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U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

Forest Management Effects on the Environment

A Bibliography

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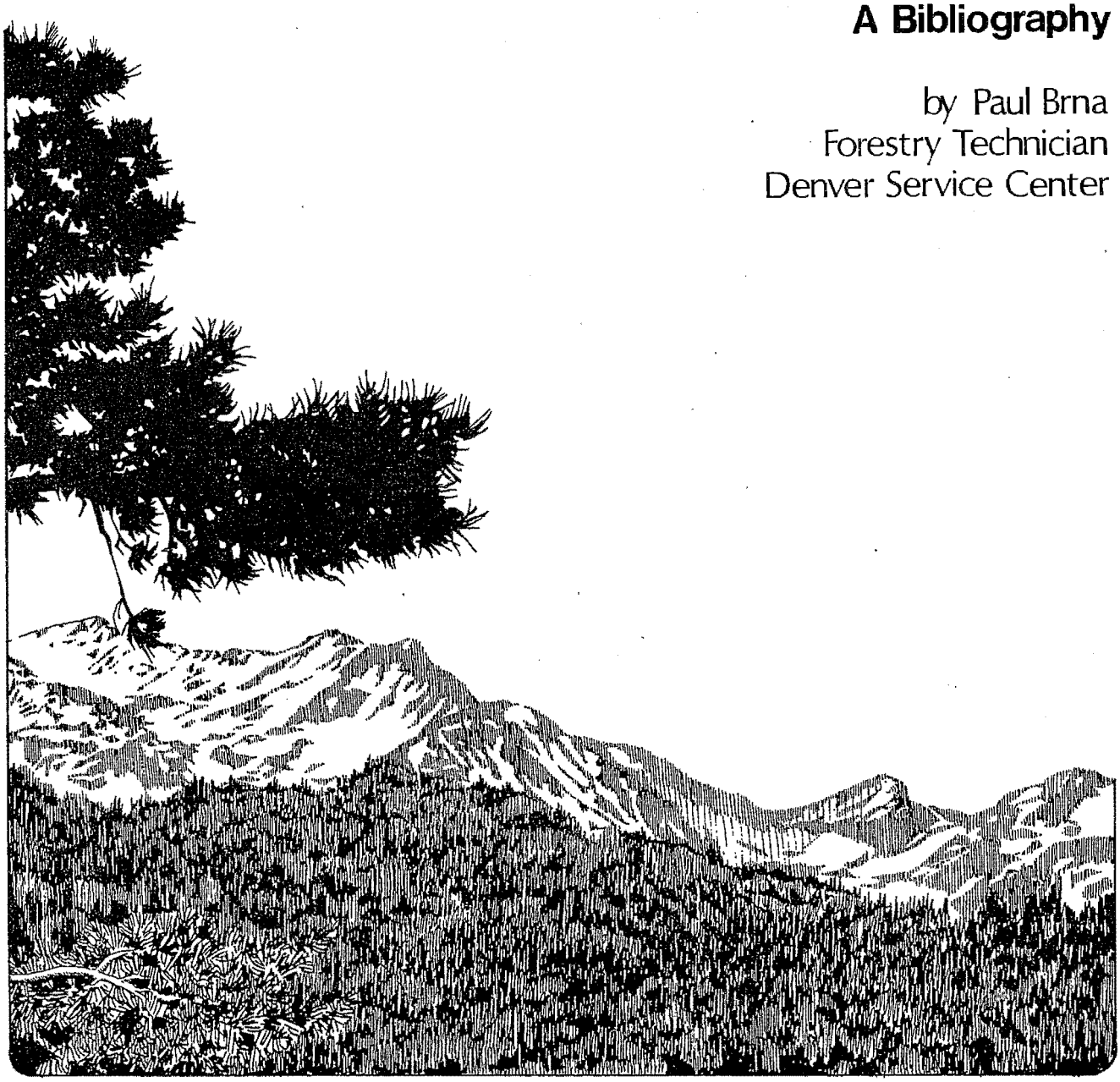

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BIBLIOGRAPHY

This bibliography contains a listing of research conducted mainly in the western United States detailing effects of timber management (with special emphasis on the Colorado riparian) on the environment. Intended primarily for use by the Colorado State Office of the Bureau of Land Management, it contains references which may be useful in areas other than the Central Rocky Mountain region.

Aldon, Earl F. 1960. "Watershed Management Research in the Ponderosa Pine Type," Watershed Management Research in Arizona Prog. Rep. 1959, pp. 17, 19-23, USDA For. Serv. Rocky Mt. For. and Range Exp. Sta.

Anderson, H. W., and C. H. Gleason. 1959. "Logging Effects on Snow, Soil Moisture, and Water Losses," 27th Ann. West Snow Conf. Proc., pp 57-65.

Anderson, H. W., and C. H. Gleason. 1960. "Effects of Logging and Brush Removal on Snow Water Runoff," Gen. Assy. of Helsinky, July 25-Aug. 6, 1960, pp. 428-489. Int. Union Geod. and Geophys. Int. Assoc. Sci. Hydro. Pub. (Gentbrugge) 51.

Water yield as affected by three types of logging in a red fir forest, by two kinds of slash disposal, and by brush removal is being studied in the snow zone of the Cascade Range and the Sierra Nevada in California. It is concluded that water yield from snow zone runoff can be influenced in both amount and time of delivery by the manner in which areas are logged and by brush removal.

Arnold, J. F. 1953. "Effect of Heavy Selection Logging on Herbaceous Vegetation in a Ponderosa Pine Forest in Northern Arizona," J. For 51(2):101-105.

Reports: (1) The extent of canopy reduction as a result of heavy selection logging (2) the overall response of the herbaceous vegetation, and (3) the separate effects of canopy release, slash accumulation, and surface disturbances on the ground cover.

Bates, C. G., and A. J. Henry. 1928. "Forest and Streamflow Experiment at Wagon Wheel Gap, Colorado," U.S. Mon. Wea. Rev. Suppl. 30, 79 pp.

Berndt, H. W., and C. H. Gleason. 1960. "Effects of Logging and Brush Removal on Snow Water Runoff," Extract of IASH Comm. of Surface Waters, Pub. No. 51, pp. 478-489.

Berndt, H. W. 1961. "Some Influences of Timber Cutting on Snow Accumulation in the Colorado Front Range," USDA For. Serv. Rocky Mt. For. and Range Exp. Sta. Res. Note 58.

To learn how canopy reduction by logging might influence snow accumulation in ponderosa pine-Douglas-fir stands, an exploratory study was made. The study was conducted on the Pike National Forest at 8,500 feet elevation within the Long Hollow drainage 35 miles northwest of Colorado Springs, Colorado. In the fall of 1957 six rectangular plots, 1 acre in size, were established on north-facing slopes of 10 to 30 percent. Twenty-five snow sampling points were marked on each plot. At all points snow depth and moisture content were measured with a Mount Rose snow sampler after each major storm and periodically during snowmelt.

Berndt, H. W. 1962. "First Year Effects of Timber Removal on Soil Moisture," Int. Assoc. Sci. Hydro. Bull. 7(2):34-38.

Bernsten, Carl M. 1975. "Management Conflicts in Lodgepole Pine," (David M. Baumgartner (ed.)), Manage. Lodgepole Pine Ecosyst. Symp. Proc., (Pullman, Wash., Oct, 1973) pp. 503-515. 2 vols, Wash. State Univ.

Bethalmy, Nevadia. 1960. "Surface Runoff and Erosion Related Problems of Timber Harvesting," J. Soil and Water Sci. 15(4):158-161.

Bethalmy, Nevadia. 1967. "Effect of Exposure and Logging on Runoff and Erosion," USDA For. Serv. Intermountain For. and Range Exp. Sta. Res. Note INT-61. 7 pp.

High-intensity rainfall was applied artificially to plots on eight steep, forested areas in the Payette National Forest in central Idaho. Logged and unlogged sites on northeast and southwest exposures were represented equally. Results show that runoff and erosion are greater on southwest than on northeast exposures, and that even after careful logging, erosion increases on southwest but not significantly on northeast exposures.

Bever, Wendell. 1952. "The Effect of Silvicultural Practices on the Production of Deer Browse," S. Dak. Dept. Game, Fish and Parks, P.R. Proj. 12-R-9, 5 pp.

Black, Peter E. 1963. "Timber and Water Resource Management," For. Sci. 9(2):137-145.

This paper presents an economic analysis of the physical relationship between the production of timber and water on wild lands. Recent studies have indicated that water yield may be increased through certain types of forest cutting under certain conditions; though this relationship is not fully known, economic research into potential management of these two resources is needed. Based on research at the U.S. Forest Service's Fraser Experimental Forest, in Colorado, a graphical and mathematical procedure for predicting stream yield increases due to forest cutting

is developed. Inventory data on streamflow and timber stands on the headwaters of the Fraser River, which supplies water to Denver, Colo., via the Moffat Tunnel, were used in the analysis. It is concluded that the management intensity indicated by the analysis for the watershed is both realistic and desirable and that the use of minimum figures throughout the analysis enhances its practical value in application to the land through good land management practices.

Bowie, James E., and William Kam. 1968. "Use of Water by Riparian Vegetation, Cottonwood Wash, Arizona," U.S. Geol. Surv. Water Supply Pap., 1858. 62 pp.

The change in water use as a result of the modification of riparian vegetation was measured in Cottonwood Wash, Mohave County, Ariz. A 4.1-mile length of the stream channel was selected and divided into a 2.6-mile upper reach and a 1.5-mile lower reach. Measurements of streamflow, ground water levels, vegetation, and meteorological phenomena in the area defined the use of water by riparian vegetation under natural hydrologic conditions. Subsequent defoliation and eradication of the vegetation in the lower reach permitted the determination of the change in water use as a result of the modification. The computed average loss of water from the lower reach before modification was 80 acre-feet per growing season, a quantity which represented about 18 percent of the average flow entering the reach in the same period.

Brown, George W., and James T. Krygier. 1970. "Effects of Clearcutting on Stream Temperature," Water Resources Res. 6:1133-1140.

Brown, G. W. 1970. "Predicting the Effect of Clearcutting on Stream Temperature," J. Soil and Water Conserv. 25(1):11-13.

Brown, G. W. 1970. "Water Temperature in Small Streams as Influenced by Environmental Factors and Logging," (James Morris (ed.)), Proc. of a Symposium--For. Land Uses and Stream Env., Oregon State Univ.

Brown, H. E. 1971. "Evaluating Watershed Management Alternatives," J. Irrig. and Drain, Am. Soc. Civil Eng., Div. 97(IR1):93-108.

Treatments in this Pilot Project on Beaver Creek were designed primarily to increase water yield, the results of the treatments are being evaluated, however, in terms of effects on sedimantation and flood damage, timber and forage yields, wildlife and aesthetics, as well as streamflow. Results of these studies will provide input for economic models being developed to analyze alternative management programs for watersheds in the Salt-Verde basin. The main purpose of this paper is to summarize the multiple use results of watershed treatments on the Beaver Creek Pilot Project to date, and to briefly outline plans for economic evaluations.

Brown, George W., and James T. Krygier. 1971. "Clearcut Logging and Sediment Production in the Oregon Coast Range," Water Resources Res. 7:1189-1199.

Brown, George W. 1972. Forest and Water Quality, School of Forestry, Oregon State Univ., OSU Bookstore. 74 pp.

Brown, George W. 1972. "Logging and Water Quality in the Pacific Northwest," Natl. Symposium on Watersheds in Transition, pp. 330-334. Am. Water Res. Assoc, and Colorado State Univ., Ft. Collins, Colo.

In the past, management of the forested watersheds in the Pacific Northwest has focused primarily on the production of timber. Many of the streams in these watersheds are also the spawning and rearing sites for a valuable anadromous fishery and, in many instances, the source of water for Northwest municipalities. Management of these watersheds is indeed in a state of transition. Recent research findings have shown that clearcut logging can significantly affect stream temperature and sediment and dissolved oxygen concentration. Water quality standards prescribed for interstate waters are being extended to small, forested streams. Oregon, for example, is now in the process of instituting a new forest practices act which will prescribe logging practices and standards of operation and enforcement to meet these water quality criteria.

Brown, G. W. 1973. "The Impact of Timber Harvest on Soil and Water Resources," Oregon State Univ., Ext. Bull. 827, Feb. 1973. 17 pp.

Campbell, C. J. 1963. "Fish Management Problems Associated with Timber Harvesting," Symp.--For. Watershed Management, pp. 331-337. Oregon State Univ., Corvallis.

Campbell, C. J. 1970. "Ecological Implications of Riparian Vegetation Management," J. Soil Water Conserv. 25(2):45-52.

Managing riparian vegetation in the Southwest to increase water yield may require selective clearcutting rather than complete removal of riparian plants to maintain a biological balance and thus prevent thermal pollution, channel erosion, and destruction of aquatic and wildlife habitats.

Chapman, D. W. 1963. "Physical and Biological Effects of Forest Practices Upon Stream Ecology," Symp.--For. Watershed Management. pp. 321-330.

Discusses effects upon fish of logging in Northwest. Mentions effect of logging in the riparian upon fish, stream temperature, turbidity and insect life.

Chase, E. S., and A. F. Ferullo. 1957. "Oxygen Demand Exerted by Leaves Stored Under Water," J. New Engl. Water Works Assoc. 71:307-312.

Cordone, Almo J. 1956. "Effects of Logging on Fish Production," Calif. Fish and Game, Inland Fish Admin. Rep. 56-7, 98 pp.

Cormack, R. G. H. 1949. "A Study of Trout Streamside Cover in Logged Over and Undisturbed Virgin Spruce Woods," Can. J. Res. 27(3):78-95.

Curry, R. C. 1971. "Soil Destruction Associated with Forest Management and Prospects for Recovery in Geologic Time," Univ. of Montana, Missoula (Unpub. Pap. prepared for testimony before the U.S. Senate.)

Davis, H. T. 1971. "The Non-silvicultural Aspects of Timber Harvest," Rep. for the Boise Cascade Co., 39 pp.

Dissmeyer, G. E. 1971. "Estimating the Impact of Forest Management on Water Quality," Preliminary Procedure Pap. presented at Cooperative Watershed Management Workshop, USDA For. Serv., Memphis, Tenn., Oct. 4-8, 1971. 14 pp.

Dissmeyer, G. E. (In press 1974.) "Evaluating the Impact of Individual Forest Management Practices on Suspended Sediment," J. Soil and Water Conservation.

Dortignac, E. J., and L. D. Love. 1961. "Infiltration Studies on Ponderosa Pine Ranges of Colorado," USDA For. Serv. Rocky Mt. For. and Range Exp. Sta. Pap. 59. 34 pp.

This study isolates and evaluates vegetation and soil influences on infiltration on granitic derived soils of the ponderosa pine-bunchgrass range of the Colorado Front Range.

Dunford, E. G., and C. H. Niederhof. 1944. "Influence of Aspen, Young Lodgepole Pine, and Open Grassland Types upon Factors Affecting Water Yield," J. Forest. 42(9):673-677.

Burned and cutover lands in the Rocky Mountains present a distinct problem in watershed management. Many of these areas support a cover of grass or aspen rather than their original stand of lodgepole pine or spruce. Generally the new cover provides adequate protection from erosion, but its other watershed qualities have been questioned. In order to evaluate some of these qualities, this preliminary study was undertaken in Colorado. The results indicate that, from the standpoint of water available for streamflow, aspen and grass are probably superior to a dense coniferous forest.

Dunford, E. G., and P. W. Fletcher. 1947. "Effect of Removal of Streambank Vegetation upon Water Yield," Am. Geophys. Union Trans. 28:105-110.

Dunford, E. G. 1954. "Surface Runoff and Erosion from Pine Grasslands of the Colorado Front Range," J. For. 52:923-927.

In the Colorado Front Range, intensity of land use must be gaged with special care to maintain acceptable watershed conditions. Sparse cover, unstable soils, and intense summer rains compound the difficulties characterizing multiple-use management. Water from the Front Range is acutely needed in the adjacent Great Plains, but its quality and regularity of flow have long since been impaired by heavy grazing and unrestricted timber cutting. While such activities can very likely be continued at a reduced scale, it is important to establish the limits dictated by good watershed management. A measure of these limits is being obtained from two small studies, described herein, which concern the influence of cattle grazing and timberland disturbance on runoff and erosion.

Dunford, Earl G. 1960. "Logging Methods in Relation to Streamflow and Erosion," 5th World For. Congr. Proc. vol. 3, Sec. VII, Seattle, Wash., pp. 1703-1708.

Various steps in logging operations and their effects on streams and soil are discussed. An "undisturbed" strip of land between a stream and parallel logging roads is recommended.

Dykstra, Dennis P., and Henry F. Froehlich. 1976. "Costs of Stream Protection During Timber Harvest," J. For. Vol. 74(10):684-687.

"Costs of three stream-protection alternatives were analyzed: conventional felling with channel cheanup, cable-assisted directional felling, and use of buffer strips. In a study of 10 deeply incised, headwater stream channels in western Oregon, none of the three alternatives was clearly preferable on a majority of the study areas. The least-cost alternative on four of the areas was a 55-foot wide buffer strip. On three of the remaining areas, conventional felling was cheapest, and on the other three, cable-assisted directional felling."

Dryness, C. T., and C. T. Youngberg. 1957. "The Effect of Logging and Slash Burning on Soil Structure," Soil Sci. Soc. Am. Proc. 21(4):444-447.

Eschner, A. R., and Larmoyeux. 1963. "Logging and Trout: Four Experimental Forest Practices and Their Effect on Water Quality," Progressive Fish Culturist, 25:59-67.

Ferrel, W. K. 1960. "The Control of Stream Flow and Water Quality Through Timber Harvesting," (E. F. Eldridge (ed.)), Water Problems of the Pacific Northwest. 7th Symp. Water Pollut. Res. Proc., pp. 45-47, U.S. Public Health Serv., Reg. IX, Portland, Oreg.

The effects of timber harvesting on stream flow and water quality are discussed. The author also discusses the idea that forest harvesting practices of various kinds can be compatible with watershed management if these practices are carefully planned and controlled.

Fredericksen, R. L. 1970. "Comparative Water Quality--Natural and Disturbed Streams Following Logging and Slash Burning," (James Morris (ed.)), Proc. of a Symposium--Forest Land Uses and Stream Environment, Oregon State Univ., Corvallis.

Fredricksen, R. L. 1970. "Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds," USDA For. Serv. Res. Pap., PNW-104. 15 pp.

Fredericksen, R. L. 1971. "Comparitive Chemical Water Quality-Natural and Disturbed Streams Following Logging and Slash Burning," (James Morris (ed.)), Proc. of a Symp.--Forest Land Uses and Stream Environment, pp. 125-137, Oregon State Univ., Corvallis.

Gessel, S. P., and D. W. Cole. 1965. "Influence of Removal of Forest Cover on Movement of Water and Associated Elements Through Soil," J. Am. Water Works Assoc., 57(10):1301-1310.

The tension lysimeter system, coupled with techniques to measure other environmental data, was used to study certain watershed management problems. Data on water and elemental movement for forested and clearcut areas at points under the forest floor and at 36-in. depth are reported for the study.

Gessel, S. P., and D. W Cole. 1965. "Movement of Elements Through a Forest Soil as Influenced by Tree Removal and Fertilizer Additions," For. Soil. Relationships in N. Amer., 2nd N. Amer. For. Soils Conf., pp. 95-105.

Gibbons, Dave R., and Ernest O. Salo. 1973. "An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada." USDA For. Serv. Pacific Northwest For. and Range Exp. Sta., Gens Tech. Rep. PNW-10. pp. 145.

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 287 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids multiple logging effects, alteration of streamflow, stream protection, multiple use management, streamside vegetation stream improvement and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

Gleason, Clark H. 1958. "Watershed Management," Annotated Bibliography of Erosion, Streamflow, and Water Yield" publications by the Calif. For. and Range Exp. Sta., USDA Forest Serv. Tech. Pap. 23, pp. 79.

Goodell, B. C. 1952. "Watershed Management Aspects of Thinned Young Lodgepole Pine Stands." J. Forest. 50(5): pp. 374-378.

This study demonstrated that the thinning of dense forest stands will appreciably increase the net precipitation received on the forest floor. In the Fraser Experimental Forest, in Colorado, thinning of lodgepole pine in one area increased the amount of snow reaching the ground by 20 percent and increased the amount of summer rainfall reaching the ground by 15.5 percent. Data indicate that evaporation and transpiration losses of the soil moisture were unaffected by the thinning treatments.

Goodell, B. C. 1958. "A Preliminary Report on the First Year's Effects of Timber Harvesting on Water Yield from a Colorado Watershed." USDA For. Serv. Rocky Mt. For. and Range Exp. Sta. Pap. 36. pp. 12.

Appreciable increases in streamflow have followed the removal of one-half of the mature timber (pine, spruce, and fir) from the watershed of the Fraser Experimental Forest, in Colorado. The spring flood peak was increased the first year, but decreased in comparison with the control the second year. Sediment yield was low following cutting. Snow accumulation has increased in the cut strips.

Goodell, B. C. 1967. "Watershed Treatment Effects on Evapotranspiration," pp. 477-482. (William E. Sapper and Howard W. Lull (eds.),) pp. 477-482. Internation Symposium on Forest Hydrology Proceedings, Pennsylvania State University, Aug. 29-Sep. 10, 1965. Pergamon Press, New York pp. 813.

Evapotranspiration from watersheds depends on the spatial and temporal confluence of water and thermal energy at watershed surfaces. Four categories of surfaces exist or may exist: (1) external surfaces of leaves and plant stems, (2) internal plant surfaces, (3) soil surface, (4) snowpack surface. Water becomes present on these surfaces through interception of precipitation, absorption and transport of soil water by plants, capillary flow of soil water, and by snow accumulation. Generally, radiant energy is the main source of the heat of vaporization. For any mass of vegetation per unit of land area, evapotranspiration should be aximum when plant substance is most uniformly distributed throughout the growing space. Canopy interception of precipitation and radiation, and transport of soil water to transpiring surfaces are then at a maximum. Forest manipulation that causes heterogeneity in canopy and root distribution, as by partial clearing, should tend to minimize evapotranspiration. To be effective, persistent discontinuities must be produced in the canopy with respect to its role as receptor for precipitation and radiant energy and/or in the root network as an absorber of soil water. Substitution of vegetation of shallower root and/or canopy depth, longer dormant season, or lower transpiration ratio are other means by which watershed management can reduce evapotranspiration.

Gray, Donald H. 1969. "Effects of Forest Clearcutting on the Stability of Natural Slopes." Progress Rep. Univ. of Michigan ORA Proj. 01939. p. 67.

Gray, J. R. A., and J. M. Edington. 1969. "Effect of Woodland Clearance on Stream Temperature." J. Fish. Res. Board, Can. 26: pp. 399-403.

Green, Geoffrey E. 1950. "Land Use and Trout Streams." Soil and Water Cons. 5: pp. 125-126.

Once productive trout streams can be restored by the control of stream temperatures through good watershed management. This, according to the author, involves careful manipulation of vegetation and other kinds of land use practices. To accomplish this it is inportant that all aspects of a watershed be developed as a unit rather than on a piecemeal basis.

Dennis, Harv. R., Warren C. Harper, James T. Krygier, and Frederic S. Hsieh. 1975. "Changes in Storm Hydrographs after Road-Building and Clearcutting in the Oregon Coast Range." Water Resources Res. 11(3): pp. 436-444.

Dennis, Harv. R. 1976. "Forest Practices and Streamflow in Western Oregon." USDA For. Serv., Pac. Northwest For. and Range Exp. Sta., Gen. Tech. Rep. PNW-49, p. 18.

Forest management activities, including roadbuilding, clearcut logging, and broadcast burning can change certain portions of the forest hydrologic cycle. Watershed studies and other hydrologic research in the coast and western Cascade Ranges of Oregon have shown that these changes may increase annual water yield up to 62 centimeters, double minimum flows in summer, and increase fall peck flows up to 200 percent and small winter flows up to 45 percent in small watersheds. Changes in streamflow resulting from clearcut logging had little effect on either onsite damage to stream channels and hydrologic structures or downstream flooding when yarding caused only light disturbance of soil. By increasing the size of larger peak flows, roadbuilding and soil compaction may cause onsite damage in small headwater basins. Increases in annual yield and minimum flows may be substantial on small watersheds that are clearcut; under sustained yield forest management, such increases are masked in large, parent watersheds by unaltered streamflow from unlogged watersheds.

Haupt, H. F. 1959. "Road and Slope Characteristics Affecting Sediment Movement from Logging Roads." For. 57: pp. 329-332.

The amount of erosion and sediment occurring below logging roads on steeply sloping granitic soils in ponderosa pine lands of southwestern Idaho was studied intensively. Seven road and slope characteristics amenable to quantitative evaluation were investigated to determine their relationship to the distance that sediment moved downslope from a road embankment. Four of these characteristics --the slope obstruction index, cross ditch interval squared, embankment slope length, and the product of the cross ditch interval and road gradient--were found to influence sediment flow distance significantly. These characteristics were incorporated into an equation that promises to be valuable in determining the safe width of buffer strips necessary to protect lower roads or stream channels from sediment damage emanating from road construction activities.

Hewlett, J. D., and A. R. Hibbert. 1961. "Increases in Water Yield after several types of Forest Cutting." Int. Assoc. Sci. Hydrol. Bull. 6, pp. 5-17.

Hibbert, Alden R. 1965. "Forest Treatment Effects on Water Yield," International Symposium on Forest Hydrology. Nat. Sci. Found. Advan. Sci. Semin. Proc., Penn State Univ., University Park, Pa., Aug. 29-Sep. 10, 1965. Pergamon Press, N.Y. pp. 527-543.

Results are reported for 39 studies of the effects of altering forest cover on water yield. Taken collectively, these studies reveal that forest reduction increases water yield and that reforestation decreases water yield. Results of individual treatments vary widely and, for the most part, are unpredictable.

First-year response to complete forest reduction varies from 34 mm. to more than 450 mm. of increased streamflow. A practical upper limit of yield increase appears to be about 4.5 mm. per year for each percent reduction in forest cover, but most treatments produce less than half this amount.

There is strong evidence that in well-watered regions, at least, streamflow response is proportional to reduction in forest cover. As the forest regrows following treatment, increases in streamflow decline; the rate of decline varies between catchments but appears to be related to the rate of forest recovery. Seasonal distribution of streamflow response to treatment is variable; response in streamflow may be almost immediate or considerably delayed, depending on climate, soils, topography, and other factors.

Holscher, C. E. 1966. "Forest Hydrology Research in the United States," pp. 99-103. William E. Sopper and Howard W. Lull (eds.), International symposium on forest hydrology proceedings, Pennsylvania State Univ., Aug. 9 to Sep. 10, 1965. Pergamon Press, New York. pp. 813.

Hoover, M. O. 1944. "Effect of Removal of Forest Vegetation on Water Yields." Am. Geophys. Union Trans. 6: pp. 969-977.

Hoover, Marvin D. 1967. "Water Yield Management for Forest Lands." Four States Irrig. Coun. (Denver, CO., Jan. 1971) Proc. 20:98, pp. 108-109.

Hoover, Marvin D. 1969. "Vegetation Management for Water Yield." Am. Water Resour. Assoc. Symp. Water Balance North Am. (Banff, Alberta, Can., June 1969) Proc. Ser. 7, pp. 191-195.

Hornbeck, J. W., and K. G. Reinhart. 1964. "Water Quality and Soil Erosion as Affected by Logging in Steep Terrain." J. Soil and Water Conserv. 19(1): pp. 23-27.

Horton, Jerome S., John P. Decker, and Howard L. Gary. 1960. "Watershed Management research in Stream-Bottom Vegetation," Watershed Management research in Arizona, progress report, 1959. p. 80 USDA For. Serv., Rocky Mt. For. and Range Exp. Sta., Fort Collins, CO. pp. 65-78.

Horton, Jerome S. 1966. "Problems of Land Management in the various Phreatophytl Zones." Pacific Southwest Inter-Agency Comm., Phreatophyte Sub-Comm., Phreatophyte Symp. (Albuquerque, N.M., Aug. 1966) Meet. 66-3, pp. 1-6.

Horton, Jerome S. 1972. "Management Problems in Phreatophyte and Riparian Zones. J. Soil and Water Conserv. 27: pp. 57-61.

Cites lack of basic research on water losses from vegetation and the ecology and life history of the plants involved. Also, expresses the

need for cooperation between resource managers and interested citizens to get together and decide what should be done to realize the greatest benefits from all resources in phreatophyte and riparian zones.

Horton, Jerome S. 1973. "Evapotranspiration and water research as related to riparian and phreatophyte management." An abstract bibliography. USDA Misc. Publ. 1234, pp. 192.

This bibliography brings together published information that will help land managers and research workers to: (1) Evaluate relations of vegetation to water loss and (2) estimate the probable effect on water yield of manipulating vegetation.

Horton, Jerome S., and C. J. Campbell. 1974. "Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Use Values." USDA For. Serv. Res. Pap. RM-117. pp. 23.

Summarizes the status of our knowledge about environmental relations of vegetation along water courses in the southwestern United States, and impacts of vegetation management to reduce evapotranspiration on other resource values. Suggests approaches to management of moist-site areas by zones based primarily on water table depth, elevation, and tree species.

Hoyt, W. G., and Troxell, H. C. 1932. Forests and Streamflow." Amer. Soc. Civil Eng. Proc. 58(6): 1037-1066. (Reprinted with full discussion in Amer. Soc. Civil Eng. Trans. 99: 1-111, 1934.)

The effect on streamflow of changes in forest and brush cover in the Wagon Wheel Gap area of Colorado (Bates and Henry 1928, 279) and the San Gabriel Canyon area near Azusa, Calif., are described in this paper. Changes were effected in Colorado by cutting and in California by accidental fire after accurate data had been recorded for several years.

It was concluded that forests did not "conserve the water supply," because after their removal there was an increase in average annual yield amounting to 15 percent in the Colorado mountains and 29 percent in the coastal mountain area of southern California.

Contrary to widely quoted opinion the increase in runoff was not confined wholly to flood periods. In both the Wagon Wheel Gap area and in the southern California area, 52 percent of the increase occurred during the nonflood period.

Hursh, C. R. 1951. "Research in Forest-Streamflow Relations." Unasylva 5: pp. 2-9.

Johnson, E. A., and J. L. Kovner. 1954. "Encreasing Water Yield by Cutting Forest Vegetation." Georgia Mineral Newsletter 7: pp. 145-148.

Johnson, E. A., and J. L. Kovner. 1956. "Effect on Streamflow of Cutting a Forest Understory." Forest Sci. 2: pp. 82-91.

Johnson, F. W. 1953. "Forest and Trout." J. Forestry 51(8): pp. 551-554.

Aside from wise regulation of the fishing, the most important features of trout stream management are: (1) to prevent silting; (2) to regulate the flow evenly; (3) to maintain proper water temperatures; and (4) to provide suitable cover. Most trout streams are in forest areas. Here the prevention of silting and abnormal water levels, as well as the maintenance of water temperature and cover, depend upon proper watershed protection and stream-side forest practices.

Johnson, J. E. 1974. "Forest Products Pollution Control Annotated Bibliography." Can. Forest Serv. West. Forest Prod. Lab. Inf. Rept. VP-X-100. pp. 11.

Kouner, J. L. 1957. Evapotranspiration and Water Yields following Forest Cutting and Natural Regrowth." Soc. Am. For. Proc. 1956: pp. 106-110.

Lantz, Richard L. 1970. "Effects of Logging on Aquatic Resources," H. J. Rayner, H. J. Campbell, and W. C. Lightfoot (eds), Progress in game and sport fishery research. Rep. Res. Div. Oregon State Univ., Corvallis, pp. 13-16.

Leaf, Charles F. 1966. "Sediment Yields from High Mountain Watersheds," Central Colorado. USDA For. Serv. Rocky Mt. For. and Range Exp. Sta. Res. Pap. RM-23. pp. 15.

This paper discusses sediment yields from two undisturbed watersheds and one watershed from which one-half of the merchantable timber was removed by careful timber harvesting. The necessary logging roads on the harvested watershed were planned and built to minimize erosion. Selected geomorphic characteristics of the watersheds are evaluated. Magnitude - frequency relationships are developed for estimating long-term sediment yields by the "design-period" approach.

Levno, A., and J. Rothacher. 1967. "Increases in Maximum Stream Temperatures after Logging in Old-Growth Douglas-Fir Watersheds." USDA For. Serv., Pacific Northwest For. and Range Exp. Sta., Res. Note PNW-65. pp. 12.

Love, L. D. 1953. "Watershed Management Experiments in the Colorado Front Range." J. Soil and Water Conserv. 8: pp. 213-218.

Love, L. D. 1953. "Watershed Management in the Colorado Rockies." J. Soil and Water Conserv. 8: pp. 107-112.

Love, L. D., and B. C. Goodell. 1959. "Effects of Forest Logging on Water Yields," pp. 111-115. Progress in Watershed Management, Third Annual Meeting (Ariz. Watershed Program, Phoenix, Sep. 1959) Proc. Ariz. State Land Dep., Ariz. Water Resour. Comm., Phoenix. pp. 120.

Lynch, J. A., W. E. Sopper, D. B. Patridge. 1972. "Changes in Streamflow following Partial Clearcutting on a Forested Watershed," Proc. of Natl. symposium on watersheds in transition, Amer. Water Resources Assn. and Colorado State Univ., Ft. Collins, CO.

Martin, Jerry L., and E. Roy Tinnery. 1962. "Logging in West Coast Watershed shows no effect on Area's Water Yield." The Timberman, 43(5): pp. 46-48.

Megahan, W. F. and W. J. Kidd. 1972. "Effects of Logging and Logging Roads on Erosion and Sediment Deposition from Steep Terrain." J. Forestry 70(3): pp. 136-141.

Erosion plots and sediment dams were used to evaluate the effects of jammer and skyline logging systems on erosion and sedimentation in steep, ephemeral drainages in the Idaho Batholith of central Idaho. Five-year plot data indicated that no difference in erosion resulted from the two skidding systems as applied in the study. Sediment dam data obtained concurrently showed that the logging operations alone (excluding roads) increased sediment production by a factor of about 0.6 over the natural sedimentation rate. Roads associated with the jammer logging system increased sediment production an average of about 750 times over the natural rate for the six-year period following construction.

Megahan, Walter F. 1976. "Effects of Forest Cultural Treatments upon Streamflow," Forest Acts Dilemma Symposium, 1975 Proceedings Montana Forest and Conservation Exp. Sta., Univ. of Montana. pp. 14-34.

In this discussion, forest cultural operations are restricted to timber harvest practices in general, including a variety of silvicultural schemes, and to the associated operations of skidding and road construction. A number of streamflow properties, including total quantity, timing, and quality of flows, are influenced by forest cultural practices. Effects of treatments upon streamflow result from modifications in watershed functions caused by reduced water use by trees, changes in the microclimate of the forest site following tree removal, and soil disturbance created by overall timber harvest operations.

Meginnis, H. G. 1959. "Increasing Water Yield by Cutting Forest Vegetation." Symposium of Hannoversch-Munden, Int. Assoc. Sci. Hydrol. Pub. No. 48, pp. 59-68.

Morrison, D. 1964. "The New Look in Timber Harvesting -- Possible Effects on Wildlife." Wildlife Society, N. Mex. - Ariz. Sec. Proc. 3: pp. 75-79.

Morrison, I. G. 1973. "Environmental Impacts of Forest Management Practices." Proc. of non-point pollution envir. quality control in forest resource mgmt., Inst. of For. Products, College of For. Res., Univ. of Washington, pp. 15-22.

Naruer, D. W., J. C. Mason and J. H. Mundie. 1973. "Streambank Management--a Brief to the Select Standing Committee on Forestry and Fisheries of the British Columbia Legislature." The Truck Logger, 29(5): pp. 16-22.

National Marine Fishery Service. "Research Summary--Environmental Impacts of Log Handling and Storage." pp. 13.

Niederhof, C. H., and H. G. Wilm, 1943. "Effect of Cutting Mature Lodgepole Pine Stands on Rainfall Interception. J. Forestry 41: 57-61.

Nimlos, Thomas J. 1972. "Soils and Logging," (Richard M. Weddle (ed.)), pp. 93-110, Forest Land Use and the Environment. Montana For. and Conserv. Exp. Sta., School of Forestry, Univ. of Montana, Missoula.

Logging operations in western Montana have been accused of being a major source of sediment. Another aspect of logging that has caused some concern is the impact of timber harvesting on soil nutrient depletion and on water chemistry. This paper discusses both possibilities especially as they relate to Montana: the first part considers the causes of soil erosion and how it can be controlled during and following logging. The second part examines the changes in the chemistry of the soil and streams that result from logging.

Packer, Paul E. 1967. "Forest Treatment Effects on Water Quality," (William E. Sopper and Howard W. Lull (eds.)), pp. 687-689. International symposium on Forest Hydrology Proceedings, Penn. State Univ., Aug. 29 to Sept. 10, 1965. Pergamon Press, New York.

Most water flowing in our streams comes from forested watersheds. With continually increasing demands for high-quality water, we need to know how forest management activities affect the quality of water supplies. As the gentler forest lands become used more intensively, and as timber harvest activities extend further into rugged terrain, the opportunities for damage to water quality increase as a result of destruction of vegetation and disturbance of soil.

An important job of watershed management research is to gain understanding of the hydrologic and erosional behavior of forest lands so that such management objectives as increasing water yields can be attained with a minimum increase in stream sedimentation.

Research to determine the effects of forest treatments associated with timber harvesting has shown that: (1) undisturbed forests produce only small amounts of sediment and a streamflow usually suitable for drinking; (2) with the possible exceptions of substantial increases in streamflow peaks, timber cutting does not adversely affect water quality; (3) logging, or skidding of logs from forests, can sometimes increase sedimentation considerably, depending upon the location and drainage of skidways, the erodibility and stoniness of soils, and the rapidity of revegetation of skidways; (4) roads that are inadequately drained or are located too close to streams are the main cause of deterioration of water quality in forests.

Phillips, Robert W. 1963. "Effect of Logging on Aquatic Resources." Oregon State Game Comm., Res. Div. Rep., pp. 105-122.

Phillips, Robert W., H. J. Campbell, W. L. Hug, and E. W. Claire. 1966. "A Study of the Effects of Logging on Aquatic Resources, 1960-1966." Oregon State Game Comm., Res. Div. Prog. Memo. Fish., 28 pp. Oregon State Univ., Corvallis.

Phreatophyte Subcommittee, Pacific Southwest Interagency Committee. 1966. Vegetation Management on Flood Plains and Riparian Lands." Phreatophyte Symp. Proc., Pac. Southwest Inter-Agency Comm. 66-3 Meet. Albuquerque, N. Mex., Aug. 30, 1966. 57 p.

More stress is being placed on the management of phreatophyte and riparian zones for multiple use instead of water salvage alone. The papers outline the status of research and future needs in research.

Pierce, R. S. 1965. "Water Quality Problems Related to Timber Culture and Harvest." Municipal Watershed Mgmt. Symposium Proc., Amherst, pp. 45-48.

Platts, William S. 1970. "The Effects of Logging and Road Construction on the Aquatic Habitat of the South Fork Salmon River, Idaho." USDA For. Serv. Zone Fish. Biol. 4 pp.

Price, Raymond. 1956. "Possibilities of Increasing and Maintaining Production from Grass and Forest Lands without Accelerating Erosion," (Gilbert F. White (ed.)), pp. 233-244. The Future of Arid Lands, Amer. Assoc. Advance. Sci., Wash., D. C.

Price, Raymond, and M. D. Hoover. 1957. "Watershed Management Research in Arizona Conducted by the Forest Service." Ariz. State Land Dep.. Ariz. Watershed Program Proc. 1: 5-10.

Reynolds, Hudson G. 1960. "Vegetation Management for Water Yield in the Southwest." N. Mex. Ann. Water Conf. Proc. 5: 21-33.

Reynolds, Hudson G. 1960. "Watershed Management Research in Arizona and New Mexico." J. Forest. 58: 275-278.

Reynolds, Hudson G. 1960. "Current Watershed Management Research" by the U. S. Forest Service in Arizona. Ariz. State Land Dep. and Ariz. Water Resources Comm. Proc. 3: 63-93.

Rice, R. M., and J. R. Wallis. 1962. "How a Logging Operation can Affect Streamflow." For. Indus. 89 (11): 38-40.

Rice, R. M., J. S. Rothacher, and W. F. Megahan. 1972. "Erosional Consequences of Timber Harvest: an Appraisal. Proceedings of a symposium on Watersheds in Transition held at Fort Collins, Colorado, pp. 321-329. 19-22 June, 1972. 405 pp.

This paper summarizes our current understanding of the effects of timber harvesting on erosion. Rates of erosion on mountain watersheds vary widely but the relative importance of different types of erosion and the consequences of disturbances remain fairly consistent. Therefore these conclusions seem to be valid for most circumstances: Most of man's activities will increase erosion to some extent in forested watersheds, erosion rarely occurs uniformly; sediment production declines rapidly following disturbance; landslides and creep are the chief forms of natural erosion in mountainous regions; cutting of trees does not significantly increase erosion, but clearcutting on steep unstable slopes may lead to increased mass erosion; accelerated erosion is a possible undesirable side effect of use of fire in conjunction with logging; the road system built for timber harvesting far overshadows logging or fire as a cause of increased erosion; and potentially hazardous areas can be identified in advance of the timber harvest.

Rich, Lowell R. 1960. "Watershed Management Research in the Mixed Conifer Type." Watershed Management Research in Arizona Progress Report 1959. pp. 7-16. For. Serv. Rocky Mt. For. and Range Exp. Sta., Fort Collins, CO

Rich, L. R. 1960. "Preliminary Effects of Forest Tree Removal on Water Yields and Sedimentation." Ariz. Watershed Symp. (Phoenix, Ariz., Sept. 1960) Proc. 4: 13-16.

Rich, L. R., H. G. Reynolds, and J. A. West. 1961. "The Workman Creek Experimental Watershed." USDA For. Ser. Pap. RM-65. 18 pp.

The riparian cut on North Fork suggests strongly that removal of a few broadleaf hardwoods along streams in mixed forests at high elevation does not result in increases in water yields. The effect that commercial timber harvest and changing from a moist forest to a perennial grass type has upon water yield and sedimentation must await further years of record. Additional measurements of water yields must be obtained before conclusions are mathematically sound.

Rich, Lowell R. 1965. "Water Yields Resulting from Treatments Applied to Mixed Conifer Watersheds." Ariz. Watershed Symp. (Tempe, Ariz., Sept. 1965) Proc. 9: 12-15.

Rothacher, Jack. 1970. "Increases in Water Yield Following Clearcut Logging in the Pacific Northwest." Water Resources Res., 6(2): 653-657.

Increases in water yield following timber harvest roughly conform to the proportion of the area cleared. In high precipitation areas of the Oregon Cascades, clear-cut logging can increase annual water yield 18 inches. Approximately 80% of the increase occurs during the October to March season.

Rothacher Jack. 1971. "Regimes of Streamflow and Their Modification by Logging." (J. Morris (ed.)) pp. 40-54. Forest Land Uses and Stream Environment, Symposium Proceedings, 1970. Contin. Educ. Pub., Oregon State Univ., Corvallis.

Rowe, P. B. 1963. "Streamflow Increases After Removing Woodland-Riparian Vegetation from a Southern California Watershed." J. For. 61(5): 365-370.

A test of applied watershed management on the San Dimas Experimental Forest in southern California has shown that streamflow yields can be appreciably increased. This was accomplished by clearing the deeprooted woodland-riparian vegetation from selected canyon bottom reaches of Monroe Canyon, a typical southern California mountain watershed. The increases in flow were especially important because they occurred primarily in summer and in the initial period of soil wetting during succeeding rainy seasons, when streamflow was lowest and water most needed. During the one rainy season of heavy precipitation and continuously wet soils the removal of the woodland-riparian vegetation had no appreciable effect on streamflow, peak discharge, or erosion rates. However, during wetting periods and during the one rainy season of light precipitation, streamflow yields, particularly during storms, were considerably increased. Streamflow was inadequate to produce sediment movement in either the treated or control watersheds during these wetting periods. Removal of the tree-brush cover shading the stream course resulted in an increase in the algae content of the late spring and summer flows but had no other detectable effect on water quality. These first results show that, while streamflow can be increased by removal of the canyon bottom vegetation, this kind of treatment, to be most successful, should be limited to carefully selected areas with conditions of climate, vegetation, soil, and water capable of yielding the desired increases. That is, to areas in which (1) the water supply is adequate to exceed evapo-transpiration losses after treatment, (2) the water table or zone of saturation is within reach of the heavy water using woodland-riparian vegetation, and (3) the canyon bottom soils overlaying the water table are of sufficient extent and depth to permit reduction in evapo-transpiration if the deeprooted vegetation is eliminated.

Russell, W. L., Jr. 1971. "Procedures for Estimating Average Annual Water Yields and Increases in Water Yield due to Vegetation Manipulation, with Interim Guidelines for the Clearwater National Forest," Unpub. Rep., Clearwater N. F., Orofino, Idaho.

Sadler, Ronald R. 1970. "Buffer Strips--a Possible Application of Decision Theory." USDI Bur. Land Manage. Tech. Note., Portland, Oregon. 11 pp.

The economic values of leaving buffer strips for stream protection are discussed. The article includes various formulas to determine economic value of the fishery as compared with the value of the timber in the buffer strips.

Schmidt, W. C. (n.d.) "The Effects of Vegetative Manipulation on Streamflow Water Quality and Water Available for Plant Growth." Int. For. and Rage Exp. Sta., Missoula, MT.

Sheridan, W. L. 1949. "Effects of Deforestation and Logging Operations on Watersheds with Special Reference to the Effects on Fish Life in Streams." Fish. Res. Inst., Univ. of Wash., Circ. 2. 15 pp.

Silvey, Lee. 1969. "Estimating the Effects of Timber Cutting on Water Yields and Determining Timber Cutting Guidelines for the St. Joe National Forest," unpublished, St. Joe National Forest, St. Maries, Idaho.

Snyder, Gordon G. 1973. "The Effects of Clearcutting and Burning on Water Quality." M. S. Thesis, Univ. of Idaho, Moscow.

Sopper, William E. 1975. "Effects of Timber Harvesting and Related Management Practices on Water Quality in Forested Watersheds." J. Environ. Qual. 4: 24-29.

Undisturbed forested watersheds are generally recognized as a primary source of high-quality water. The physical and chemical nature of these waters fluctuate constantly in response to natural stresses but are most influenced by man's activities. Three major forest land activities--timber harvesting, fertilization, and herbiciding--which may have an effect on water quality are reviewed. In general, research results indicate that nutrient losses, particularly nitrogen, following forest clearcutting are small to negligible. Similarly, forest fertilization studies indicate that nitrogen concentrations in streams are not drastically increased. Large areal applications of selected herbicides in the West have demonstrated that, if carefully applied, they can be used without impairment of water quality.

Sopper, William E., and Howard W. Lull. 1967. International symposium on Forest Hydrology. Proceedings of a national science foundation advanced science seminar, held at the Pennsylvania State Univ., Univ. Park, PA Aug. 29 to Sept. 10, 1965. 813 pp.

Forest watershed research has shown that water yield and water quality are measurably influenced by forest cutting practices and has provided quantitative evidence of this relationship worldwide. The symposium was held to provide an opportunity for scientists engaged in the field of forest hydrology research to get together to determine the present state of knowledge, current research needs and trends, and to provide a bench mark which might serve as a point of departure for anticipated future research.

Steinbrenner, E. C., and S. P. Gessel. 1955. "The Effects of Tractor Logging on Physical Properties of Some Forest Soils in Southwestern Washington." Soil Science So. Amer. Proc. 19: 372-376.

Streeby, Larry. 1971. "Buffer Strips--Some Considerations in the Decision to Leave." (James Morris (ed.)) pp. 194-198. Proc. of a Symposium--Forest Land Uses and Stream Environment, Oregon State Univ., Corvallis.

Buffer strips have been receiving a great deal of attention as a means of protecting streams and the stream environment. But they are not equally useful in all places. The desirability of applying buffer strips is dependent on three classes of factors--physical-biotic factors, outside cultural factors, and management objectives. Some potential costs and benefits associated with buffer strips are identified, but all these costs and benefits should not be expressed in dollar terms. Rather, all costs and benefits associated with each management objective should be explicitly recognized in their own natural measure of contributions to goals, and decisions should be made on the basis of this information.

USDA Agricultural Research Service. 1975. "Present and Prospective Technology for Predicting Sediment Yields and Sources." Proceedings of the sediment-yield workshop, USDA Sedimentation Laboratory, Oxford, Miss. Nov. 28-30, 1972.

These proceedings, which include 31 papers, present material on the procedures presently in use to estimate sediment yield. There is a considerable amount of knowledge available in the field of sediment yield and sources. However, a new level of sophistication is needed, particularly because of the water-quality implications of transported and deposited sediments. The papers indicate many new avenues for needed additional research.

USDA Forest Service. (n.d.) "Forest Hydrology: Hydrologic Effects of Vegetation Manipulation, Part II."

Part II of Forest Hyrdology is concerned with the manipulation of vegetation and the subsequent effects which can be expected from water yield. The techniques, procedures, and guidelines contained herein are designed for use by the field forester to assess past, present, and future vegetation manipulation practices on the water and watershed resource. It provides timely and proper consideration for the objectives of watershed, stream channel, and water quality protection. The use of these procedures, guides and recovery programming techniques provides the Resource Manager with a wide range of alternatives when considering treatment of vegetation.

USDA Forest Service. 1964. "Moist-site Timber Harvest Increases Streamflow in Arizona," Annual Report 1963. Rocky Mountain Forest Exp. Sta., Fort Collins, CO p. 59.

USDA, Forest Service. 1971. A Procedure for Determining the Hydrologic Impact of Vegetation Manipulation." Missoula, MT 37 pp.

USDA Forest Service (n.d.) Forest Hydrology: Hydrologic Effects of Vegetation Manipulation, Part II."

Part II of Forest Hydrology is concerned with the manipulation of vegetation and the subsequent effects which can be expected from water yield. The techniques, procedures, and guidelines contained herein are designed for use by the field forester to assess past, present, and future vegetation manipulation practices on the water and watershed resource. It provides timely and proper consideration for the objectives of watershed, stream channel, and water quality protection. The use of these procedures, guides and recovery programming techniques provides the Resource Manager with a wide range of alternatives when considering treatment of vegetation.

U.S. Environmental Protection Agency. 1973. "Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants." EPA 430/9-73-014. 261 pp.

This report presents results of a three month study whose specific objectives were:

1. To provide descriptions of nonpoint sources information relevant to water pollution problems, including the nature of sources, type of pollutants, relative importance of pollutants from each source, and pollution loads related to natural and operational factors.

2. To determine methods, techniques, and procedures that can be used for identifying, measuring, and evaluating the nature and extent of the pollutants from nonpoint sources.

3. To provide analyses of the effect of nonpoint sources pollutants on water quality management.

U. S. Environmental Protection Agency. 1973. "Processes, Procedures, and Methods to Control Pollution Resulting from Silvicultural Activities."

The primary concern of this study is control of pollutants which originate in commercial forest lands and degrade the quality of surface waters and groundwater. The major identified sources of pollutants are mineral sediments; humic matter present in the soils and mineral sediments; humic matter present in the soils and in the forest cover; tree debris; pesticides, including insecticides, fungicides, rodenticides, and silvicides; fertilizers; and fire retardants. Thermal effects resulting from solar energy, specifically the effect of forestry practices on stream temperatures, are also considered.

U. S. Environmental Protection Agency. 1971. Study of Effects of Watershed Practices on Streams. Water Poll. Control Res. Ser. 173 pp.

Verry, Elon S. 1972. "Effect of an Aspen Clearcutting on Water Yield and Quality in Northern Minnesota." National symposium on Watersheds in Transition Proceedings. pp. 276-284. Am. Water Resour. Assoc., Urbana, Ill.

Wilm. H. G. 1944. "The Effect of Timber Cutting in a Lodgepole Pine Forest on the Storage and Melting of Snow." Am. Geophys. Union Trans. 25: 153-155.

Wilm, H. G., and E. G. Dunford. 1948. "Effect of Timber Cutting on Water Available for Streamflow from a Lodgepole Pine Forest." USDA Tech. Bull. 968. 43 pp.

The study area selected is near the Continental Divide in Colorado, in the headwaters of the Fraser River. For two years records were taken of snow stored on the ground in the uncut forest before melting started each spring; of the length of time required for the snow to melt; and of the amounts of precipitation reaching the soil through the forest canopy In addition, observations were made to show the effect of timber cutting on the forest environment and especially on soil erosion. Timber cutting exerted pronounced effects on all the measured components except soil moisture, and these effects increased consistently with the intensity of timber removal.

Worley, David P. 1965. The Beaver Creek pilot watershed for evaluating multiple-use effects of watershed treatments. USDA For. Serv. Res. Pap. RM-13. 12 pp.

Ziemer, Robert R. 1964. "Summer Evapotranspiration Trends as Related to Time after Logging of Forests in Sierra Nevada." J. Geophys. Res. 69 (4): 615-620.