FOREST HYDROLOGY RESEARCH IN MISSISSIPPI

by

S. J. Ursic
Hydrologist, Southern Forest Experiment Station
Forest Service, U. S. Department of Agriculture
Forest Hydrology Laboratory[1/]
Oxford, Mississippi

The most critical water problem facing the Nation is an evergrowing demand. Ground water accumulated and held in natural storage is the only real water reserve. How wisely this reserve is developed and managed will largely dictate future economic development.

How much ground water is held in storage? Estimates vary and exact figures are not essential to this discussion. The quantity is at least 100 times the annual runoff of all streams (2, 7). Where is it? This is important. One estimate places 20,000 cubic miles of fresh water within 1,000 feet of the land surface of the Coastal Plain province of ten southern States--an amount sufficient to cover the 48 contiguous States to a depth of 35 feet (4). Available estimates suggest that less than 10 percent of the land area--the southern Coastal Plain--holds more than 40 percent of the ground-water reserve. Moreover, this area receives ample rainfall to replace ground water as it is utilized.

The projected demand for water by 1980 is estimated as 560 billion gallons per day (5). Almost one-half of the increase over the 270 billion gallons per day used in 1960 is expected to come from ground-water sources (6). One fact seems certain. Ground-water supplies of Mississippi and the other Coastal Plain States will have to satisfy a large percentage of the future municipal, industrial, and agricultural demands of a thirsty country.

The preference for ground water stems from its attributes: its clarity, purity, consistent temperature, and generally acceptable chemical quality. For many industries, one or more of these characteristics is a necessity. Streams draining Mississippi watersheds carry away 16 to 30 area-inches of water annually (1); but of 234 municipal water facilities which served a million people in 1963, only two depended wholly on streamflow (10).

1/ Maintained by the Southern Forest Experiment Station in cooperation with the University of Mississippi.

The title of this paper is Forest Hydrology Research in Mississippi. What have Coastal Plain forest lands to do with ground-water supplies? Finding the answers to that question is the job of a Southern Forest Experiment Station research project located at the Forest Hydrology Laboratory in Oxford, Mississippi. Today, I want to probe the relationships of forested lands to ground-water supplies, to outline briefly some of the research we are doing at the Laboratory, and to discuss the significance of our early findings. First, however, let's examine the present situation and the problems developing in areas of intensive ground-water use.

GROUND-WATER PROBLEMS OF THE COASTAL PLAIN

Most southern aquifers are full and are rejecting recharge in amounts equivalent to the base flows of streams. Much of the year-to-year circulation of ground water occurs at shallow depth in the zone of the water table and the uppermost artesian aquifers. Surface and ground waters, almost without exception, are parts of a common supply.

An untapped aquifer is in dynamic equilibrium with the climate, the recharge and discharge areas, and the adjacent rocks. Dewatering results when withdrawals are not balanced by an increase in natural recharge or a decrease in discharge to streams.

Pumping from an unconfined aquifer is analogous to withdrawing water from a reservoir refilled each year by winter and spring rains. The supply depends directly on the amount of rainfall that infiltrates the land surface and percolates to the water table, a level below which all sediments are saturated. The aquifer is depleted when pumping exceeds the average annual recharge. The alluvium underlying the Mississippi River flood plain, the Delta, is tapped by some 1,500 wells and constitutes an example of a heavily used water-table aquifer.

Pumping from an artesian aquifer initially creates a cone of depression, but does not drain the aquifer. Water is first obtained from storage. Pumping more than is transmitted through the aquifer gradually depletes storage. In areas of high well concentrations, a regional cone of depression develops, expands, and deepens. Most areas of heavy use are depleting storage in this way. Eventually, the cones will extend to the area of recharge, and then production will be limited by recharge as under water-table conditions.

Lowering the water table and steepening the hydraulic gradients in the outcrop by pumping properly spaced well fields may induce additional recharge. The capture of this additional recharge is at the expense of base flows in streams, but such recovery may be an important aspect of future water management.

Development of the "500-foot" aquifer from which the Memphis area obtains 90 percent of its water supply exemplifies such management (3). In 1960, 135 million gallons per day were withdrawn. Although less than one percent of the annual withdrawals since 1935 have come from depletion, water levels at the center of the major cone of depression have dropped as much as 50 feet and the cone of depression has expanded at least 30 miles. If present rates of pumping remained constant, water levels would cease to decline in several years, but annual pumping is expected to increase at the rate of five million gallons per day each year and water levels to fall one foot for each one million gallons per day increase in production. Present trends indicate that water-table conditions may exist over the entire area in about 30 years. This change may not be detrimental, but the quality of the water may be altered and the water will have to be pumped from increasing depth or transported from well fields located away from the present centers of pumping.

The present annual pumping rate in the Memphis area is not great enough to enable hydrologists to determine whether the transmissibility of the aquifer or the amount of recharge will ultimately limit water withdrawals. That the aquifer can accept additional recharge was indicated by an arresting of the downward trend of water levels of wells following the heavy rainfall of 1957. While large amounts of potential recharge are being rejected in the main outcrop 30 to 60 miles to the east during parts of the year, low summer streamflows may reflect opportunities for increased recharge. What is happening on the surface of the outcrop is undoubtedly important.

The newest Memphis well field, designed to yield 8 to 20 million gallons per day, was scheduled to begin operations in 1965 (8). It is 10 miles southeast of the center of the regional cone of depression in the direction of the outcrop. Pumping this field will increase the rate of movement from areas of recharge but will require careful management to maintain artesian conditions. Thus the yield from this part of the aquifer is even more dependent on the amount of recharge than wells farther downdip. Additional recharge in the outcrop would provide an immediate benefit. In Mississippi, similar management problems have developed in areas of concentrated water use: Tupelo, Aberdeen, and Jackson are examples.

RESEARCH OBJECTIVES

The average annual recharge from precipitation ultimately limits the quantity of water that can be developed from any aquifer system. The amount of recharge is greatly influenced by surface conditions and land use. Forests cover over 60 percent of Mississippi, and an even higher proportion of the rougher, sandy uplands characteristic of the outcrops of the more productive aquifers. How forest lands affect accretion to ground water is our study at the Forest Hydrology Laboratory.

The objective is to determine, and eventually to be able to predict, how much water is delivered below the root zones of forest vegetation to replenish aquifers and maintain the base flows of streams; how much, in dimensions of time and amount, this contribution can be altered by modifying the forest cover; and the conditions of soils, topography, and stratigraphy that make such management most feasible.

Watershed cover that permits maximum amounts of precipitation to enter the ground is compatible with solution of all water problems in Mississippi. The effectiveness of forests in reducing overland flows and consequent soil losses has been amply demonstrated, but increased infiltration into the soil mantle is not synonymous with replenishment of an aquifer. Evaporation and transpiration from foliage take their toll. If forests are to increase water available for recharge, the amount of increased intake must exceed any additional losses. The problem is one of maintaining forest conditions that will minimize overland flow (a waste) and, where desirable, loss to evapotranspiration (a potential debit to base flows and ground water). Resolving the problem requires study of the interactions of soil, water, and vegetation in the zone of aeration--the layer between the surface and the water table often described as the no-man's land of hydrology.

CURRENT RESEARCH

One north Mississippi situation under study is a 3.35-acre watershed of 28-year-old loblolly pine. Soils are medium- to well-drained silt loams and sandy loams underlain by deep sandy strata. The conditions are representative of large areas of the South.

Runoff from the area, measured since 1957, is now negligible. When the watershed was in cultivation and while it stood idle before being planted to pine, though, it lost an estimated two feet of surface soil through erosion.

Objectives of this study include determination of the amount of water that percolates below the soil zone occupied by roots, and the time when this percolation occurs.

The water regime is followed by weekly measurements with neutron soil-moisture probes in 25- to 40-foot access wells. Recharge to and drainage from the soil around these wells is determined for sections between 6.5 feet, a depth essentially void of roots, and the bottom of the wells, which are above the water table.

Preliminary data from two of the installations give a good idea of the nature of this areal flow. The data are for one year beginning November 11, 1963, when the moisture content was near field minimum. Accretions between November 11 and April 28 (when the soil held the most water) totaled 15.7 inches for one installation and 15.1 inches for another. These values are conservative since they do not take into account drainage to lower depths during this interval.

In contradiction to some concepts, recharge was augmented by summer and fall rains, although storm amounts were far less than the moisture-holding capacity of the soil within the rooting zone. An additional 3.3 inches percolated through the 6.5-foot depth of one column and 4.2 inches through the other between April 28 and November 5, 1964. Thus total deep percolation was at least 19 inches for the year.

Drainage from the columns of soil was continuous from April 28 to November 5, 1964, amounting to 14.5 inches from one and 18.3 inches from the other. The highest rates occurred during June and July on one site and during May and June on the other. Thus the recharge, even if shunted to local streams by impervious strata or fully charged sediments, was delayed sufficiently to miss the period of maximum flood risk on tributary bottoms. The maximum drainage rate of 0.40 inch per day illustrates the regulation of flow when compared to overland runoff.

The study area, and similar Coastal Plain sandhills, function as a water-storage or flood-prevention impoundment with costs limited to proper forest management. Water quality is maintained and losses to evaporation minimized, and the life of these natural underground reservoirs is unlimited.

Opportunities for influencing ground-water recharge through vegetative management appear most promising. Evaporation of rain intercepted by the crowns of pole-size stands of pine can be reduced one inch annually for every 20 square-foot reduction in tree basal area (sum of stem cross-sections at breast height) (9). Many stands of pine have more basal area than needed for satisfactory tree growth. The amount of rain reaching the forest floor could be increased by 1 to 3 area-inches without greatly affecting the amount of wood fiber produced. Thinning also decreases losses to transpiration and, since thinning at 3- to 5-year intervals is practical, such decreases could be maintained. A study installed on three modal Coastal Plain soils in 1966 will determine if additional deep percolation can be induced by reducing stand densities. If results are promising it will be desirable to extend the study to pilot watersheds to determine the lowest levels of stocking to which stands can be thinned without increasing overland flow.

Other studies on small calibrated watersheds are determining if runoff from depleted hardwood stands and abandoned fields can be reduced by changing the cover to pine. The average now from such sites is 6 area-inches per year (11). Small changes may be vital. An annual increase of one inch of recharge per square mile amounts to almost 50,000 gallons per day.

Still other studies are concerned with the hydrologic effects of cultural practices and operations necessary to manage forest lands. Foresters, for example, may wish to make prescribed burns to control trees of undesirable species or to aid regeneration. Many working on erosive uplands in Mississippi and elsewhere are tempted to burn but, being increasingly aware of the total forest resource, are concerned with the consequences on runoff and erosion. Recent burns on small calibrated watersheds increased surface flows one to three area-inches the first year. These studies are continuing to determine the duration of burning effects. Such increases may be tolerable in some situations, but in others more costly methods of establishing or regenerating forest stands may be justified.

When expected increases in population and water demand materialize, it seems quite probable that forests occupying outcrops of productive southern aquifers supplying areas of concentrated needs will be managed for one major purpose--the maximum contribution of ground water.

LITERATURE CITED

1. Board of Water Commissioners, State of Mississippi.
1964. Water for industry. 30 pp., illus.

2. Conover, C. S.
1961. Ground-water resources--development and management. U.S. Dep. Interior Geol. Surv. Circ. 442, 7 pp.

3. Criner, J. H., Sun, P-C. P., and Nyman, D. J.
1964. Hydrology of aquifer systems in the Memphis area, Tennessee. U.S. Dep. Interior Geol. Surv. Water-Supply Pap. 1779-0, 54 pp., illus.

4. LaMoreaux, P E.
1960. Ground-water resources of the South--A frontier of the Nation's water supply. U.S. Dep. Interior Geol. Surv. Circ. 441, 9 pp., illus.

5. MacKichan, K. A., and Kammerer, J. C.
1961. Estimated use of water in the United States, 1960. U.S. Dep. Interior Geol. Surv. Circ. 456, 26 pp., illus.

6. McGuinness, C. L.
1963. The role of ground water in the national water situation. U.S. Dep. Interior Geol. Surv. Water-Supply Pap. 1800, 1121 pp., illus.

7. Nace, R. L.
1960. Water management, agriculture, and ground-water supplies. U.S. Dep. Interior Geol. Surv. Circ. 415, 12 pp., illus.

8. Nyman, D. J.
1965. Predicted hydrologic effects of pumping from the Lichterman well field in the Memphis area, Tennessee. U.S. Dep. Interior Geol. Surv. Water-Supply Pap. 1819-B, 26 pp., illus.

9. Rogerson, T. L.
1965. Throughfall in pole-size loblolly pine as affected by stand density. Presented at Int. Symp. on Forest Hydrol. Penn. State Univ., State Coll., Penn., Aug. 29-Sept. 10, 1965.

10. U.S. Department of Health, Education, and Welfare.
1965. Statistical summary of municipal water facilities in the United States. Public Health Serv. Pub. 1039, 66 pp., illus.

11. Ursic, S. J., and Dendy, F. E.
1965. Sediment yields from small watersheds under various land uses and forest covers. U.S. Dep. Agr. Misc. Pub. 970, pp. 47-52, illus.