PRELIMINARY PROPOSAL

A STUDY TO RELATE THE NATURAL CHEMISTRY OF STREAM WATER TO ITS SOURCE ON THE FORESTED BASIN

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and
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The natural mineral constituents of stream water from forested basins constitute the threshold quality level above which the impacts of forest management must be measured or assessed from experiment. In any given region, according to Gibbs (1970), the average concentration of minerals in natural stream water will be under the dominance of processes associated with solution of the weathering soil mantle (rock dominance), the concentrations of ions in precipitation (precipitation dominance) or the balance between evaporation and crystallization within the basin (evaporation - crystallization dominance). Within this classification, the streams of the Southeast lie somewhere between precipitation and rock dominance. It is possible under extreme cases that man's activities on forest land, if severe and prolonged, can be classified as a fourth type of dominance in stream water chemistry. Some of these activities are logging, roadbuilding, timber stand improvement, fire, site preparation, recreation development, chemical control of insects and diseases, forest fertilization and forest type conversions. To know how these activities affect water chemistry, we must assess not only the level but the source of minerals found naturally in headwater streams.

Two lines of recent research have combined to raise a clear question about the source and timing of various ions measured in forest waters. One line is the recent work by the U.S. Forest Service and several ecologists from Dartmouth University in New Hampshire, the now well-known Hubbard Brook studies (Bormann and Likens, 1970; Likens et. al., 1967; Johnson et. al. 1970). The main conclusion of these studies was that the felling of all trees on a forested basin, plus subsequent herbiciding to eliminate regrowth for several years, caused a sudden five to ten-fold increase in the export of nitrogen, calcium, magnesium, potassium and sodium in stream water. These authors attributed the changes to the clear-felling over the whole basin and failed to make any reference to the possibility of a differential source area. More recently, Cleaves et. al., (1970) attempted to relate certain water minerals to weathering of the soil and earth mantle (the regolith) in a forested basin in Maryland. The latter authors refer to the possibility that variable sources of the minerals are affecting their interpretations.

The second line of research stems from the work of Hewlett (1961 a & b), Hewlett and Hibbert, (1963 and 1967), Tischendorf (1969), and Hewlett and Nutter (1970). A copy of the latter paper is attached as Addendum I to this proposal. It explains the variable source area concept of storm and baseflow generation in the headwaters. Application of these hydrological ideas to the results of Bormann, Likens, Johnson, Cleaves and others reveals the gap that exists between the measurement of stream ions and the understanding of the cause and effect relations between man's watershed activities and water quality response. The effects of forest activities, such as logging and roadbuilding, will not be understood from whole basin tests alone, but must be analyzed in relation to an intensity-source-area factor.

The purpose of the proposed study is to test the hypothesis that normal stream water minerals are under the dominance of processes that take place along and within the vicinity of the upland stream channel and its intermittent extensions during storm period. At the same time, the time and space variations in concentrations of a few selected ions will be measured as background information on the basic quality of the forested Piedmont stream. A fair degree of success can confidently be expected if sufficiently accurate analysis of water samples can be secured.

Description of the Study Area:

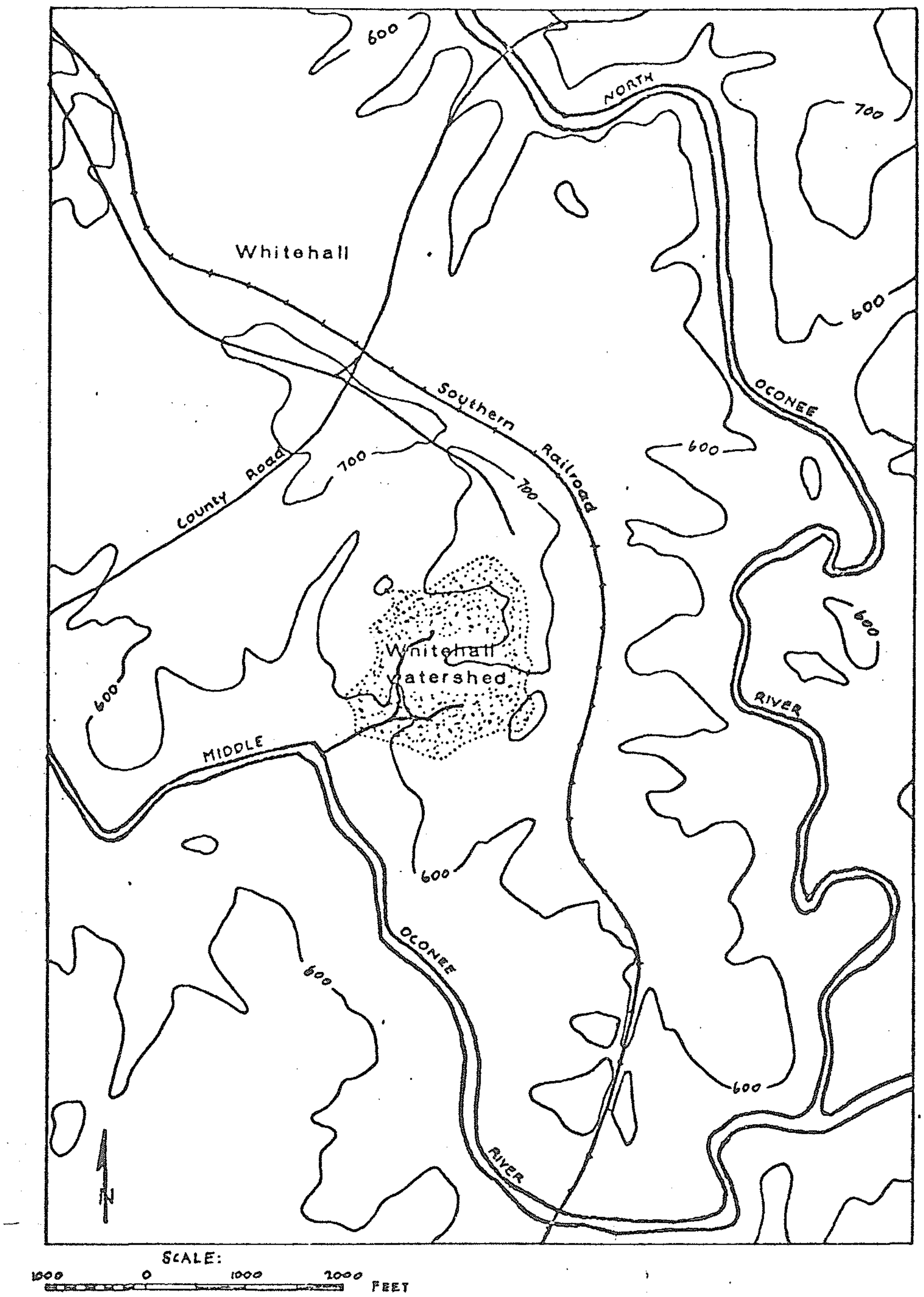
The area chosen for this study is the Whitehall Watershed, a small forested subdrainage of the Middle Oconee River in Clarke County, Georgia (Figure 1 & 2). A detailed description of its location, climate, vegetation, geology, and soils is given by Tischendorf (1969).

Specific Objectives:

During baseflow -

1. To measure the relationship of the ionic composition of stream water to its source areas.
2. To determine any interactions within the stream channel that may produce changes in the ionic composition of water as it flows from spring heads to weir.

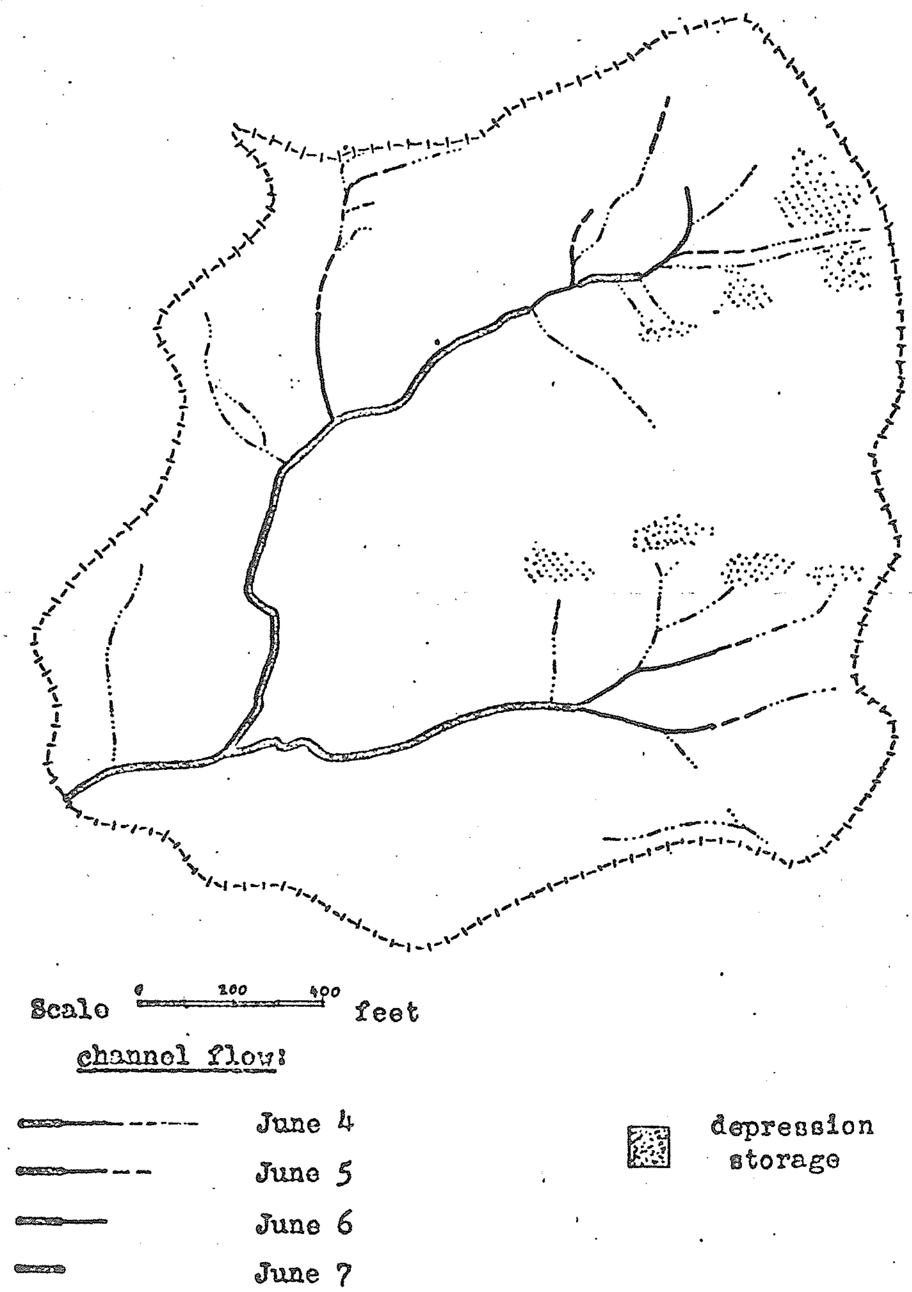
FIGURE 1



LOCATION OF THE WHITEHALL STUDY AREA

Source: Athens East Quadrangle, and Barnett Shoals Quadrangle, 7.5'. 1:24,000. U.S. Geological Survey, Washington D.C. 1964.

FIGURE 2



THE SHRINKING NET OF WATER CARRYING CHANNELS
AFTER 4.14 INCHES OF RAIN, JUNE 1967

During stormflow -

1. To measure the input-output mechanisms relating to source areas of stormflow minerals.

Procedure:

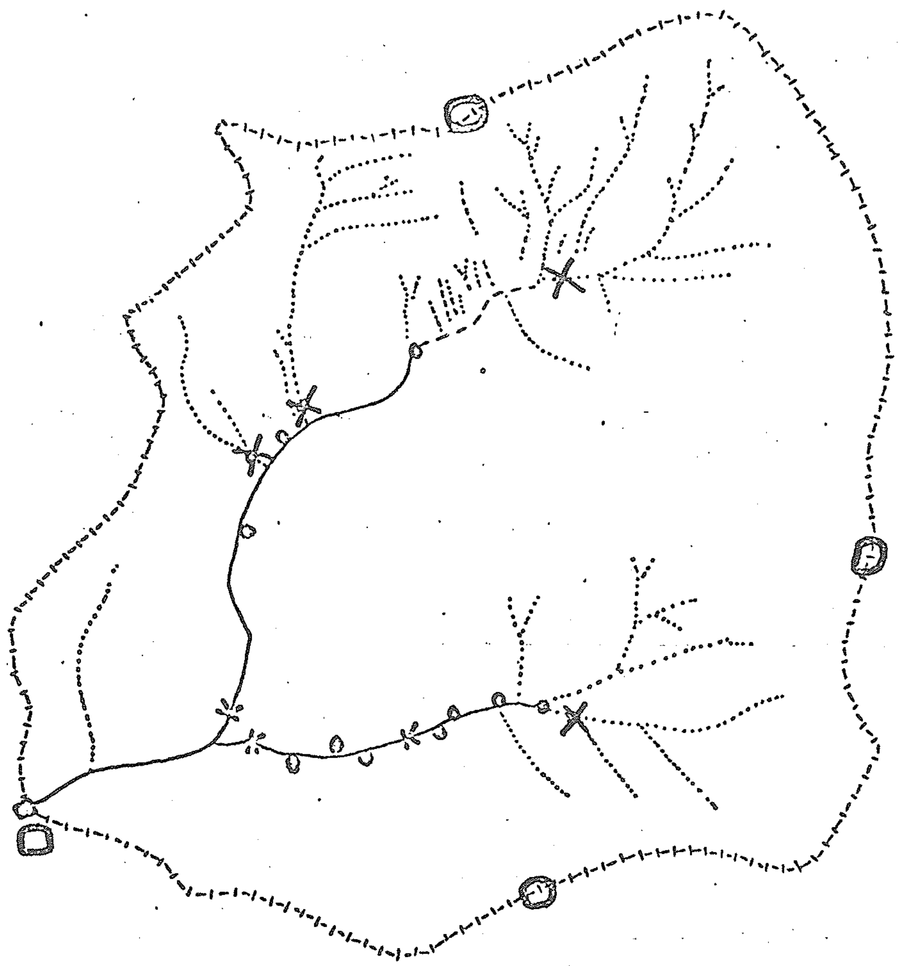
A systematic procedure has been designed to sample stream water and source area water, and to measure their quantity and ionic composition (Figure 2). Before sampling can begin, it will be necessary to install temporary weirs to measure stream discharge at three selected points upstream from the permanent weir (Figure 3).

The baseflow portion of the study will require the sampling of stream water and ground water at certain selected positions along the stream. Stream water samples will be collected by dipping and filling one liter nalgene bottles at six designated locations; one at the permanent weir, one at each of the two spring heads, and one at each of the three temporary weirs. Ground water samples will be extracted at ten selected probe sites along the stream banks; one at each of the two spring heads and one at each of eight selected seep areas along the channel system. Therefore, each baseflow sampling run requires a total of sixteen samples for determination of ionic composition and the measurement of discharge at four weir sites.

Baseflow measurements will be run on a bi-monthly basis and also will include four days monitored for diurnal fluctuations, each day having three sampling runs. A maximum of five hundred and seventy-six samples will be required for the baseflow portion of this study.

FIGURE 3

MAP OF THE DRAINAGE NET



Scale 0 200 400 feet

———	perennial channel	▭	weir, permanent
— — —	intermittent channel	⨯	weir, temporary
....	ephomeral channel	o	ground probe sites
▢	rain sample sites	X	intermittant or expansion sample sites
		———	throughfall sample sites are random along stream

The second phase of the study is designed to sample all the components that contribute to stream discharge during a rainfall period. This will require another 18 sampling sites in addition to those mentioned in the baseflow phase above, a total of 34 sites.

The input of precipitation to the system will be measured at four locations around the watershed (Figure 3). A system of four rain gauges and one recording rain gauge are already in place to measure the quantity of rainfall. Four bulk rain samplers and one fractional rain sampler will be added to measure the quality of rainfall. The precipitation that penetrates the canopy cover as throughfall and contributes to stormflow will be measured by ten bulk rain samplers placed at random along the centerline of the stream. Finally, samples at four intermittent or expansion channels will be obtained during stormflow by filling liter nalgene bottles (grab samples).

A maximum of 14 storms will be monitored for the second portion of the study for a total of 476 stormflow samples. A grand total of 1052 samples will be required for the whole study.

Sample Handling and Preservation

The nalgene sample bottles will be thoroughly washed with detergent and tap water; rinsed with chromic acid, tap water, nitric acid, and finally distilled water in that order. Since only the soluble constituents are desired for analysis, the sample will be filtered through a 0.45 micron membrane filter as soon as practicable. If it is necessary that the samples be preserved, the filtrate will be acidified by adding proportionate amounts of three milliliters of 1:1 redistilled nitric acid per liter of filtrate. This will lower the pH to 2 or 3 and should be sufficient to preserve the sample indefinitely (FWPCA 1969).

Sample Analysis

The success of the study not only depends on sampling design and on proper sample handling, but on the accurate analysis of the ionic composition of the samples as well. It is judged that the personnel and facilities of the Soil Testing Laboratory, College Station Road, will be capable of providing the accuracy needed.

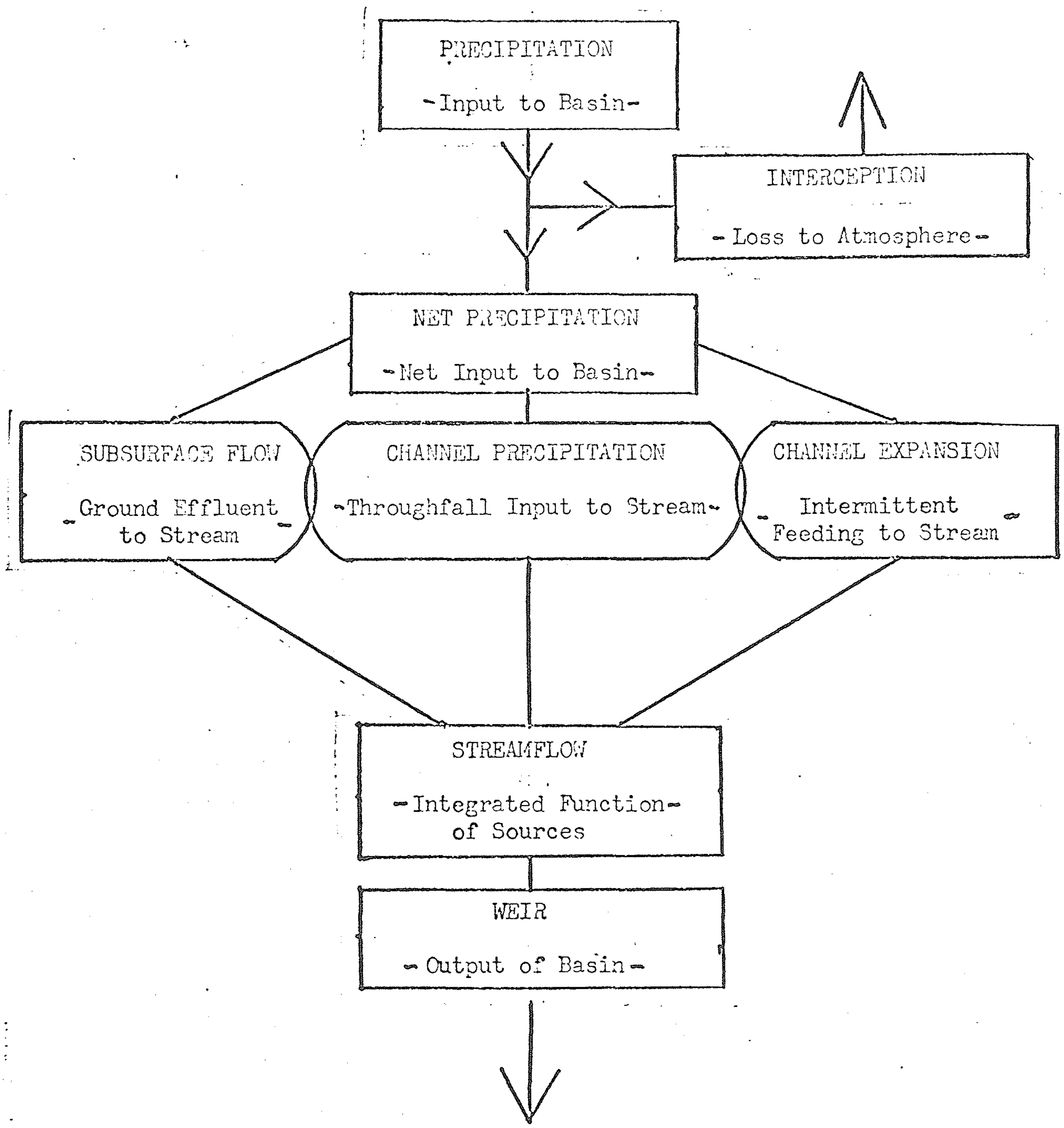
A preference order of the ions to be analyzed has been decided upon and is dependent chiefly on the availability of funds. The order of desired ions, given from most to least, is thus: chloride (-), potassium (+), magnesium (++), sodium (+), calcium (++), aluminum (+++), and on for another nine metallic ions. The Soil Testing Lab is capable of analyzing for 14 metallic ions simultaneously with their spark emission photometer chloride will be analyzed with a technican.

Analysis

Analysis will test the hypothesis implied in the objectives, that the source of storm water ions is the rainfall and the immediate vicinity of the stream channel and that the source of base flow ions is also related to dynamic behavior of the variable source area (Figure 4). The information will be used to comment constructively on the interpretation of water quality changes as a direct or indirect consequence of land use practices, as well as on the behavior of mobile pollutants ("non-point" sources) within a drainage basin.

FIGURE 4

FLOW DIAGRAM OF THE MINERAL-WATER BALANCE OF A SMALL STREAM



Duration of the Project

Because the basic hydrologic and basin morphological information is already available the study should require only one year of field sampling plus six months for analysis, from the date of initiation. Exploratory sampling will begin immediately under support already provided by the University of Georgia. Regular sampling should begin by March 15th, or at whatever date some indication appears that support will be forthcoming. Therefore the project will be completed by December 31, 1972.

Project Personnel

The Principal Investigator, Dr. John D. Hewlett, is well-known among hydrologist, ecologists and foresters for his work in forest hydrology. A brief resume follows:

One Master's thesis is in draft:
Helvey, Junior D., "The Prediction of Soil Moisture in the Southern Appalachians from soil, topographic and rainfall," scheduled January 1971.

Unusually heavy involvement as a graduate committee member on:
Neal, William P., "The Southern Piedmont Upland of the Southeastern United States: A geomorphic system in a steady state of dynamic equilibrium," September, 1967. (Geography).

External examiner for:
Carson, Elizabeth, "The hydrologic response of the Eaton River Basin, Quebec," August, 1970. (Geography, McGill University).

Dissertations supervised:
Tischendorf, Wilhelm G., "Tracing Stormflow to varying source areas in a small, forested watershed in the Southeastern Piedmont," May, 1969.

One other is in draft:

Douglass, James E., "Prediction equations for estimation of peak discharge from small forested watersheds," scheduled for June 1971.

Unusual involvement as committee member on:

Murlless, Richard, "Detritus export from a small forested watershed," still in process.

Articles published:

"Water or forest: Can we have all we need of both?", by ______________, Frontiers of Plant Science, Vol. 17(1), p. 2-3, 1964.

"Soil water absorption by mountain and piedmont forests," by J. H. Patric, James E. Douglass, and ______________. Soil Science Soc. Amer. Proc., Vol. 29(3), p. 303-308, 1965.

"Test of a transpiration inhibitor on a forested watershed," by Paul E. Waggoner and ______________. Water Resources Research, Vol. 1(3), p. 391-396, 1965.

"A hydrologic response map for the State of Georgia," by __________, Water Resources Bulletin, Vol. 3(3), p. 4-20, 1967.

"In defense of experimental watersheds," by __________, H. W. Lull and K. G. Reinhart, Water Resources Research, Vol. 5(1), p. 306-315, 1969.

"Effects of Forest clear-felling on the storm hydrograph," by __________ and J. D. Helvey, Water Resources Research, 6(3): 768-782, 1970.

"Determining and mapping the average hydrologic response of Eastern United States," J. F. Woodruff and __________, Water Resources Research, 6(5): 1325-1340, 1970.

"The relation of forests and forestry to water resources in South Africa," by __________, South African Forestry Journal, in press, 1970.

"The hydrologic response of small basins in Georgia," by J. F. Woodruff and __________, Southeastern Geographer, 12(1) - - , April 1971 (in press).

Books published:

"An Outline of Forest Hydrology," by __________ and W. L. Nutter, Georgia University Press, Athens, p. 139, 1969.

Other publications, including published proceedings:

"Research in hydrology of forested headwaters at the Coweeta Hydrologic Laboratory," by __________. Proc. 29th N. A. Wildlife and Natural Resources Conference, Las Vegas, Nevada, p. 103-112, 1964.

"Factors affecting the response of small watersheds to precipitation in humid areas," by __________ and A. R. Hibbert, Proc. of the Intern. Symposium on Forest Hydrol., Penn State, Pa., Sept. 1965, Pergamon Press, (Oxford), p. 275-290, 1967.

"Forests and precipitation: Session summary," by __________, Proc. of the Intern. Symposium on Forest Hydrol., Penn State, Sept. 1965, Pergamon Press (Oxford), p. 241-243, 1967.

"Will water demand dominate forest management in the East?" by __________, Proc. Soc. of Amer. Forest., Annual Mtng., Seattle, Wash., p. 154-159, 1966.

"Blending forest uses," by __________ and J. E. Douglass, USDA Forest Service Research Paper SE-37, 15 p., September 1968.

"The variability of the source area of stormflow," by Wilhelm G. Tischendorf and __________, Proc. Intern. Water Erosion Symposium, Prague, 1969.

"Review of the catchment experiment to determine water yield," by __________, Proc. Joint FAO/USSR Intern. Symposium on Forest Influences, Moscow, Aug. 1970 (in press).

"The relation of the variable source area concept to hydrologic modeling," by __________ and W. L. Nutter, Proc. Clemson Conf. on Hydrologic Models, Clemson, March 25, 1970.

Papers presented at regional, national and international meetings:

"Combining forest, range, and watershed management," by __________, Distinguished Lectureship Series, Texas A&M University, Coll. of Agriculture, February, 1970.

"The varying source area of streamflow from upland basins," by __________ and W. L. Nutter, Presented at the Symposium on Interdisciplinary Aspects of Watershed Management, Montana State University, Bozeman, August 3-6, 1970.

Scholarly Activities:

As a consultant with the Food and Agricultural Organization of the United Nations, is one of four American forest hydrologists engaged to deliver several papers to an International Workshop on Forest Hydrology in Moscow, Russia.

Was invited to deliver a paper and serve as Session Chairman at the first International Symposium on Forest Hydrology, held at Penn State in 1965.

Has been invited (expenses paid) to deliver a paper on small watershed experiments at the International Symposium on Experimental and Representative Watersheds, to be held in Wellington, New Zealand in 1970.

Is retained by the Forestry Department of the Government of South Africa as a three-month consultant on problems of forests and water yield in that country, beginning in April.

Is invited to be a guest lecturer at Stellenbosch University by the Faculty of Forestry during the above trip.

Was requested by the Bureau of Natural Resources of Rhodesia for a consulting tour of duty on problems of land use and hydrology in that country.

Gave a series of invited lectures at Oxford University and the Institute of Hydrology, Wallingford, England, during a tour of British hydrology and forestry, summer 1968.

Graduate Associate: Mr. Mark Ayers, a candidate for the Master of Science degree in Forest Hydrology, graduated from University of Illinois in June, 1970.

Research Assistant: Mr. Ray Doss, Technician, School of Forest Resources, has served as assistant to the hydrological unit of the School since 1965 and is well trained in the collection of hydrological data. He is responsible for sustained operation of the hydrological network on the experimental basin at Whitehall.

____________________: Laboratory Technician, will be recruited from several trained young women now working for the School on temporary projects. The help and advice of several scientists on the University Staff will be solicited as the need arises. In particular, it is expected that the personnel and facilities of the Soil Testing Laboratory, College Station Raod, will be incorporated into the study plans.

Budget -(A preliminary Budget is attached).

References

Bormann, F. H., and G. E. Likens. The nutrient cycles of an ecosystem. Scientific American, Vol. 223 (4): 92-101, Oct., 1970.

Cleaves, E.T., A. E. Godfrey, and O.P. Brickler. Geochemical Balance of a Small Watershed and its Geomorphic Implications. Geological Society of America Bulletin, Vol. 81: 3015-3032, Oct. 1970.

Gibbs, R. J., Mechanisms controlling world water chemistry. Science, Vol. 170: 1088-1090, Dec. 1970.

Federal Water Pollution Control Administration. In FWPCA Methods for Chemical Analysis of Water and Wastes. U.S. Dept. of Interior, pp. 90-91, 1969.

Hewlett, J.D. Watershed Management, In Annual Report for 1961, Southeastern Forest Experiment Station, U.S. Forest Service, pp. 61-66, 1961 a.

Hewlett, J. D. Soil moisture as a source of base flow from steep mountain watersheds. Southeastern Forest Experiment Station, U.S. Forest Service, Station Paper 132, 1961 b.

Hewlett, J. D. and A. R. Hibbert. Moisture and energy conditions within a sloping soil mass during drainage. Journal of Geophysical Research, 68: 1081-1087, 1963.

Hewlett, J.D. and A. R. Hibbert. Factors affecting the response of small watersheds to precipitation in humid areas. In Sopper, W. E. and H. W. Lull (Editors), International Symposium on Forest Hydrology, Pergamon Press, Oxford, pp. 275-290, 1967.

Hewlett, J. D. and W. L. Nutter. The varying source area of streamflow from upland basin. Paper presented at the Symposium on Interdisciplinary Aspects of Watershed Management, Montana State University, Bozeman, Aug. 3-6, 1970. (Addendum I)

Johnson, N. M., G.E. Likens, F. H. Bormann, D. W. Fisher, and R. S. Pierce. A working model for the variation in stream water chemistry at the Hubbard Brook Experimental Forest, New Hampshire. Water Resources Research, Vol. 5 (6): 1353-1363, 1969.

Tischendorf, W. G. Tracing stormflow to varying source areas in a small, forested watershed in the Southeastern Piedmont. Unpublished Dissertation, University of Georgia, School of Forest Resources, 1969.

PART 1, SECTION D-1, FINANCIAL SUMMARY

1. ESTIMATED PROJECT COSTS DURING GRANT PERIOD

	ITEM	PROPOSED BY APPLICANT		FWPCA USE ONLY	
		TOTAL FOR GRANT PERIOD	GRANT REQUESTED	ELIGIBLE COSTS	FWPCA OFFER
RESEARCH/DEVELOPMENT/DEMONSTRATION STUDIES	A. SALARIES AND WAGES	10400	6400		
	B. FRINGE BENEFITS (12% & 5½%)	956	476		
	C. CONSULTANT SERVICES	0	0		
	D. EQUIPMENT	500	500		
	E. SUPPLIES (inc. computer)	2000	2000		
	F. TRAVEL	200	200		
	G. PUBLICATION COSTS	300	300		
	H. OTHER				
	I. CONTRACTS (Sample Processing)	1000	1000		
	TOTAL DIRECT COSTS (A thru I)	15356	10876		
	J. INDIRECT COSTS (45.3%)	5144	3115		
	TOTAL R/D/D STUDIES (A thru J)	20500	13991		
FACILITIES	K. CONSTRUCTION-ENGINEERING PLANS				
	L. CONSTRUCTION - SUPERVISION				
	M. CONSTRUCTION - CONTRACTS				
	N. CONSTRUCTION - MATERIALS				
	TOTAL CONSTRUCTION (K thru N)				
	O. OPERATION - SALARIES & WAGES				
	P. OPERATION - FRINGE BENEFITS				
	Q. OPERATION - SUPPLIES				
	R. OPERATION - UTILITIES				
	S. OPERATION - REPAIRS				
	TOTAL OPERATION (O thru S)				
	TOTAL FACILITIES (K thru S)				
	TOTAL PROJECT COSTS (A thru S)	20500	13991		