An annotated

BIBLIOGRAPHY of WATERSHED MANAGEMENT RESEARCH

by the Northeastern Forest Experiment Station, 1931-65

by Howard W. Lull

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This Bibliography . . .

THIS bibliography contains annotated citations to 156 publications in forest-watershed-management research produced by the staffs of the Allegheny and Northeastern Forest Experiment Stations from January 1931 to April 1965. Twenty-one of these publications antedate the formal establishment of watershed-management research at the Northeastern Station on July 1, 1948.

The publications listed here are arranged alphabetically and chronologically by author. An asterisk (*) preceding the item indicates that copies of reprints of the publication are available from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pa. An author index will be found at the end of the bibliography.

Annotation and assembly of a bibliography of this kind provides an excellent opportunity to view and assess research results. Certain groupings become manifest: some papers obviously present new knowledge; a number review and embroider it for different audiences; a number simply state that problems for research exist and due to their importance, a research program is needed, or planned, or under way; others, written for colleagues, describe how research is done, often giving detailed descriptions of instrumentation and analytical methods; and an occasional publication will carry the burden of reviewing and correlating research results from different geographical or technical fields.

In evaluating research results of the past quarter century, some trends and generalizations become apparent. Following are some of the highlights of research accomplishments in watershed management.

Humus

The role of humus in forest hydrology was clarified: It appears that under present forest conditions the water-storage capacity of humus is 1 to 3 inches less than the potential capacity that can develop under full protection; further, the degree to which the forest floor remains intact after cutting indicates

the extent to which the beneficial hydrologic effects of the forest may still be present.

Infiltration and Overland Flow

From observation and measurement, infiltration is not limited and overland flow is not produced in forest areas where humus and litter are intact, even when these areas have been heavily cut over, except from very unusual heavy rainfall of prolonged high intensity. Overland flow is produced from logging roads and landings when the forest floor has been scraped or worn away, and the soil compacted.

Concrete Frost

Concrete frost has been observed in all types and conditions of forest stands but never of a magnitude to produce overland flow of any consequence.

Snow Accumulation and Melt

Snow accumulates to greater depths—and melts and disappears earlier in the spring—in the open and under hardwoods than under conifers. Accumulation remaining thereafter under conifers may produce peak flows during unusual warm spells. A mixed cover of hardwoods, conifers, and open land should lengthen the melting season and ameliorate peak flows.

Forest Cutting and Water Yield

Increases in water yield from forest cutting on shallow, stony soils in West Virginia are inversely related to the forest cover left on the area. Commercial clearcutting produced the greatest annual increase, about 5 area-inches of water. Most of the increase appeared during the growing season. Cost of the increased water yield, in terms of treatment cost and loss in timber income, amounted to $0.04 per 1,000 gallons. Yield increases were smaller each year after cutting; they were negligible after 6 years on the commercial clearcutting, sooner than that in the partial cuttings.

Forest Cutting and Peak Flows

Substantial increases in storm flow, which sometimes occur after clearcutting, are due to reduction in transpiration and soil drying rather than to drastic changes in amounts of overland, subsurface, or groundwater flows.

Sedimentation

Sources of sedimentation in forest areas are limited to the disturbed area described above and to channel-cutting. Erosion from logging roads may be minimized by proper road location and drainage, and sediment may to a large extent be kept out of streamflow by locating roads at stipulated distances from channels. Erosion from logging roads constructed on stony soils may be strongly and rapidly reduced by formation of a rock pavement.

Herbicide Pollution

In studies where forest vegetation was killed by basal, stump, and foliage sprays of 2,4,5-T, no significant herbicide contamination appeared in streamflow.

Regional Streamflow

For watersheds of 100-square miles or less in area, there was a significant difference in annual, seasonal, and storm flows between and within physiographic regions. Within regions there was considerable similarity between streamflow of experimental watersheds and the average regional streamflow.

Research Methods

In instrumentation and analytical methods, experience was drawn upon to prepare monographs on construction of stream-gaging-stations for research on small watersheds, and on the all-important procedure of calibrating watersheds before treatment. Correlation and review papers covered the subjects, among others, of soil compaction, forest humus, and light. In research problems, perhaps the most significant were the importance of municipal watersheds in the Northeast and the need to find means of broadening both the fundamental basis and the practical application of research results.

But That Is Not All

This compilation and review is strictly limited to the watershed research conducted by the Northeastern Forest Experiment Station. It may enable a reader to find out what has been done here and what publications have been prepared and are available. But this is a small drop in a big bucket. Forest watershed research is conducted by other agencies in the Northeast, at universities, and in other regions. And there are many disciplines not functionally tied to forest watershed research whose research results impinge upon it. Obviously there must be a continual cross-fertilization of ideas and methods, and at times a summing-up such as this.

The Publications

(1) Behre, C. Edward. 1932. **Are further studies needed on the relation of forests to water supply in New England?** Jour. New England Water Works Assoc. 46: 170-175.

In the Northeast, water-resource problems chiefly concern suppliers for municipal use and for power. Southern New England is already using about one-sixth of its potential water supply. If streamflow can be made more uniform and flood peaks reduced through control of vegetation, a larger proportion of water yield could be utilized with a given reservoir storage capacity. Research is needed to determine the effect of vegetative cover of various kinds on quantity, regularity, and quality of streamflow.

(2) Behre, C. Edward. 1932. **The relation of forests to the water supplies of New England.** Water Works Engin. 85: 276-279.

A briefer version of the same material described above.

(3) Belotelkin, K. T. 1940. **Soil freezing and forest cover.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Tech. Note 37. 4 pp.

In northern New Hampshire before snowfall the soils in the open froze before forest soil. Open soil froze solid whereas forest soil, when frozen, maintained good permeability far into the winter. Frost penetration was least in the hardwoods, deeper in the open, and deepest in the spruce swamp where, because of interception, snow depth was shallowest. Frost remained in the ground longer under softwoods than in the open or under hardwoods. Frost disappeared earliest under the hardwoods.

*(4) Bethlahmy, Nedavia. 1951. **An alinement chart for use with the fiberglas soil-moisture instrument.** Soil Sci. 71: 377-380, illus.

An alinement chart is described that shortcuts computations involved in computing soil moisture from resistance readings obtained with the fiberglas soil-moisture instrument. Results are well within the limits of accuracy of charts provided with the instrument.

(5) Bethlahmy, Nedavia. 1951. **Distant earthquakes affect local ground-water levels.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Res. Note 9: 1-3.

Ground-water levels at the Delaware-Lehigh Experimental Forest in eastern Pennsylvania fluctuated a few hundredths of a foot with occurrence of severe earthquakes in India and British Columbia. Checking ground-water-level records against notices of earthquakes throughout the world, the author found that levels were being affected by distant earthquakes every 8 to 12 days.

(6) Bethlahmy, Nedavia. 1952. **A method for approximating the water content of soils.** Amer. Geophys. Union Trans. 33: 699-706, illus.

A procedure is described for calibrating fiberglas soil-moisture units and for preparing tables needed to convert resistance readings into inches of water. Shapes and slopes of calibration curves were determined in the

laboratory and their positions along the moisture-percent scale were determined by field calibration. Estimates of bulk density based on soil depths and moisture content were used to convert moisture percentages into inches of water.

*(7) Bethlahmy, Nedavia. 1952. **Why do plants wilt in cold weather?** Ecology 33: 301-303, illus.

Studies of soil freezing indicate that, when a soil is frozen, the fiberglas soil-moisture units react as though the soil had been desiccated. A frozen soil is, physiologically, a dry soil. Concrete frozen soil is equivalent to a soil that is below its wilting point in moisture content. Thus a plant growing in frozen soil has no moisture available for growth; if it transpires, it will wilt. Frost, root, and snow depths are influencing factors. These relationships can determine the advisability of fall planting of conifers.

*(8) Bethlahmy, Nedavia. 1953. Discussion of **Frost penetration into soils as influenced by depth of snow, vegetative cover, and air temperatures,** by Clyde E. Bay, George W. Wunnecke, and Orville E. Hays. Amer. Geophys. Union Trans. 34: 635-637.

Gypsum blocks and fiberglas units can be used to measure movement of frost into and out of the soil, but resistance measurements do not indicate frost type. Also, frozen soil may draw moisture from lower unfrozen horizons, thus changing the type of frost without a change in resistance readings.

(9) Bethlahmy, Nedavia. 1953. **Estimating summer evapotranspiration losses in a Pennsylvania scrub oak forest.** Soil Sci. Soc. Amer. Proc. 17: 295-297, illus.

Soil moisture was measured with fiberglas units, and losses were calculated daily for periods when soil was below field capacity. A significant relationship between losses and saturation deficit was found; the regression coefficient was related to the percentage of sand in the soil profile. Calculated evapotranspiration losses checked well against the water balance of the experimental watersheds.

(10) Bevan, Arthur. 1947. **Flood control surveys in the Northeast.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 10. 9 pp., illus.

The Omnibus Flood Control Act of 1936 directed the Secretary of Agriculture "to make preliminary examinations and surveys for runoff, and waterflow retardation, and soil erosion prevention." The Forest Service has been engaged in surveys on the Allegheny, Connecticut, and Merrimac watersheds. Purpose of the surveys is to develop a comprehensive program for flood control based primarily on land-use management effects on runoffs. Costs and benefits of the proposed programs are estimated. The approach to flood control is a comprehensive integrated program including engineering structures and land-use structures that will produce the most flood control for the least cost.

(11) Bjorkbom, John C., and George R. Trimble, Jr. 1958. **Sow seed on logging roads to control erosion.** Northeast. Logger 7: 18-19, 36-37, 46, illus.

Several combinations of seed, lime, and fertilizer successfully revegetated

and stabilized bare soil of logging roads in the White Mountains of New Hampshire. Two seeding mixtures are suggested for heavily shaded roads and three for open or lightly shaded roads. Lime and fertilizer are necessary. Seeding is particularly needed on steep pitches and on grades over 5 percent cut deeply into mineral soil, and on raw and unstable cut and fill banks.

(12) Day, Gordon M. 1940. **Topsoil changes in coniferous plantations.** Jour. Forestry 38: 646-648.

Soils of 18 conifer plantations in Vermont and New York were compared with those in adjacent openings. In 18 to 61 years the plantations accumulated 6,000 to 38,000 pounds of forest floor material per acre. Plantations with mull humus showed an increase in organic content of the upper layers of mineral soil. Where mors developed, the topsoil had less organic matter than open areas under grass cover. Surface layers of mineral soil in the plantations were about twice as permeable to water as those in open areas. Differences in percolation between the planted and open areas were much greater in the mull types than in the other types.

(13) Diebold, C. H. 1940. **Strip planting for flood control.** Jour. Forestry 38: 810-812.

Crown closure and humus development were studied in 17 fully stocked coniferous plantations in southwestern Pennsylvania in order to assess flood-control benefits. Crowns of Scotch and pitch pines planted 4 x 4 or 5 x 5 feet closed in 6 to 8 years; planted 6 x 6 or 7 x 7 1 to 3 years longer. Pitch and Scotch pine closed 2 to 4 years earlier than red and white pine. Norway spruce closed in 12 to 15 years where planted 4 x 4 or 5 x 5. Pitch pine planted 5 x 5 developed a humus layer of 1½ to 2 inches in 15 years; other pines developed somewhat shallower layers. Little or no humus was found under Norway spruce. Strips of pine, hardwood, and shrubs for game food, 10 to 20 rows wide, are suggested for flood control.

(14) Dunford, E. G., and Sidney Weitzman. 1955. **Managing forests to control soil erosion.** *In* **Water.** U. S. Dept. Agr. Yearbook 1955: 235-242.

Outlines principles of integrating timber and watershed management to control erosion from forest lands. Describes factors responsible for accelerated erosion from forest lands. Recommends measures of fire prevention, grazing control, logging, and construction of logging roads for erosion control.

*(15) Eschner, Arthur R. 1960. **Effect of scrub oak and associated ground cover on soil moisture.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 133. 16 pp., illus.

Soil was consistently wettest on areas where scrub-oak overstory and ericaceous groundcover had been deadened, and driest on undisturbed areas. An area covered chiefly by sheep laurel generally had the second lowest soil-moisture content, and a bare area from which the natural humus layer and several inches of topsoil had been removed was generally intermediate in rank. A site treatment that completely deadens low-growing vegetation will make maximum amounts of water available to

planted seedlings. Deadening the scrub oak alone will not reduce transpiration losses by any appreciable amount.

(16) Eschner, A. R., B. O. Jones, and R. C. Moyle. 1957. **Physical properties of 134 soils in six Northeastern states.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 89. 23 pp., illus.

Mechanical analysis, organic-matter content, plasticity, bulk density, and soil-moisture contents at saturation and field capacity are given for 134 soils in the six Northeastern States from Pennsylvania to New Hampshire. Regressions express the relationship of bulk density to organic-matter content and soil texture.

*(17) Eschner, Arthur R., and Jack Larmoyeux. 1963. **Logging and trout: four experimental forest practices and their effect on water quality.** Progressive Fish-Culturist 25: 59-67, illus.

Clearcutting a West Virginia watershed resulted in significantly higher maximum stream temperatures, above those generally tolerated by brook trout. The increase in dissolved solids noted was not great enough to affect stocking. Late summer and early fall increases in streamflow from the cutting would be beneficial to trout, for they come at a time when flow in many trout streams is dangerously low. High turbidities would be detrimental to trout.

*(18) Eschner, A. R., and D. R. Satterlund. 1963. **Snow deposition and melt under different vegetative covers in central New York.** U. S. Forest Serv. Res. Note NE-13, p 66., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Analysis of snow measurements in 5 cover types in the Allegheny Plateau suggests that if a warm period comes early in the spring, forest snow melt contributes less and slower runoff than open areas. But when warm weather comes late, and with an appreciable snowpack only in the forest, the reverse should be true. A mixture of forest cover and open area may provide the best land-use control of snowmelt runoff.

*(19) Felton, Paul M., and Howard W. Lull. 1963. **Suburban hydrology can improve watershed conditions.** Public Works 94: 93-94, illus.

Infiltration measurements in woods, fields, and lawns in Philadelphia's suburban Wissahickon watershed showed that relative infiltration under present land-use is about one-half of what it was for forested conditions, and it has dropped 10 percent by reason of land-use changes since 1950. Methods by which suburbanites may increase infiltration are discussed.

(20) Flaccus, Edward. 1958. **Landslides and their revegetation in the White Mountains of New Hampshire.** Ph.D. dissertation, Department of Botany, Duke Univ., Durham, N. C.

About 550 slides in the White Mountains were studied to determine the factors contributing to their occurrence and the nature of their revegetation. The immediate cause of slides is the sudden failure of internal resistance to downslope movement—resulting from a complex of interacting factors. Heavy rainfall was found to be the single most important contributing factor when slope steepness ranged from 25-35 degrees. Slides

are not likely to occur on slopes that do not exceed 25 degrees. They occur naturally and are not appreciably affected by man's activity. The degree of revegetation is related to slide features—bare cliffs and ledges, talus or rock debris, gullies, residual areas, and deposit areas.

*(21) Fletcher, Peter W., and Howard W. Lull. 1963. **Soil-moisture depletion by a hardwood forest during drought years.** Soil Sci. Soc. Amer. Proc. 27: 94-98, illus.

In Butler County, Missouri, during two drought years, daily soil-moisture measurements were taken in a mixed oak-hickory stand in plots that were bare, had litter only, trees only, and trees and litter (no treatment). As compared with undisturbed soil at field capacity, litter removal increased soil drying rates about 10%; tree removal decreased them about two-thirds; removal of both trees and litter decreased soil drying rates about one-third. Soil-moisture regimens are interpreted with respect to tree mortality due to drought. Upland sites with subsoil pan formations are especially vulnerable to periodic drought losses.

(22) Forbes, R. D. 1931. **Watershed cover and water conservation.** (Address delivered before the annual meeting of the Maryland and Delaware Water and Sewerage Assoc., Wilmington, Del.) U. S. Forest Serv. Allegheny Forest Expt. Sta. 7 pp.

Results from recent studies on use of water by forest vegetation, percent runoff from areas under different land use, and influence of forest cover on surface runoff and evaporation suggest possibilities of increasing water supplies by vegetation management. Revenue from recreational use of watersheds may help in acquisition of watershed lands by water companies. Research on forest influences will be undertaken by the U. S. Forest Service. The Allegheny Station has asked for funds for studies in the headwaters of the Allegheny River and on the watershed of some large city on the Atlantic Seaboard. A plant physiologist, soils expert, silviculturist, and meteorologist should be employed on each study.

(23) Forbes, Reginald D. 1934. **Ruling the river.** Sci. Monthly 38: 524-533.

The influence of forests on streamflow has been argued in connection with acquisition and administration of the national forests and in connection with the Mississippi River flood of 1927. Complexities of forest influences are brought out in a review of the climactic and geological factors that affect streamflow, and the role played by the forest, particularly the influences of forest humus on water-holding capacity of the soil and on percolation, and the influences of the canopy on interception and snow-melt. Whether the forest influences are beneficial or detrimental depends upon region and season. For instance, Appalachian forests are indispensable to well-regulated streamflow. In southern California, however, canyon-bottom forest uses excessive amounts of water. More knowledge of forest influences is needed.

(24) Forbes, R. D. 1936. **Forests and flood control.** Pa. Forest Leaves 26: 19-20.

Foresters have accomplished little in determining the influence of forest cover on streamflow. No research of this kind has been conducted in the

Northeast. Urges that streamflow and weather records for 125 streams in the Allegheny area that have been gaged for more than 5 years should be assembled, together with forest data, and studied to give at least preliminary information on the relationship of forests and streamflow.

(25) Fridley, Burley D. 1953. **Home-made gadgets aid forest-influence research.** Jour. Forestry 51: 907-908, illus.

Three home-made devices have proved helpful: (1) an ordinary bucket made into a simple stove for thawing ice and snow in rain gages; (2) a spring clamp for holding a measuring tape to a stake when measuring erosion on road cross-sections and (3) a portable datum level for measuring erosion on logging roads where reference stakes cannot be used on the road.

(26) Garland, Lloyd E., Robert S. Pierce, and George R. Trimble, Jr. 1959. **A soil survey of forest land.** Jour. Soil and Water Conserv. 14: 199-204, illus.

A modification of detailed soil-surveying methods on farmlands is described for use in mapping extensive areas of woodland in the Northeast, as worked out at the Hubbard Brook Experimental Forest in New Hampshire. Mappable topographic, soil, and geologic factors are considered that would broadly define the growing potential and watershed-management aspects of any area of woodland. Certain criteria are set up to indicate logging and road-building limitations.

(27) Gedney, Donald R. 1949. **Land abuse, a flood, and then more floods.** Pa. Forest Leaves 34: 17.

Destructive use of forest land in northwestern Pennsylvania set the stage for the damaging flood of July 17-18, 1942, which cost 15 lives and millions of dollars worth of damage. Floods in this area were infrequent before this; but since that flood, the worst on record, annual and semi-annual floods have occurred. A remedial program of better land-use management is needed.

(28) Grossman, Sidney J. 1941. **Comments on strip planting for flood control.** Jour. Forestry 39: 728-730.

In opposition to Diebold's paper (1940) the author questions the flood-control benefits brought about from crown closure, points out instances where frost remained 7 to 10 days longer in conifer plantations than in the open, where infiltration rates were lower in plantations than in the open, and raises economic questions that should be considered in choices of species and spacing of conifer plantations.

(29) Hale, Charles E., and G. R. Trimble, Jr. 1950. **Permanent wilting percentages of glacial soils in the Northeast.** Jour. Soil and Water Conserv. 5: 135-136.

Moisture contents of soils at permanent wilting were determined during a drought the summer of 1949 in the upper Susquehanna river watershed in New York state. Percent moisture contents by weight and volume are given for humus layers and soil horizons.

*(30) Hart, George. 1961. **Humus depths under cut and uncut northern hardwood forests.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 113. 4 pp.

In a stand of high site quality on the Bartlett Experimental Forest in New Hampshire, H-layers in 1959 averaged 2.35 inches deep in an area clearcut in 1939, 2.95 inches deep in an area thinned in 1937 with 40 percent of the volume removed, and 3.37 inches deep in an uncut stand. Differences were not so great in a stand of lower site quality: comparable depths were 2.05, 2.27, and 2.33 inches.

*(31) Hart, George. 1963. **Snow and frost conditions in New Hampshire, under hardwoods and pines and in the open.** Jour. Forestry 61: 287-289, illus.

At maximum snow accumulation there was no significant difference in snow-water contents between the open field (6.8 inches) and a 40-to-50-year-old hardwood stand (7.0 inches). Forty-year-old white pine and red pine plantations had maximum contents of about 5.0 inches. Differences were attributed mainly to canopy density. Order of snow disappearance was: (1) open field, (2) hardwoods, (3) red pine, (4) white pine. Melt rates were 0.10, 0.05, and 0.04 inches per day for hardwoods, white pine, and red pine respectively. Yearly differences in temperature and snow depth produced large variations in occurrence of concrete frost.

*(32) Hart, George, and Howard W. Lull. 1963. **Some relationships among air, snow, and soil temperatures and soil frost.** U. S. Forest Serv. Res. Note NE-3, 4 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Winter temperatures of air, snow, and soil measured on snow-covered and bare plots near Laconia, N. H., showed an increase in temperature and reduction in its temporal variation going from air to snow to soil. Twelve inches of snow will prevent soil freezing at air temperatures down to 5° F, and 6 inches of snow down to 25° F.

*(33) Hart, George, Raymond E. Leonard, and Robert S. Pierce. 1962. **Leaf fall, humus depth, and soil frost in a northern hardwood forest.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 131. 3 pp.

Annual leaf accumulation under a second-growth northern hardwood forest in New Hampshire in the mound-and-depression microtopography typical of the region averaged 1,478 pounds per acre on mounds, 2,582 on slopes, and 5,515 in depressions. Humus depths averaged 2.0, 3.5, and 7.1 inches for the three sites respectively. Greater depths of leaves and humus in the depressions protected the soil from concrete frost.

*(34) Hornbeck, James W. 1964. **The importance of dew in watershed-management research.** U. S. Forest Serv. Res. Note NE-24, 5 pp. Northeast. Forest Expt. Sta., Upper Darby, Pa.

From May through November 1962 monthly dew deposition at the Fernow Experimental Forest in West Virginia ranged from 0.017 to 0.055 inch. Dew or frost was recorded on 111 of the 200 days of record. Total deposition during July, August, and September was 0.131 inch, or 1.2 percent of the precipitation. For any one month the error in precipitation measurements probably exceeds dewfall. Dewfall is probably not large enough to warrant measurement in watershed-management studies.

*(35) Hornbeck, J. W., and K. G. Reinhart. 1964. **Water quality and soil erosion as affected by logging in steep terrain.** Jour. Soil and Water Conserv. 19: 23-27, illus.

A study at the Fernow Experimental Forest in West Virginia has shown that excessive damage to water quality can be avoided even when logging on steep terrain. Measured maximum stream turbidities were 56,000 ppm. on a commercial clearcut area where skidroads were steep and close to the stream and only 25 ppm. on an intensive selection-cut watershed where skidroad location was carefully planned to prevent eroded materials from reaching the stream channel. Most of the damage to water quality occurred during and immediately after logging. Recommended practices include planning of the logging operation; proper location, drainage, and grade of skidroads; and timely completion of the operation.

*(36) Hornbeck, James W. 1965. **Accuracy in streamflow measurements on the Fernow Experimental Forest.** U. S. Forest Serv. Res. Note NE-29, 8 pp. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Sources of error were evaluated in respect to stream-gaging instrumentation, stage-discharge relation, hook-gage measurements, and compilation of data. Total error from all sources was estimated to be about 3 percent of annual streamflow values.

(37) Hough, A. F. 1945. **Frost pocket and other microclimates in forests of the northern Allegheny Plateau.** Ecology 26: 235-250.

Frost pockets result from heavy cutting followed by forest fires. Once opened, these areas persist for many years. Conversion to good forest depends on fire protection, reduction of browsing by deer and rabbits, and possibly planting of frost-resistant conifers. Partial cuttings should be the rule in all forests on the high plateau, especially on topography susceptible to formation of frost pockets.

*(38) Lavigne, Raymond W. 1960. **A time-corrector device for adjusting streamflow records.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 98. 4 pp., illus.

A plexiglas graph was constructed with time corrections on the vertical scale and days of record on the horizontal, to prorate time corrections on streamflow charts. Adjustable arms were attached for determining 8- and 15-day corrections, the most common periods used. This device eliminates the necessity of making a separate graph for each time-scale correction. It can be adapted for making time corrections for precipitation and hygrothermograph charts.

*(39) Leonard, Raymond E. 1961. **Interception of precipitation by northern hardwoods.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 159. 16 pp., illus.

A study of rainfall interception at the Hubbard Brook Experimental Forest during two growing seasons showed that net precipitation (throughfall plus stemflow) averaged 87 percent of precipitation measured in the open. During the leaf period it averaged 82 percent, and in the leafless period 88 percent. Rainfall that ran down the tree stems amounted to 5 percent of that measured in the open. Stemflow from a 10-inch

beech for a 1-inch storm amounted to 30 gallons of water or to a depth of about 7 inches of water at the base of the tree.

(40) Leonard, Raymond E. 1961. **Net precipitation in a northern hardwood forest.** Jour. Geophys. Res. 66: 2417-2421, illus.

Throughfall and stemflow measurements for two growing seasons were related to gross storm rainfalls by linear regressions. Net precipitation averaged 87 percent of gross rainfall, of which 82 percent was rainfall and 5 percent was stemflow. Large differences in amounts of stemflow were found among various hardwood species. American beech had twice the stemflow of yellow birch.

*(41) Leonard, Raymond E., and Kenneth G. Reinhart. 1963. **Some observations on precipitation measurement on forested experimental watersheds.** U. S. Forest Serv. Res. Note NE-6, 4 pp. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Exposure of precipitation gages as a result of clearcutting a West Virginia watershed reduced annual catch by a little less than 3 percent and winter catch from 3 to 7 percent. Tilting precipitation gages did not give the increased catch that had been reported in the West, probably because the gages were protected somewhat from the wind. Vertical gages provide an index of precipitation on the watershed. Tilted gages, when exposed on representative slopes and aspects, will give absolute estimates.

*(42) Little, Silas, Howard W. Lull, and Irwin Remson, 1959. **Changes in woodland vegetation and soils after spraying large amounts of waste water.** Forest Sci. 5: 18-27, illus.

Waste water from a food-processing plant in New Jersey, sprayed onto woodland at a rate of 400-600 inches a year, has killed off practically all trees and native shrubs and herbs and stimulated a rank growth of elder and common field weeds. Soils have remained highly permeable; forest floors have deepened and become more mull-like. Continuing high rates of water absorption are ascribed to the undisturbed soil condition and the protective forest floor that breaks the impact of spray.

(43) Lull, Howard W. 1955. **Water supplies and our forest.** Pa. Forests 45: 58-60.

Defines and describes forest watershed management and considers present and future demands for water, the importance of forested watersheds to water-supply problems, and the watershed research program of the Northeastern Station.

(44) Lull, Howard W. 1957. **Forest watershed management research in Pennsylvania.** Pa. Forests 37: 41-42, illus.

Forest watershed-management research was begun in Pennsylvania in 1948 at the Delaware-Lehigh Experimental Forest to find methods of converting scrub oak to commercial timber and to determine the effect of this conversion on streamflow. Daily streamflow and climactic records have been published in a series of three progress reports, each covering 2 years of record. Prediction equations for monthly, seasonal, and annual streamflow have been developed. Watershed research was started at the Pocono Experimental Forest in 1949. Snow and frost studies were made in the Pocono Plateau in 1950-52, and recently periodic snow surveys were

started in the Allegheny Plateau. Other areas where watershed research is needed include the Ridge and Valley Region.

(45) Lull, Howard W. 1957. **What they said about forests and floods in Pennsylvania 50 to 75 years ago.** Pa. Forests 37: 91-92, 107.

Early conservationists in Pennsylvania were deeply concerned about the effect of forest cutting on the water resources, as evidenced by a succession of statements and reports in the Annual Reports of the Commonwealth's Board (later Department) of Agriculture and Department of Forestry from 1877 to 1901-02. Interest in this subject abruptly lessened with acquisition of state forest lands in 1897.

(46) Lull, Howard W. 1958. **Better water through forest management.** *In* **Better water through forestry and engineering:** 10-19. Interstate Comn. on Potomac River Basin. Washington, D. C.

Outlines forest watershed problems in the Potomac River basin, various measures undertaken to improve the situation, and research under way to determine what effects forest type and condition have on water yield, distribution, and quality.

*(47) Lull, Howard W. 1958. **Municipal watersheds in the Northeast.** Jour. Amer. Water Works Assoc. 50: 979-982.

There are more than 300 forested watersheds in the Northeast from which municipalities draw part or all of their water supplies. Numbers and areas of watersheds are listed, by states, and largest areas are noted. Management plans have been prepared for several watersheds. Possibilities of increasing water yield by forest cutting are considered, and watershed research in the Northeast is described.

*(48) Lull, Howard W. 1959. **Soil compaction on forest and range lands.** U. S. Dept. Agr. Misc. Pub. 768. 33 pp., illus.

A review of the literature on soil compaction on forest and range lands as related to soil and water conservation: the compaction process; the extent of compaction by logging, grazing, and other agencies; the effects of compaction by logging and trampling on soils, soil-water relations, and vegetal growth; and remedies for compaction and methods of preventing or minimizing it.

*(49) Lull, Howard W. 1959. **Humus depth in the Northeast.** Jour. Forestry 57: 905-909, illus.

Humus depth under virgin spruce-fir in mountains of the Northeast ranged from 8 to 16 inches, under hemlock and hardwoods in the Adirondacks from 3 to 9 inches, and from 2 to 5 inches elsewhere in the Northeast. Except for spruce in the White Mountains and hemlock in the Adirondacks, the depths under virgin stands are about 1 inch greater than present accumulations under sawtimber-poletimber stands. Pertinence of humus depths to flood protection is considered.

*(50) Lull, Howard W. 1960. **Watershed management research in the Northeast.** Jour. Forestry 58: 285-287.

Forest watershed research programs are conducted in 7 of the 12 Northeastern States by the U. S. Forest Service, U. S. Geological Survey, the

Cities of Baltimore, Md., and Newark, N. J., Yale University, Syracuse University, and the Pennsylvania State University. In all, 30 experimental watersheds are being studied to determine how forest cover and changes in cover affect streamflow.

*(51) Lull, Howard W. 1960. **Forested municipal watersheds in the Northeast.** Jour. Forestry 58: 83-86.

Forested municipal watersheds and forest-bounded reservoirs provide and protect water supplies for 360 municipalities in the Northeast, total well over 1 million acres of forest land, and serve about one-third of the region's population. Originally set aside for protection of water supplies, many of these areas are now managed also for forest products. Examples are given.

*(52) Lull, Howard W. 1962. **Management for water production on municipal watersheds.** World Forestry Cong. Proc. 5: 1686-1690.

Few if any of the forested municipal watersheds in the United States are now being managed to regulate water yield, yet increasing demands for water indicate need for such management. Possible approaches are suggested. Logging methods, erosion control, and pros and cons of recreation on watersheds are discussed.

*(53) Lull, Howard W. 1963. **Forest influences research by questionnaire.** Jour. Forestry 61: 778-782.

Early conservationists employed polls to find out the effects of forest cutting on streamflow. For instance, around the 1900's the states of New York, Pennsylvania, and Ohio queried engineers and long-time residents as to their opinions. More recently, the director of forestry in South Africa conducted a similar poll. Most of those polled believed that forest cutting had reduced streamflow, though there were some differences of belief.

(54) Lull, Howard W. 1964. **Ecological and silvicultural aspects.** *In* **Handbook of applied hydrology:** 6-1 to 6-30, illus. McGraw-Hill Book Co., New York.

The proportion of precipitation intercepted by forest vegetation, the rate of infiltration of water into the soil, and the amount of water evapotranspired tend to increase as ecological succession proceeds from the preclimax to the climax condition, or with silvicultural practices that increase the density of vegetation. Exceptions are noted.

(55) Lull, Howard W. 1964. **Some recent results from forest watershed research.** Soc. Amer. Foresters Allegheny Sect. Proc. 1964: 44-48.

Recent research results suggest some new concepts in forest-streamflow relationships and some practical management applications. Among items considered were reduction in sedimentation rates from logging roads, overland flow and flood peaks from a heavily cutover watershed, snowmelt contributions to flood peaks from conifers and hardwoods, small watershed research application to large watersheds, sources of base flow, and the use of silvicides on watersheds.

(56) Lull, Howard W., and John H. Axley. 1958. **Forest soil-moisture relations in the Coastal Plain sands of Southern New Jersey.** Forest Sci. 4: 2-19, illus.

Soil-moisture measurement during the growing season on upland sites in the New Jersey Barrens indicated that stands of shortleaf pine and scrub oak used about the same amount of water at about the same rate from the upper 5 feet of soil. Both removed moisture to a depth of at least 12 feet. Seven-year-old pine and oak-sprout stands removed moisture as rapidly and at the same depth as older oak stands. A 15-year-old shortleaf pine stand utilized moisture to a depth of 8 feet, and a bare area dried to a depth of 6 feet.

(57) Lull, Howard W., and Peter W. Fletcher. 1962. **Comparative influence of hardwood trees, litter, and bare area on soil-moisture regimen.** Univ. Mo. Agr. Expt. Sta. Res. Bul. 800, 15 pp., illus.

In a mixed oak-hickory stand in Butler County, Mo., pairs of plots were treated to obtain the following conditions: trees and litter (no treatment), trees only, litter only, and bare. Daily soil-moisture readings were taken to determine the soil-moisture regimen. During two growing seasons the litter-only plots were wettest, and the trees-only plots dried most rapidly. Summer rainfalls were stored, for the most part, in the top 20 inches of soil. Rates of moisture loss tended to decrease with increasing depth. Watershed management implications are examined.

(58) Lull, Howard W., and Ralph W. Marquis. 1957. **Forests guard the Potomac.** *In* **Upstream Conservation.** Interstate Comn. on Potomac River Basin: 44-58, illus. Washington, D. C.

Forest influences on Potomac streamflow are discussed in relation to forest-use of water; the effects of forest cutting, planting and composition on water yield; and effects on flood peaks and water quality. A program of forest watershed protection is recommended.

(59) Lull, Howard W., and Robert S. Pierce. 1959. **Frost and forest soil.** Internatl. Union Geodesy and Geophys. Pub. 48 vol. 1: 40-48.

Average depths of concrete frost in 14 forest-condition classes in the Northeast and the percentage of days concrete frost occurred during the frost period are compared with frost depth and occurrence in four open-land use conditions. Average depth ranged from 4.7 to 6.2 inches in open lands, 2.5 to 3.5 inches in conifer stands and hardwood reproduction, and 1.2 to 2.5 inches in hardwood stands. Percentage occurrences in the above order were 57 to 80, 17 to 44, and 12 to 20. Forest watershed management implications are considered.

*(60) Lull, Howard W., and Robert S. Pierce. 1960. **Prospects in the Northeast for affecting the quantity and timing of water yield through snowpack management.** Western Snow Conf. Proc. 1960: 54-62.

Snowfall, snowmelt runoff, and the influence of forest cover on snow accumulation and melt are evaluated in respect to flood prevention and

water yield. Areas of management possibility lie largely in New York and northern New England, where one-third to one-half of the average annual streamflow comes from snowmelt and rainfall in April and May.

*(61) Lull, Howard W., and Irvin C. Reigner. 1957. **A program of watershed-management research on forest lands in the Upper Delaware and Susquehanna River basins.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 92. 33 pp., illus.

Water, forest, and soil resources are described and watershed research problems of 7 regions are noted. A 5-point program is proposed, designed to provide the information needed for the management of forested watersheds in the area.

*(62) Lull, Howard W., and Francis M. Rushmore. 1960. **Snow accumulation and melt under certain forest conditions in the Adirondacks.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 138. 16 pp., illus.

In the spring of 1959, maximum snow accumulation in hardwood sapling and sawtimber stands contained 2 more inches of water than the snowpack in balsam fir and red spruce stands. Snow melted about twice as fast in hardwood stands as in conifer stands and disappeared about 9 days earlier. In mixed conifer and hardwood stands, accumulation and melt were intermediate. Accumulation and melt were correlated with canopy closure, as measured with a spherical densiometer.

*(63) Lull, Howard W., and Francis M. Rushmore. 1961. **Further observations of snow and frost in the Adirondacks.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 116. 4 pp., illus.

Snow-depth and water-content measurements in March and April 1960 were checked against values predicted with procedures developed in 1959. Predicted and actual values were very close. During 51 days of snow interception observation, average snow depth on balsam fir branches was 2.13 inches, on red spruce 1.84, white pine 1.78, and hemlock 1.18. Concentrations of concrete frost were found beneath conifer crowns where snow was shallowest.

(64) Lull, Howard W., and Francis M. Rushmore. 1962. **Influence of forest cover on snow and frost in the Adirondacks.** Eastern Snow Conf. Proc. 1961-62: 71-79, illus.

Maximum accumulation of snow-water in mid-March 1959 in a northern hardwood stand was 9.01 inches as compared to 6.92 inches in a red spruce-balsam fir stand; by mid-April the greater melt rate in the hardwoods had more than erased this 2-inch difference. Maximum accumulation and rates of melt were related to canopy closure as measured with a spherical densiometer, and predictions were checked against 1960 data. Snow catch on branches of various conifers was related to their form and needle habit. Concrete frost tended to form beneath conifer crowns in the snow-interception zone.

*(65) Lull, Howard W., and Donald R. Satterlund. 1964. **What's new in municipal watershed management.** Soc. Amer. Foresters Proc. 1963: 171-175.

Recent research shows that forested watersheds can produce high-quality

water when carefully logged. A review of the effects of clearcutting on water yield shows that first-year water yields are increased about 4 to 8 inches. Reforestation over a 20-year period has reduced annual yield about 5 inches. In two studies, cost of increasing water yield was 4 cents and 21 cents per 1,000 gallons of increased yield. A method of evaluating low flow occurrence and persistence is given.

*(66) Lull, Howard W., and Herbert C. Storey. 1957. **Factors influencing streamflow from two watersheds in northeastern Pennsylvania.** Jour. Forestry 55: 198-200, illus.

Comparison of the Lehigh and Lackawaxen watersheds (located about 12 miles apart) offers an example of the difference that forest cover, land use, and soil make in the streamflow of two watersheds that have similar climate. Annual maximum daily flows of the Lackawaxen were consistently greater than Lehigh values, and annual minimum daily flows lower. The Lehigh was 93 percent forested, the Lackawaxen 61 percent. Most soils of the Lackawaxen were poorly drained while the Lehigh soils were better drained.

*(67) Lull, Howard W., and Norman R. Tripp. 1958. **The management of forested watersheds in New England.** Jour. New England Water Works Assoc. 72: 341-349.

Describes how quantity and quality of water from a forested watershed is influenced by type of forest cover, cutting treatments, and logging operations, with some practical management suggestions based on water shed research.

(68) Lull, Howard W., and others. 1962. **Forest land management in watershed programs.** Chapter III (23 pp.). *In* **Watershed management.** FAO Occas. Paper 13. Rome.

The protective function and water-yield effects of forest management on streamflow are discussed in respect to reforestation, logging, fire, disease, and insect attack. Watershed-management techniques for protection and for increasing water yield are described in terms of general principles, and examples are given of applications to several environmental situations: intense cold, snow, high and low rainfall, deep or shallow soils, and slow or rapid growth.

*(69) McLintock, Thomas F. 1959. **Soil moisture patterns in a northern coniferous forest.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 128. 5 pp., illus.

A brief description of major soil-moisture trends in relation to the hummock-and-hollow topography of a mixed pine-fir-spruce stand near Orono, Maine. Moisture content of soils in hummocks dropped below saturation 1 to 2 weeks before that in hollows. Differences suggest that hummock positions may have more favorable growing conditions early in the season when the soil is wet, and may be but little more adverse when the soil is dry.

(70) *McQuilkin, W. E., E. F. McNamara, Irvin C. Reigner, and Howard W. Lull. 1955. Report No. 3: **Forest and Water Research Project, Delaware-Lehigh Experimental Forest.** Pa. Dept. Forests and Waters. 44 pp., illus. Harrisburg.

Progress in cooperative watershed and scrub-oak-conversion studies is

described with some notes on fire control. Tabular daily data from watershed study include precipitation, air temperature and other climatic factors, streamflow, groundwater levels, soil moisture content, and soil freezing, for October 1952 to September 1954.

(71) Mitchell, Wilfred C., and G. R. Trimble, Jr. 1959. **How much land is needed for the logging transport system?** Jour. Forestry 57: 10-12, illus.

At the Fernow Experimental Forest 4.8 to 7.0 percent of the area was used for skidroads in road systems located by loggers' choice and from 2.5 to 4.6 percent in systems located by foresters. Careful planning by foresters can reduced skidroad areas by 40 percent. Average grade of loggers' roads ranged from 14 to 21 percent and of foresters' roads, 9 to 15 percent.

(72) Morey, H. F. 1931. **Climatological charts for the Allegheny forest region.** Mo. Weather Rev. 59: 18-28.

Average annual and summer temperatures, mean maximum and minimum summer temperatures, average dates of first frost in fall and last killing frost in spring, average annual precipitation, average summer precipitation, and average length of growing season are indicated on maps of Pennsylvania, Maryland, New Jersey, and Delaware. Climate of the beech-birch-maple type is worked out from these maps, and the climatic significance of the dividing line that marks the southern limit of oak and the northern limit of loblolly pine is discussed.

(73) Morey, Harold F. 1942. **The application of our knowledge of the organic layers of the soil profile to flood control.** Pa. State Coll. School Engin. Tech. Bul. 27: 143-151.

Changes in humus depth following clearcutting and regrowth of grazed and ungrazed conifers and hardwoods were studied during the Connecticut Flood-Control Survey. After clearcutting, humus reduction is greater and the rate of accumulation slower in temporary than in long-lived hardwoods. Light partial cutting had little effect on humus depth. In 70-year-old stands of long-lived hardwoods on medium soils, humus depth in ungrazed woodland is more than twice that in grazed woodland.

(74) Munns, E. N., W. R. Chapline, R. D. Forbes, L. F. Kellogg, and H. G. Meginnis. 1933. **Watershed and related forest influences.** *In* **A national plan for American forestry.** 73d Cong. 1st Sess. Sen. Doc. 12: 299-461.

Magnitude of national problems of streamflow and erosion are described in relation to domestic and industrial water supplies, irrigation, water power, navigation, floods, and erosion. The role of forest management in solving these problems is considered in relation to how forest cover influences runoff and erosion, and consequences of forest fires, logging, grazing, and other agencies on runoff and erosion. The influence of the forest on watershed problems, and the present condition and effectiveness of the forest in exerting this influence are given for 17 drainage regions. Forest areas in each region are classified according to their influence on streamflow regulation, erosion control, and other watershed values into three groups: major influence, moderate influence, and slight to no influence.

(75) Northeastern Forest Experiment Station. 1948. **Delaware-Lehigh Experimental Forest, the first unit of the Delaware Basin Research Center.** U. S. Forest Serv. Northeast. Forest Expt. Sta. 6 pp., illus. Upper Darby, Pa.

A brief description of the objectives of scrub-oak conversion and watershed studies.

*(76) Northeastern Forest Experiment Station. 1962. Proceedings: **Watershed management research conference on collection and compilation of streamflow records.** U. S. Forest Serv. Northeast. Forest Expt. Sta., 65 pp.

A conference was held at Laconia, N. H. to review methods of collecting and compiling streamflow data, to learn about recently developed machine methods for handling data, and to compare costs. Papers, discussion, and summaries are given.

*(77) Northeastern Forest Experiment Station. 1964. **Hubbard Brook Experimental Forest.** U. S. Forest Serv. Northeast. Forest Expt. Sta. 13 pp., illus.

A brochure describing watershed research at Hubbard Brook and the major water problems of the mountainous forested region of New England —low floods, floods, and water quality. The research program involves an inventory and assessment of the components of the hydrologic cycle, determination of the effect of forest cutting on streamflow, and the translation of single-treatment effects on small watersheds into multiple-treatment effects on large ones. Vegetation, geology, soils, climate, and research facilities of the Experimental Forest are described.

(78) Pierce, Robert S. 1965. **Forest watershed management in the Northeast.** Univ. Maine, Maine Forester 1965: 48-52.

Floods, low streamflow during summer months, and sedimentation are the principal forest water-resource problems. Research by the Northeastern Forest Experiment Station on these problems is described, with particular attention to the program at the Hubbard Brook Experimental Forest in New Hampshire.

*(79) Pierce, Robert S., Howard W. Lull, and Herbert C. Storey. 1958 **Influence of land use and forest condition on soil freezing and snow depth.** Forest Sci. 4: 246-263, illus.

A two-winter study of frost and snow in 18 different land-use conditions (bare cultivated fields to mature forest) was conducted at 6 locations in the Northeast. Concrete frost depth in hardwood stands was about one-half that in conifer stands. Concrete frost was observed over twice as often in open as in forest lands, and occurred twice as often in conifers as in hardwoods. Based on accumulated depth, three categories of frost intensity were classified: high for open-land conditions, intermediate for brushy land and conifer stands, and low for hardwood cover. Snow accumulated to greater depth in the forest than in the open, and in hardwoods than in conifers.

(80) Reigner, Irvin C. 1951. **Erosion studies on the Schoharie Watershed, New York.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 44. 17 pp., illus. Upper Darby, Pa.

Sedimentation of Schoharie reservoir was measured in 1950, when drought had dropped water levels to record lows. Accumulated sediment had reduced total capacity by 1.75 percent in 24 years. Fifty-five percent of the watershed is covered with forest and 43.5 percent is in grass. Forty-six percent of the watershed was moderately eroded: 80 percent of this area was in grass. Only 0.39 percent of the watershed was severely eroded. Road banks, streambanks, and reservoir shore lines contributed about 6 percent of the sediment. Better grazing practices would do much to prevent erosion. A thorough study of the watershed, with view to planning a land-use program, is recommended.

*(81) Reigner, Irvin C. 1963. **A vinyl-lined weir for small watershed studies.** Jour. Forestry 61: 297-298, illus.

An inexpensive weir to gage small streams was built of wood and lined with a sheet of vinyl film. The cost was about $850 (including labor and instrumentation) and the weir is expected to last 5 to 10 years without repair. Construction details are given.

*(82) Reigner, Irvin C. 1964. **Calibrating a watershed by using climatic data.** U. S. Forest Serv. Res. Paper NE-15, 45 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

In a single-watershed calibration of the 1,529-acre forested experimental Dilldown Watershed in Pennsylvania, equations were developed for predicting annual runoff and monthly water loss or runoff. The basic relationships were developed from streamflow, climatic, groundwater, and soil-moisture records; but final equations were expressed in terms of runoff and climatic variables only. Standard errors of estimate were well below the minimum change in yield considered significant; namely, 10 percent of the annual or monthly runoff.

*(83) Reigner, Irvin C. 1964. **Evaluation of the trough-type rain gage.** U. S. Forest Serv. Res. Note NE-20, 4 pp. Northeastern Forest Expt. Sta., Upper Darby, Pa.

Trough gages used to measure throughfall under vegetation and rainfall in the open at the Dilldown Watershed in Pennsylvania gave deficient catches due to rainfall splashing out of the trough. The deficiency was inversely related to the slope of the trough, and correction regressions were computed. A 90° and 120° V-shaped trough may give a better catch than the semicircular trough used in this study, for raindrops would not bounce vertically from the sloping sides.

*(84) Reigner, Irvin C. 1964. **How to make a wind-movement recorder from any spare drum-type recorder.** U. S. Forest Serv. Res. Note NE-21, 4 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

A recording instrument that has a clock-driven chart drum and pen-arm assembly may be converted to a wind-movement recorder with a $5 expenditure for an electromagnet, dry cells, and assorted small hardware. Dry cells are connected in series with the anemometer contacts and the

electromagnet. Closure of contacts activate the magnet, a counterweight, and the pen-arm. If no instrument is available the necessary parts may be purchased for about $80.

(85) Reigner, Irvin C., William R. Byrnes, and E. F. McNamara. 1958. **Forest watershed management research in the Ridge and Valley Section of Pennsylvania.** U. S. Forest Serv. Northeast. Forest Expt. Sta. 7 pp., illus.

The Leading Ridge Experimental Watershed is a cooperative watershed research project of the Pennsylvania Department of Forests and Waters, The Pennsylvania State University, and the Northeastern Forest Experiment Station of the U. S. Forest Service. Streamflow of three watersheds is being gaged and climatic measurements are taken. Forest, soil, and geological surveys are planned and 25 possible studies are listed.

*(86) Reigner, I. C., W. E. McQuilkin, and E. F. McNamara. 1961. Report No. 4: **Forest and water research project, Delaware-Lehigh Experimental Forest.** Pa. Dept. Forests and Waters. 97 pp., illus. Harrisburg.

This is the fourth progress report on results of the scrub oak conversion studies and calibration of the Dilldown watershed. A single-watershed calibration was developed, based on prediction of annual and monthly runoff from climatic variables. Daily streamflow and climatic data are tabulated for 4 water-years, October 1954 to September 1958.

*(87) Reigner, I. C., and John J. Phillips. 1964. **Variations in bulk density and moisture content within two New Jersey Coastal Plain soils, Lakeland and Lakehurst sands.** Soil Sci. Soc. Amer. Proc. 28: 287-289.

A relationship between bulk density and soil depth plus stone content was developed for Lakeland sand and Lakehurst sand in the Coastal Plain of New Jersey. From this, bulk density was estimated for each soil-moisture sample from five 1-foot layers, and moisture contents by weight were converted to moisture content by volume. Variations in bulk density and moisture content within and between the relatively closed-space plots are given for each of the 1-foot layers.

*(88) Reigner, I. C., W. E. Sopper, and R. R. Johnson. 1964. **Control of riparian vegetation with phenoxy herbicides and the effect on streamflow quality.** Northeast. Weed Control Conf. Proc. 18: 563-570.

To determine the extent of streamflow contamination by herbicides, vegetation along the stream channels of two small forested watersheds was sprayed with 2,4,5-T by means of a mistblower. Water samples were taken just above and below the treatment area and 1 mile downstream immediately after spraying, 4 hours later, and for several days thereafter. Contamination was found in samples taken within 4 hours of treatment just below the treated area and later after a 1-inch rain. There was no contamination 1 mile downstream. If mist-sprayed with normal precautions, phenoxy herbicides can be used on municipal watersheds.

*(89) Reigner, I. C., and Walter C. Sushko. 1960. **The Baltimore watershed . . . an example of good management.** Public Works 91: 85-88, illus.

The development of municipal watershed management by the City of Baltimore is described, from the building of its first water-supply reservoir in 1862 to its present system of three water-supply reservoirs surrounded by 17,300 acres of forested watershed land. The Watershed Control Division manages the forest land for water protection, timber products, and recreation. Conifers have been planted on 2,299 acres. Three small watersheds are being gaged and studied to determine the effect of forest treatment on water yield.

(90) Reinhart, K. G. 1958. **Calibration of five small forested watersheds.** Amer. Geophys. Union Trans. 38: 933-936, illus.

Problems and methods are described for calibrating five watersheds on the Fernow Experimental Forest in West Virginia in order to determine effects of different cutting methods on streamflow. Five years of record gave high correlations in streamflow characteristics between watersheds. Length of the calibration was determined and treatment assignments made.

*(91) Reinhart, K. G. 1960. **A simple filter dam for small streams.** U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 107. 4 pp., illus.

Four simple log-and-post dams were built to filter sediment out of muddy streamflow coming from a heavily cut forested watershed with poorly located skidroads. In the year after logging, the dams trapped about 350 cubic feet of sediment, an amount equivalent to an average of 70 parts of soil per million parts of water.

(92) Reinhart, K. G. 1961. **The problem of stones in soil-moisture measurement.** Soil Sci. Soc. Amer. Proc. 25: 268-270.

Soil-moisture measurements by gravimetric sampling can be improved by removing stones from the samples and deducting their weight from the total soil weight and the weight of moisture in the stones from the weight of moisture in the sample. Correcting for stone content helps remove the moisture-content variation due to the variation of the proportion of stones in different samples. To obtain moisture volume, bulk density of stone-free material must be calculated. To apply stone-free volumetric moisture contents on an areal basis requires estimation of the volume of the profile occupied by stones. In effect the disproportionate amount of stones in the original sample is removed and a proportionate amount substituted.

(93) Reinhart, K. G. 1963. **Efficient logging protects water quality.** South. Lumberman 206 (2567): 39, 42.

Research results from the Fernow watersheds in West Virginia showed that with proper planning and construction of skidroad systems, serious damage to water quality could be avoided. Maximum turbidities occurred during the logging operation. On the clearcut watershed average turbidity during logging was 490 ppm.; the first year after, 38 ppm.; and the next year, 1 ppm. Careful planning reduced length of skidroad system by 35 percent.

*(94) Reinhart, K. G. 1964. **Approximating soil-moisture storage in experimental watersheds by means of precipitation and streamflow records.** Soil Sci. Soc. Amer. Proc. 28: 575-578, illus.

Reliable estimates of total soil-moisture storage capacity of an experimental watershed may be difficult to obtain, particularly in a forested watershed, because of variations in and difficulties of measuring soil depth, root depth, soil texture, bulk density, stone content, and moisture content. Precipitation minus runoff—in selected periods when ample precipitation follows a dry spell—can provide an estimate of soil-moisture storage capacity. The method is illustrated with data from the Fernow Experimental Forest in West Virginia and is applied to two other watersheds in the Northeast. Limitations of the method are pointed out.

*(95) Reinhart, K. G. 1964. **Effect of a commercial clearcutting in West Virginia on overland flow and storm runoff.** Jour. Forestry 62: 167-171, illus.

A commercial clearcutting was made on a 74-acre gaged watershed; skidroads were constructed without grade limitations or provisions for drainage. After-logging infiltration rates in the watershed remained well above maximum rainfall intensities except on portions of the skidroads. Overland flow occurred only from the skidroads; it resulted from the combination of rain directly on the skidroads and interception of subsurface flow by the road cuts. Increased storm runoff in the growing seasons—up to a maximum of about ½ area-inch in any one storm—was largely the result of decreases in field-moisture deficiency rather than changes in the proportions of surface and subsurface flow. In judging hydrologic condition of logged areas, perhaps as much emphasis should be placed on road condition and forest-floor disturbance as upon the amount of timber cut and the condition of the stand.

(96) Reinhart, K. G. 1964. **Forest watershed research by the U. S. Forest Service in West Virginia.** W. Va. Water Res. Symposium Proc. 1963: 55-56.

Research begun in 1948 at the Fernow Experimental Forest, Parsons, West Virginia, has shown that erosion from logging operations can be controlled by practical and economical methods, that most of the harmful effects of logging are the results of disturbance of the forest floor, and that forest management does influence water yield. Future research will involve study of the energy budget and potential evapotranspiration, snowmelt, and forest microclimate.

*(97) Reinhart, K. G. 1964. **Frequency of streamflow measurements required to determine forest treatment effects.** U. S. Forest Serv. Res. Note NE-23, 7 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Streamflow data from control and clearcut watersheds at the Fernow Experimental Forest were reanalyzed to determine if measurements taken once a day, twice a week, once a week, twice a month, or once a month could be used instead of continuous records to determine the effects of forest treatment. The results suggest that, under some situations, much might be learned from relatively few measurements.

(98) Reinhart, K. G. 1965. **Herbicidal treatment of watersheds to increase water yield.** Northeastern Weed Control Conf. Proc. 19: 546-551.

Before clearcutting a portion of an experimental watershed on the Fernow Experimental Forest during the winter of 1963, all trees above 1-inch d.b.h. were basal sprayed with 2,4,5-T in No. 2 diesel oil. After cutting sawlogs and pulpwood, all stumps were sprayed with the same mixture. In the following May and June the foliage of residual vegetation was sprayed with 2,4,5-T with knapsack mistblower. During these treatments numerous water samples were obtained from the stream immediately below the treatment area and sniff-tested. There was no evidence of contamination by the herbicide. The watershed treatment increased water yield from the treated area by almost 200,000 gallons per acre during May-October 1964.

(99) Reinhart, K. G., and A. R. Eschner. 1962. **Effect on streamflow of four different forest practices in the Allegheny Mountains.** Jour. Geophys. Res. 67: 2433-2445, illus.

After a 6-year calibration period, four forested watersheds were cut with practices ranging from a commercial clearcutting to a light selection cutting. Annual streamflow increased up to 5 area-inches on the clearcut watershed the year after treatment. Most of the increase came in the growing season. From May to October 1959, increases were 3.0, 1.8, 1.4, and 0.3 area-inches for per-acre cuts of 8.5, 4.2, 3.7, and 1.7 thousand board feet, respectively. Effect on water quality was related directly to degree of care taken in logging and skidroad planning. Effects of treatments are diminishing with passage of time.

*(100) Reinhart, K. G., A. R. Eschner, and G. R. Trimble, Jr. 1963. **Effect on streamflow of four forest practices in the mountains of West Virginia.** U. S. Forest Serv. Res. Paper NE-1, 79 pp. illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Four intensities of forest management, ranging from commercial clearcutting to an intensive selection cutting, were applied on calibrated watersheds. Increases in annual flow ranged from 5.1 to 0.3 area-inches in relation to volume cut. Most of the flow increase came during the growing season. Road location and drainage affected water quality. Maximum turbidities ranged from 56,000 ppm. on the watershed with unplanned and undrained skidroads to 25 ppm. on the watershed with carefully planned skidroads. Effects of treatment are diminishing with time.

*(101) Reinhart, K. G., R. E. Leonard, and G. E. Hart. 1961. **Automatic devices to take water samples and to raise trash screens at weirs.** Northeast. Forest Expt. Sta. Forest Res. Note 112. 7 pp., illus.

The sediment sampler and trash-screen lifter are activated by tripping devices that operate when the water level in the weir basins reaches a predetermined height. When the sediment sampler is tripped, a hose connected to a sampling bottle drops into a flume carrying a portion of the streamflow. When the bottle is filled, its weight lifts the hose from the flume. The trash screen is removed when the head of water through the weir-notch is between 0.2 and 0.3 feet.

(102) Reinhart, K. G., and John J. Phillips. 1959. **Poor logging makes muddy streams.** W. Va. Conserv. 22: 20-23, illus.

Clearcutting a watershed in the Fernow Experimental Forest where skidroads were located without consideration of water value produced water turbidities up to 50,000 ppm. Before logging, turbidities had been less than 10 ppm. Much stream damage can be avoided by carefully planning a skidroad system. The better logging methods not only reduce erosion but are also cheaper for the operator.

*(103) Reinhart, K. G., and Robert S. Pierce. 1964. **Stream-gaging stations for research on small watersheds.** U. S. Dept. Agr. Handb. 268. 37 pp., illus.

Construction of stream-gaging stations is described, from selection of site and station design to detailed procedures for construction of a sharp-crested 120° V-notch weir. Necessary instrumentation for measurements of water level, and station operation and maintenance — including cold weather maintenance — are described. Gives costs of construction and a partial list of gaging stations used for small-watershed research in the United States. Numerous photographs and drawings illustrate various construction features, examples of instruments, and types of gaging stations.

(104) Reinhart, Kenneth G., and George R. Trimble, Jr. 1962. **Forest cutting and increased water yield.** Jour. Amer. Water Works Assoc. 54: 1464-1472, illus.

Cutting four watersheds at the Fernow Experimental Forest in West Virginia gave increases in annual streamflow, depending on the amount of timber removed, ranging from 8,000 to 140,000 gallons per acre. With regrowth of vegetation 4 years after cutting, increases had almost disappeared. During logging of the clearcut watershed, streamflow turbidity averaged 490 ppm., the next year it dropped to 38 ppm., and the next year to 1 ppm. Sedimentation was associated much more closely with the method of logging than with the amount of timber cut.

*(105) Sartz, Richard S. 1955. **Skidroad erosion.** Northeast. Logger 4(1): 10-11, 51, illus.

Modern logging methods with machines such as the bulldozer, which exposes mineral soil, have brought an erosion problem to the White Mountains of New Hampshire. Undisturbed forest soils are quite safe from erosion. But once the litter and humus are scraped away the soil can be washed away at startling rates. The solution is to prevent erosion by careful location and drainage of logging roads.

*(106) Sartz, Richard S. 1957. **Influence of land use on time of soil freezing and thawing in the Northeast.** Jour. Forestry 55: 716-718, illus.

During the winters of 1950-51 and 1951-52, open-land soils froze before softwood forest soils, and softwood forest soils froze before hardwood forest soils at six study areas from south-central Maine to northeastern Pennsylvania. Open-land soils thawed before softwood forest soils, but after hardwood forest soils. Dates of frost disappearance depended in part on frost depth. The number of days from first frost on open land to first frost on forest land ranged from 3 to 47 on softwood plots and 26 to

48 on hardwood. Number of days from last frost on open land to last frost in the forest ranged from 0 to 26 for softwoods, and from −22 to 4 for hardwoods.

*(107) Sartz, Richard S. 1957. **Snow and frost measurements in a watershed-management research program.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 96. 6 pp., illus.

Periodic measurements of frost and snow on a small gaged watershed in the Hubbard Brook Experimental Forest in New Hampshire are described and first winter (1955-56) results given. Little concrete frost was found in hardwood stands. Differences between snow-water measurements by gage (with Alter shield), snowboard, and snowpack for a 6-week period were not significant.

(108) Sartz, Richard S., and William D. Huttinger. 1950. **Some factors affecting humus development in the Northeast.** Jour. Forestry 48: 341-344, illus.

Studies during flood-control surveys of the Allegheny River watershed showed that humus depth increased with age of stand until maximum foliage production was reached. At any given age, humus depths tended to be greater under well-stock stands. Stand density controls the balance between organic accumulation and decomposition. The destructive effects of logging, fires, and grazing on humus depend on their intensity and frequency or duration. Northeast slopes seem to develop deeper humus, and microtopographic features cause extreme variations in humus depth. Heavy texture soils apparently develop deeper humus than sandy soils.

*(109) Sartz, Richard S., and George R. Trimble, Jr. 1956. **Snow storage and melt in a northern hardwoods forest.** Jour. Forestry 54: 499-502, illus.

A study of snow storage and melting behavior in the White Mountains of New Hampshire indicates that snow accumulation in hardwood forests could be increased and the snowpack prolonged by cutting narrow openings in an east-west direction. Openings in a pole stand had 7 to 10 percent more snow water than the woods, and openings in a sawtimber stand had 4 percent more. Slowest melting was in the south sector of openings.

(110) Satterlund, Donald R., and Arthur R. Eschner. 1963. **Forest watershed management in New York.** 32 pp., illus. N. Y. State Univ. Coll. Forestry, Syracuse.

Forest-watershed management problems of six water-resource regions are noted and their relative importance is assessed. Research is needed to determine the limits within which forest watershed management can be expected to be effective in increasing water yield, the flood-control potential of the forest area in the Allegheny Plateau, New England Upland, and the Catskills, and the integrated net effect of changes in land use on streamflow. In view of increasing water needs, the potential damage from floods, and the fact that one-half of the State's land is forested, a program of forest-watershed research should be undertaken in New York State.

(111) Satterlund, Donald R., and Arthur R. Eschner. 1964. **Snowmelt studies on the Tully Forest in central New York.** Eastern Snow Conf. Proc. 1964: 14-22, illus.

Accumulated figures of snowmelt for open, hardwood, and conifer areas

on the Tully Forest for the winter 1961-62 were applied to the cover types of the Albright Creek (largely open) and Shackham Brook (largely forested) watersheds and related to their actual runoff. After March 28 little snow remained on Albright and peak rates were generated from snow remaining on Shackham. Results suggest again that a desirable pattern of land use on the Allegheny Plateau, for improved streamflow regimen, would be a combination of open and forested lands.

*(112) Satterlund, Donald R., and Arthur R. Eschner. 1965. **The surface geometry of a closed conifer forest in relation to losses of intercepted snow.** U. S. Forest Serv. Res. Paper NE-34, 16 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

On the basis of equations for turbulent heat and vapor transfer, and reasoned application of knowledge about intercepted snow, the authors predicate great differences in the energy and vapor balance between an intercepted "snowfield" and one on level open ground. The differences, resulting from the complex surface geometry of a closed conifer forest, are sufficient to account for considerably greater losses from intercepted snow.

(113) Shirley, Hardy L. 1935. **Light as an ecological factor and its measurement.** Bot. Rev. 1: 355-381.

A review of literature about the effects of light on plants, light relationship of submerged plants, light in the forest, light intensity and quality requirements of vegetation, light and succession, and light measurement.

*(114) Sopper, William E., and Howard W. Lull. 1965. **Streamflow characteristics of physiographic units in the Northeast.** Water Resources Res. 1: 115-124.

An analysis was made to determine the amount of annual and seasonal water yield, flow duration, and peak flow frequency for seven major physiographic units in the Northeast. All watersheds (137) in the Northeast that were less than 100 square miles in area, that had continuous records from 1940 to 1957, and that were not appreciably affected by regulation and diversion were included in the analysis. In addition, streamflows of four small forested experimental watersheds were compared with average streamflow values of the physiographic units in which they were located. The longest simultaneous record available was for a 3-year period from 1959 to 1962. Results indicate significant differences in water yield between physiographic units as well as between watersheds within units. Water yields from the small experimental watersheds, although based on a shorter and different period of time, were found to correspond closely with average water yields of their respective physiographic units.

(115) Stewart, Guy Robertson. 1933. **A study of soil changes associated with the transition from fertile hardwood forest land to pasture types of decreasing fertility.** Ecol. Monog. 3: 107-145.

Typical soil conditions associated with the growth of hardwood forest, pasture grasses, and moss and fern were investigated in central New York. Change from trees to grass resulted in a loss of permeability to water, smaller water-holding capacity, and lessened air space. Forest soils and better pasture types had significantly deeper A and B horizons than did

the poor grazing land, or the moss and fern areas. Root growth of better pasture grasses was more extensive than that of the poorer. Forest soils possessed the highest initial content of nitrates. Kentucky blue grass soils had the highest level of mineral nutrients.

(116) Stickel, Paul W. 1933. **Relation of forests to the evaporating power of the air.** Jour. New England Waterworks Assoc. 47: 229-238.

Average monthly evaporation from Livingston atmometers at four locations in the Northeast from April to October was 1.3 to 1.8 times greater in the open than in the forest. Average temperatures in the duff layer ranged from 11 to 24° F. lower than soil-surface temperatures in the open, and in the 1-inch soil layer below the duff from 4 to 10° F. lower than a similar exposure in the open.

(117) Storey, Herbert C. 1949. **A year's progress at the Delaware-Lehigh Experimental Forest.** INCODEL Annual Meeting. U. S. Forest Serv. Northeast. Forest Expt. Sta., 10 pp., mimeo.

During the first year of study, the principal effort was establishment of streamflow, groundwater, climate, and soil-moisture installations and beginning of record collection. A topographic survey is underway and a geologic survey completed. Studies of soil freezing have been started, and some 200 plots have been prepared and planted to 10 different tree species to determine which species are best suited to scrub oak areas. An interception study will be started and soil and vegetation surveys will be made.

(118) Storey, Herbert C. 1949. **Watershed research in the Delaware and Lehigh.** Pa. Forest Leaves 34: 15-16.

Watershed-management problems in the Northeast involve increasing supplies of good water, regulating flow, and improving quality under more intensive land use. Research by the Northeastern Station has begun at the Delaware-Lehigh Experimental Forest, Monroe County, Pennsylvania, on an 1,800-acre scrub-oak watershed. Objectives are to determine the water relations of scrub oak, to find the best method for converting scrub oak to commercial timber, and to measure the effects of this conversion on water relations. Streamflow and climatic instruments have been installed, soil-moisture studies have been initiated, and groundwater observation wells have been drilled.

*(119) Storey, Herbert C. 1951. **Forest and water research project.** Delaware-Lehigh Experimental Forest. Pa. Dept. of Forests and Waters. 44 pp., illus. Harrisburg.

A cooperative forest and water research project was started at the Delaware-Lehigh Experimental Forest in eastern Pennsylvania in 1948. Forest-management (scrub-oak conversion) and watershed studies are described, and other studies planned are outlined. Daily discharge of Dilldown Creek, groundwater elevations, climatic measurements, and other hydrologic data are given for the period October 1948 to September 1950.

(120) Storey, Herbert C. 1954. **Water problems and watershed management.** Pa. Forests 44: 60-62, 70-73, illus.

Watershed management plays an important part in solving problems of

water shortages, floods, and water quality. Defined as the establishment and carrying out of measures and practices intended to attain certain desired characteristics of water yield from a watershed, watershed management requires positive steps to accomplish a specific objective. This requires quantitative knowledge of the relationships of vegetation, soils, and water, the hydrologic cycles, interception of rainfall and snow, infiltration, soil freezing, and other factors. The Northeastern Station is carrying out soil-plant-water relations studies in Pennsylvania and West Virginia, and region-wide a study of snow and frost depths in relation to forest cover.

(121) Storey, Herbert C., W. E. McQuilkin, and Eugene McNamara. 1953. Report No. 2: **Forest and Water Research Project, Delaware-Lehigh Experimental Forest.** Pa. Dept. Forests and Waters. 48 pp., illus. Harrisburg.

Progress report on studies on the Delaware-Lehigh Experimental Forest in Pennsylvania, including scrub-oak conversion and watershed studies. Planting results are reviewed and results of direct-seeding and natural-regeneration studies are described. Detailed studies of soil and vegetation have been made on the gaged watershed. Streamflow and climatic measurements are summarized, and estimations of evapotranspiration and of the water balance are discussed. Daily streamflow, groundwater, climate, soil-moisture and other hydrologic data are given for the period October 1950 to September 1952.

*(122) Sushko, Walter C., and Irvin C. Reigner. 1961. **A city manages its forested watershed lands.** Jour. Soil and Water Conserv. 16: 119-122, illus.

The city of Baltimore manages 17,300 acres of watershed lands, mostly forested, that surround three water-supply reservoirs. Water-supply protection measures include reforestation of idle land, careful location and drainage of logging roads and revegetation of steep grades following logging, and close supervision of recreation. Streamflow from three small experimental watersheds is being gaged to determine the effect of forest treatment on water yield.

(123) Trimble, George R., Jr. 1952. **A method of measuring increase in soil depth and water-storage capacity due to forest management.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 47. 8 pp.

Depth and water-storage capacity of shallow forest soils can be increased through forest management that maintains well-stocked stands. As examples, organic-matter content and pore space are given for soils found under three different forest-stand conditions. Soil in a well-stocked older stand of mixed hardwoods was 0.339 inch deeper than soil in a young understocked stand and 0.655 inch deeper than soil in a grazed stand.

(124) Trimble, G. R., Jr. 1954. **Forests are important on the watershed.** W. Va. Conserv. 18: 3-7, illus.

A review of watershed-research objectives and programs at the Fernow Experimental Forest. Relationships of forest cover to water quality are discussed, and logging methods and equipment that protect water values are recommended.

(125) Trimble, George R., Jr. 1955. **Watershed research begins in New Hampshire.** N. H. Forest Notes 46: 22-25. illus.

Outlines the water problems of New Hampshire and describes the watershed-management research project begun by the U. S. Forest Service on the 7,500-acre Hubbard Brook Experimental Forest near West Thornton, N. H.

(126) Trimble, George R., Jr. 1959. **A problem analysis and program for watershed-management research in the White Mountains of New Hampshire.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 116. 46 pp. illus.

A long-range forest watershed-research program is described that is centered on the Hubbard Brook Experimental Forest where the effects of forests on streamflow are being studied. Problems of water quality and water quantity are discussed. Forest hydrologic processes that affect the distribution of precipitation are described in respect to their importance, status of present knowledge, deficiencies in knowledge, and types of studies needed. Finally, a program of water-quality and -quantity studies is given and priorities are considered.

(127) Trimble, George R., Jr. 1959. **Logging roads in Northeastern municipal watersheds.** Jour. Amer. Water Works Assoc. 51: 407-410.

Because of erosion and sedimentation hazards, logging of municipal watersheds has often been considered risky. Sedimentation hazards may be practically eliminated if the location, construction, and maintenance of logging roads are in accordance with recommendations developed from watershed research. Recommendations are given for reducing erosion from road surfaces and adjacent disturbed areas and for preventing eroded materials from reaching the stream course. Close supervision of the logging operations is necessary.

(128) Trimble, G. R., Jr. 1961. **Water management. One of the multiple uses of forest land.** Va. Tech. Forester 13: 17-21.

Multiple-use management of forest land involves consideration of the water resources because water supplies and water quality are affected by forest cutting practices. Water-quality control involves reducing erosion from disturbed areas, and keeping eroded material out of streams; these are illustrated by recommended methods for locating and constructing logging roads.

(129) Trimble, George R., Jr. 1962. **Good and bad in logging.** Northeastern Logger 11(3): 18, illus.

Two photographs taken in West Virginia are compared, a picture of a horse-logging operation with skid trails running straight up-and-down hill and a picture of a contour logging-road system. In the former, skid trails averaged 51 percent in grade with centers about 45 feet apart. Twelve percent of the area was severely eroded. Contour logging reduced erosion and left the roads in good condition for future operations.

(130) Trimble, G. R., Jr. 1963. **Watershed management research.** Amer. Pulpwood Assoc. Tech. Paper 63-P-3. 6 pp.

Forest watershed research in Appalachia is conducted at the Coweeta

Hydrologic Laboratory in western North Carolina, at the Timber and Watershed Laboratory at Parsons, W. Va., and at The Pennsylvania State University, University Park, Pa. The nature of the research on water yield and quality problems is described and some results are given.

*(131) Trimble, G. R., Jr., and Burley D. Fridley. 1963. **13 years of forestry research in West Virginia.** U. S. Forest Serv. Res. Paper NE-5, 55 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

A progress report on the activities and accomplishments of the field unit of the Northeastern Forest Experiment Station established at Elkins, W. Va., in 1948 to conduct research in timber and watershed management in the northern Appalachian Mountain region.

(132) Trimble, George R., Jr., Charles E. Hale, and H. Spencer Potter. 1951. **Effect of soil and cover conditions on soil-water relationships.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 39. 44 pp., illus, Upper Darby, Pa.*

Soil samples were taken from representative parts of the Allegheny River watershed to find out how soil condition and land use affect movement and storage of water in the soil. Percolation rates, detention storage, retention storage, and transmission rates and capacities were determined and analyzed in relation to soil characteristics and land use. Physical soil improvements resulting from better land-management practices were greatest in the upper soil horizons. Major factors that affect soil-water relationships on forest lands are grazing, drainage conditions, and humus type. Correlations and regressions were developed between volume weight and organic content, percolation rate and detention storage, detention storage and organic content, and detention storage and volume weight.

(133) Trimble, G. R., Jr., and Howard W. Lull. 1956. **The role of forest humus in watershed management in New England.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 85. 34 pp., illus.

Watershed functions of forest humus involve its effect on infiltration and percolation, water storage, and evaporation. These reflect its physical properties. In the Northeast, depth of hardwood humus ranges from 2 to 5 inches, with water-storage capacities of 0.5 to 2.0 inches. Conifer humus varies between 3 and 6 inches with storage of 1 to 2.5 inches. Conifer humus accumulates at the rate of about ⅔ inch every 10 years, hardwoods on medium-texture soil ¾ inch, and on coarser soil ¼ inch. Major gaps in our knowledge of humus are listed.

(134) Trimble, George R., Jr., K. G. Reinhart, and Henry H. Webster. 1963. **Cutting the forests to increase water yields.** Jour. Forestry 61: 635-640.

Watershed-research results in West Virginia indicate that the cost of increasing water yields by clearcutting, based on loss in timber income and cost of treatment, is about 4 cents per 1,000 gallons. Effects of cutting on peak flows and water quality are also discussed.

*(135) Trimble, George R., Jr., and Richard S. Sartz. 1957. **How far from a stream should a logging road be located?** Jour. Forestry 55: 339-341, illus.

Based on studies made in the White Mountains of New Hampshire, the rule of thumb for determining how wide a filter strip is needed along logging roads to keep sediment from getting into streams: starting with a strip 25 feet wide on level land, the width of the strip should increase 2 feet for each 1 percent increase in slope of land between road and stream. For municipal watersheds the safety factors are doubled.

*(136) Trimble, George R., Jr., Richard S. Sartz, and Robert S. Pierce. 1958. **How type of soil frost affects infiltration.** Jour. Soil and Water Conserv. 13: 81-82.

Ring-infiltration tests in New Hampshire showed that concrete frost in open ground is impermeable, whereas in forest land frost is permeated by root holes and animal burrows that offer passageway to surface runoff. Granular frost was more permeable than unfrozen soil.

(137) Trimble, George R., Jr., and Sidney Weitzman. 1953. **Soil erosion on logging roads.** Soil Sci. Soc. Amer. Proc. 17: 152-154.

Erosion from logging roads in mountainous West Virginia was measured before, during, and after logging. Erosion was found to be related to grade, length of slope, intensity of use, vegetation, soil, and climate. First-year erosion from logging roads ranged from 0.4 to 1.2 inches depending on grade and slope length. Erosion was much greater on heavily used than lightly used skid roads, and much greater during skidding than after skidding. On some roads formation of a rock pavement stopped erosion.

*(138) Trimble, G. R., Jr., and Sidney Weitzman. 1954. **Effect of a hardwood forest canopy on rainfall intensities.** Amer. Geophys. Union Trans. 35: 226-234, illus.

Ground rainfall intensities and throughfall were measured under a fully stocked hardwood stand in West Virginia for 1 year. Maximum 5- and 15-minute intensities were compared with similar measurements made in the open. The study showed that low rain intensities (below 0.5 in./hr.) are reduced more by summer canopy, and higher intensities (above 0.5 in./hr.) are reduced more by winter canopy. Throughfall is about the same in both winter and summer. The authors conclude that forest cover has only a limited value in reducing the erosion potential of rainfall as it strikes the forest floor. Litter and humus provide the necessary protection.

(139) Trimble, G. R., Jr., and Sidney Weitzman. 1956. **Chaff seeding—one answer to soil washing on logging roads.** W. Va. Conserv. 19 (12): 12-13, illus.

Chaff from farm harvesting operations, spread over skidroads and log decks, and limed and fertilized, proved effective for stabilizing disturbed areas that otherwise might have eroded. Two years after treatment the road seeded, limed, and fertilized was 76 percent covered by vegetation; the road seeded only, 51 percent; and the road with no treatment, 28 percent.

(140) Trimble. George R., Jr., et al. 1957. **New Hampshire guides for logging roads and skid trails.** Univ. N. H. Ext. Serv. Ext. Folder 35. 4 pp., illus.

Practical guides for locating, constructing, and maintaining logging roads and skid trails for efficient logging, with emphasis on measures to prevent erosion and damage to the water resource.

(141) Tripp, Norman R., and Howard W. Lull. 1958. **Management problems and opportunities on forested watersheds in the Northeast.** Soc. Amer. Foresters Proc. 1957: 30-32.

Water problems are discussed in terms of population pressures, uncertain water supplies, inadequate reservoir storage, and water pollution. Lack of technical knowledge and a need to convince the public that management of land to assure reliable water supplies is a concern for all segments of the population are seen as obstacles to watershed management.

(142) Watts, L. F., E. N. Munns, W. R. Chapline, and Luther G. Schnur. 1933. **A watershed protection program.** *In* **A national plan for American forestry.** 73d Cong. 1st Sess. Sen. Doc. 12: 1509-1536.

Three-fourths of the total forest area in the United States has major or moderate influence on watershed values; about two-thirds of this exerts a major influence, one-third a moderate. Watershed condition is determined principally by land ownership, the most acute streamflow and erosion problems existing on private lands. Major critical watershed conditions are described for 11 areas. A program for adequate watershed protection includes improved fire protection, the adoption to some degree of selective logging, reforestation of 11 million acres, grazing management, and other measures including research. Avenues of approach to the private-land problem include public cooperation with private owners, public regulation of private-land use, and public ownership of major-influence forest land.

(143) Weitzman, Sidney. 1949. **The Fernow Experimental Forest.** U. S. Forest Serv. Northeast. Forest Expt. Sta. 16 pp., illus. Upper Darby, Pa.

The Fernow Forest of 3,640 acres of second-growth Appalachian hardwoods was set aside from the Monongahela National Forest for forest- and watershed-management research in northeastern West Virginia. The research program involves determination of the effects of forest cutting practices on timber volume, growth, and natural regeneration, and on quantity and quality of water supply; pilot-plant tests and demonstrations of timber-and-watershed-management practices; and collection of a complete set of records of quantity and quality yield of timber and water under management, and costs records. Climate, soils, and cover-types are described.

(144) Weitzman, Sidney. 1952. **Mountain log roads—design and construction.** W. Va. Conserv. 16(3): 16-21, illus.

In mountainous West Virginia the customary practice is to run logging roads straight up and down hill, which results in erosion and damage to watershed values. To avoid this, grades should be kept low by running the road slantwise up the mountainside and by using switchbacks. Roads

are located by using maps, aerial photos, and ground reconnaissance. The road should be constructed from the top of the mountain down. Water bars and grass seeding are important in preventing erosion. Advance planning gives the most economical road and one that will be usable for future operations.

*(145) Weitzman, Sidney. 1952. **Mountain logging.** South. Lumberman 185(2321): 199-202, illus.

Repeats material in West Virginia Conservation article described above and adds discussion of use of power saw, tractor, winch, and logging sulky. Logging-crew organization is also discussed.

(146) Weitzman, Sidney. 1953. **Five years of research on the Fernow Experimental Forest.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 61. 44 pp., illus.

A description of the Fernow Experimental Forest in West Virginia and its research aimed towards finding practical solutions to problems of managing timber and water resources. Results of timber-and-watershed-management compartment studies and special studies are outlined. Skid-road erosion and revegetation, truck roads and water quality, and the influence of the canopy on rainfall intensity are discussed.

(147) Weitzman, Sidney. 1954. **Forestry.** *In* **W. Va. Watershed Development Conf.** October 19-20, 1954, Proc.: 31-37.

In West Virginia demands for water for industrial and domestic use are increasing, stream pollution and sedimentation are serious problems, and floods cause great damage. These problems are accentuated by the present poor hydrologic condition of the forest land due to poor logging methods, grazing, and fire. Measures needed to solve these problems include improved cutting practices and logging methods, elimination of woodland grazing, intensification of fire control, reforestation, and strengthened timber and watershed research.

(148) Weitzman, Sidney. 1954. **Why we need watershed research in West Virginia.** W. Va. Conserv. 17(12): 4-7, illus.

In West Virginia, demands for water supply are increasing, and shortages threaten. Excessive stream fluctuations, sedimentation, heavy pollution, and floods indicate a growing problem. Some problems could be remedied by direct engineering action; others will take more time, since research is needed to find practical and economic answers.

(149) Weitzman, Sidney, and Kenneth G. Reinhart. 1957. **Water yields from small forested watersheds.** Jour. Soil and Water Conserv. 12: 56-59, illus.

Rainfall-streamflow records on the Fernow Experimental Forest in West Virginia provide an example of how such data can be used to estimate available streamflow for areas of similar vegetation, soils, and climate for a city water supply, or a site for an industry, or a pond. As a theoretical problem, water requirements of a small industry are analyzed.

*(150) Weitzman, Sidney, and G. R. Trimble, Jr. 1952. **Skid-road erosion can be reduced.** Jour. Soil and Water Conserv. 7: 122-124, illus.

On an experimental logging job in West Virginia, erosion was measured

from four kinds of skidroads that varied in slope, length per unit area, and water-bar installation. Erosion during the first year of operation ranged from 52 to 91 cubic feet per 100 feet and from 275 to 2,165 cubic feet for the total road length. Erosion from skidroads can be controlled by planning an efficient skidroad system that reduces mileage, avoids steep gradients, and provides simple water bars to keep the road drained.

*(151) Weitzman, Sidney, and G. R. Trimble, Jr. 1955. **Integrating timber and watershed management in mountain areas.** Jour. Soil and Water Conserv. 10: 70-75, illus.

Since forests cover two-thirds of the Appalachian Mountain area, water problems are closely tied up with the use made of forest land. Uses for water and wood products must be integrated and compatible with limitations imposed on an area by soils, climate, and topography. Results from the Fernow Experimental Forest indicate that commercial forest land may be managed to supply both timber and good water. Recommendations on methods of logging that will be helpful in protecting watershed values include a planned road system, low grades, shortened skidding period, logging road maintenance, and proper equipment. These recommendations have proved economically sound in practice.

*(152) Whelan, Donald E. 1950. **A method of evaluating the hydrologic effects of land use on large watersheds.** Trans. Amer. Geophys. Union 31: 253-261, illus.

To determine the effect of land use on flood runoff the total flood hydrograph is subdivided into separate hydrographs for surface, subsurface, and groundwater runoff. A unit hydrograph is then derived by considering surface and subsurface runoff contributing simultaneously by unit time periods. The total flood hydrograph as modified by a corrective land-use program is computed by using the derived unit hydrograph, groundwater relations, and infiltration rates of soil-cover complexes under the modified program. The method is applied to two flood hydrographs of the Baker River in the Merrimack watershed.

*(153) Whelan, Donald E., Lemuel E. Miller, and John B. Cavallero. 1952. **A method of determining surface runoff by "routing" infiltrated water through the soil profiles.** U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 54. 15 pp., illus., Upper Darby, Pa.

Infiltration on a watershed basis was calculated by routing infiltrated water through the soil profile. Soil water storage and movement were determined from measurements of percolation rate, transmission velocities, and retention and detention storage volume for each horizon of principal soil-cover complexes. Percolation rates were adjusted to give the volume of surface runoff determined from the streamflow hydrograph. A sample routing is given. This method can be used to evaluate the effects of a land-use program on runoff.

(154) Wood, O. M. 1933. **Litter cover and soil surface temperatures, oak-pine type.** U. S. Forest Serv. Allegheny Forest Expt. Sta. Tech. Note 3. 1 p.

From July 5 until September 17, 1932, mean daily maximum temperatures at the soil surface within an 80-year-old stand of oak-pine was 81° F.

under oak leaves, 91° under black mulch paper, and 96° with no cover. There was no direct relation to daily maximum air temperature.

(155) Wood, O. M. 1935. **Forest removal affects local climate and growing conditions.** U. S. Dept. Agr. Yearbook 1935: 206-208.

A comparison of light-intensity conditions, soil-surface temperatures, evaporation, soil-moisture content, wind movement, and minimum air temperatures in the forest and in the open suggests that partial cutting is better than clearcutting because the resulting change in local climate is less severe.

(156) Wood, O. M. 1937. **The interception of precipitation in an oak-pine forest.** Ecology 18: 251-254.

Four rain gages set up in a mixed forest of oak and pine in New Jersey were read following 145 storms during a period of 17 months. Total precipitation ranged from 85 to 91 percent of the catch in a gage in the open. The proportion of rain reaching the ground in the woods increased with intensity and duration of storm. A statistically significant difference among the gages in the woods indicated that too few gages had been used.

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