by the mountain people according to the common local practice. Another watershed, entirely forested (beyond car at left center), is being grazed. Still another watershed (at top right) has been cut over.

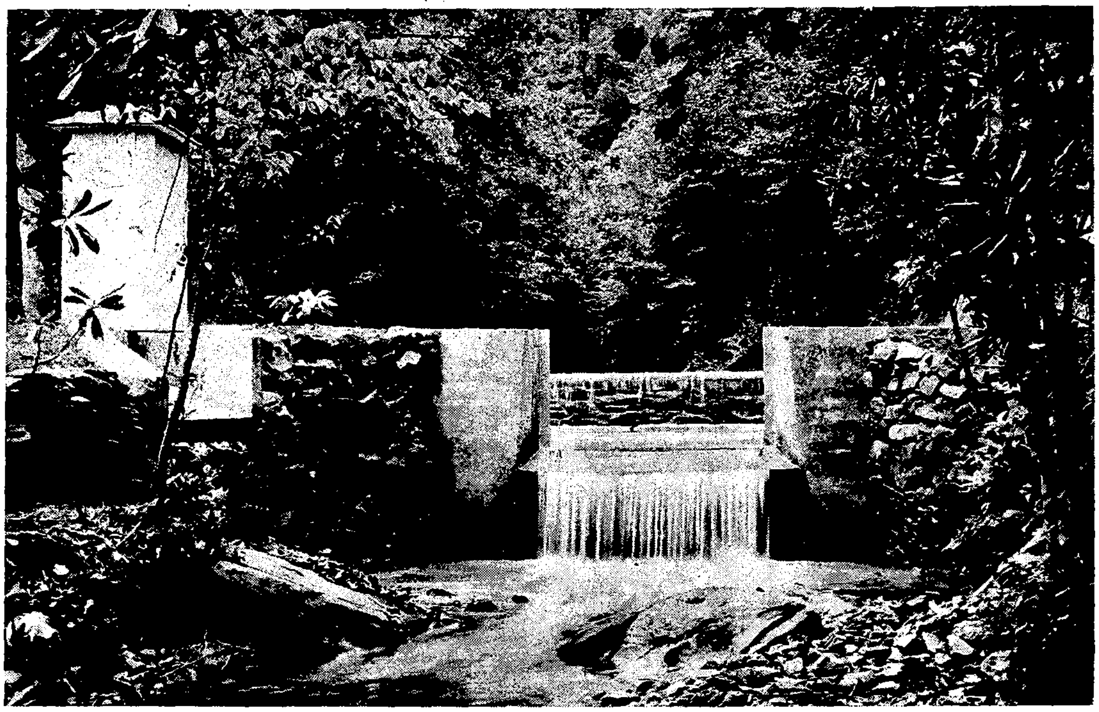

Figure 3.—Water is the main product of the Coweeta Forest. How it behaves when the cover is disturbed is written on charts at 32 gaging stations, many of which control small watersheds.

skidding have resulted not only in changes in the stream flow but also in the quality of the water as the stream carried large amounts of soil. Skid trails yielded several times as much debris as had been expected, rendering volume measurements impossible. Further an immediate rise in stream flow occurred as each trail provided an avenue for prompt surface run-off. Erosion continued also throughout periods when logging was shut down because of operational difficulties.

Perhaps the most interesting small drainage is one that was first cleared for agricultural use. After clearing the 23-acre watershed, a local farmer was induced to operate the "farm" according to his own lights. On the "more gentle" 30 percent slopes, he grew corn; on the steeper ones, he grazed cattle. For the first two years water production increased without much damage to water quality, although erosion was evident in the corn field. By the third year, the organic material was largely gone and the soil structure breaking down. Infiltration then decreased. Surface run-off took place with each rain and the peak discharges increased more than 10 times over those recorded before clearing and cultivation. Erosion became generally prevalent and so much soil material was washed out of the drainage that it discolored the main creek for a considerable distance downstream. Although efforts were made to measure the amount of soil lost, the sediments in the first flash floods exceeded the capacity of the silt traps and the maintenance crew. Now that the corn yields have greatly fallen off and gullies developed, the local farmer is indifferent towards further cultivation of the area. He insists now that his equipment is worn out, he has much other work, he's getting too old and doesn't feel so well, and his animals need a rest!

Grazing on a 145-acre watershed is demonstrating the damage livestock can do. Although from a distance the forest cover appears just as dense as ever, the interior of the stand shows what is taking place. Soil compaction is general. It is worse on the best soils because here the best forage grows. Porosity was reduced more than 10 percent in the first six weeks. The undergrowth of palatable tree seedlings is being wiped out. Then too, with the loss of the under-story, wind is able to get under the crowns of the forest and blow the litter out of the area. Soil compaction and loss of litter are steps towards eliminating the beneficial effects of the forest while the land is still covered with trees.

Studies Reveal Management Practices

These Coweeta studies not only have suggested some of the measures to be used in intensive watershed management but they have taught us much about water and forest relations. The mixed hardwood forest of the Appalachian area uses much more water each year, especially in the growing season, than anyone realized. Whether this water was actually needed for growth or whether the forest uses it merely because it was available remains to be worked out. Removal of the vegetation reduced this transpiration draft and provided more water for run-off. So long as the soil and its humic cover are not disturbed or lost, this does not cause floods. Possibly this is untrue for other areas even in the same region.

Soil disturbance when associated with stand treatment changes the picture. Logging provides numerous compacted skid trails becoming focal points for surface run-off and erosion. Livestock also compact soils and when associated with litter removal, similarly provide opportunities for stimulated run-off and attendant erosion. Compaction by livestock is unlike that by other agencies in that stock are more or less constantly in motion over the whole area on a 24-hour basis. This fact places stock at the top of the list of all soil compacting agencies.

The study of mountain agriculture at Coweeta shows that soil structure must be maintained if such cultivated lands are not destroyed. It is planned to continue the deterioration of this agricultural drainage until some degree of uniformity in run-off and erosion is obtained, after which the effort will be to determine how long a period is required to reestablish a good forest soil. Nature, however, may interfere, as black locust sprouts have already appeared. In other areas, these sprouts have spread and reclaimed mountain farmlands despite efforts to eliminate them.

Flood Control Depends on Kind of Forest

The Coweeta studies suggest that for flood control, a dense vigorous water-using forest is highly desirable. By depleting the soil moisture such a forest provides storage during time of storm. In such a forest an excellent litter and humus are formed which provide for a maximum of infiltration capacity. During the growing season, therefore, the forest operates at a maximum in taking care of the storms which sometimes provide heavy precipitation at high intensities.

On the other hand, when water yield is the important item, an increase in flow is indicated if the water-using forest is reduced in density. If we do not wish to remove all the forest, we can take the trees in the valley bottoms and flood plains, for these are gross dispensers of water. By reducing transpiration, industries and communities dependent upon local watersheds may augment their supplies. Studies have not yet reached the point where the "Old Soaks" of the forest, i.e., those species which use abnormal supplies of water, can be identified. Grazing within the hardwood forest area appears to cause more damage to a watershed than is generally realized. Similarly the damage to water quality by agriculture on steep slopes, alone seems sufficient justification for its elimination in important Appalachian watersheds.

Timber harvesting in the Appalachians does affect water adversely. Most of the damage it causes is the result of indifference and carelessness. This need not be so. If roads can be built without excessive damage in hilly lands, then thoughtful planning and careful work during the logging operation should minimize the harm. Then too, the injury from raw soil surfaces can

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brings ecological principles to bear on land problems. A practical, fresh point of view destined to be of increasing importance in the land use field.

13 *Food or Famine* by Ward Shepard. 225 pp., illus., New York, Macmillan, 1945.

Shephard deals in a challenging way with the question of what we are going to do about erosion. It is packed with ideas with which you may not agree, but nevertheless important and fundamental.

14 *Man and the Soil* by Karl B. Mickey. 110 pp. International Harvester Co., Chicago, 1945.

An easily-read, simply written story offered by the International Harvester Company, and still available free from their public relations department. It is unusual for a commercial concern to put out a book, and even more so to put out such a good one.

There are a great many more books that could appear on this list. Personally, I should like to see it contain Russell Lord's "*To Hold This Soil*" and C. F. S. Sharp's "*What Is Soil Erosion.*" I think Stanley Gaine's "*Bibliography of Soil Erosion and Soil Conservation,*" while not a book to read, is an important milestone of the science. Gustafson's *Conservation of the Soil* is a textbook—still the only thing of its kind in this wide-open field. The new "*Population Roads to Peace or War*" by G. I. Burch and Elmer Pendell is worth any soil conservationist's time. And so on.

Undoubtedly this list of classics will change as time goes on. Probably it will be changed at once by many who disagree with the choices. But it seemed worthwhile to publish it as a suggestion to the man seeking to gain or hold professional status.

It has always seemed pretty clear that a professional worker must read a great deal if he hopes to maintain his standing. He must keep up with current literature of his own as well as foreign countries. Likewise he must also read to gain historical perspective, as the editor of the JOURNAL pointed out in the second issue. If ever the time comes when a professional man lags in his search for new ideas and his striving for a broader understanding of his field, disaster is about to overtake him. Habitual self-teaching is a downright necessity for any soil conservationist not actually going to school. After graduation a professional man either advances in his field—or he stagnates. Good reading can do much to prevent the latter.

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be overcome by adopting soil restorative measures as a common practice for cut-over areas along with reforestation, slash disposal, stand improvement, and other comparable practices.

Coweeta is demonstrating that water problems can be solved and that specific management of forest lands in the interest of the water resource is possible. We now know the effects of certain forestry measures and have indications on others. By opening the hydrologic door, the Coweeta Experimental Forest is helping us to understand the problem and to stimulate our thinking on solutions.

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"The late rain had in many places washed away great pieces of the ground sown with wheat and rye." So wrote Peter Kalm, a Swedish botanist traveling in New Jersey, in the year 1749.