

Fifth Annual Report

Water Resources Research Center

**A Report of Activities Supported
by the Graduate School and the
Office of Water Resources Research
U.S. Department of the Interior
Washington D.C.**

The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379

OCTOBER 1969
MINNEAPOLIS, MINNESOTA

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

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Preface

This is the fifth in a series of annual reports covering the activities of the Water Resources Research Center, University of Minnesota. The report indicates the nature of the program conducted in the twelve months beginning July 1, 1968, and ending June 30, 1969, with funds provided by the Graduate School and the Office of Water Resources Research in connection with the Water Resources Research Act of 1964. It also gives some insight into the potential of the Center for both research and training with federal and non-federal support. It is hoped that the academic community will continue to expand its service to the state and nation by conducting competent research in relation to water resources and by assisting in training additional scientists for work in the field of water resources through research.

William C. Walton

Director

Water Resources Research Center

October 1969

DIRECTOR'S SECTION

Introduction

Stimulated into action by the passage of the Federal Water Resources Research Act of 1964 and recognizing the urgent need for a comprehensive approach to water resources research, the University of Minnesota established on September 1, 1964, in the Graduate School, an interdisciplinary Water Resources Research Center. The Center did not find it necessary to seek and develop a competent team of researchers, for the faculty and graduate students working on the various problems of water resources had already demonstrated their ability. The Center has responsibility for unifying and stimulating University water resources research through the administration of funds associated with the Federal Water Resources Research Act of 1964 and made available by other sources; coordinating University Research with programs of local, state, and federal agencies and private organizations throughout the State; and assisting in training additional scientists for work in the field of water resources through research. The Center plans and arranges for Divisions of the University to conduct competent research of either a basic or practical nature, or both, in relation to water resources.

The government, management, and control of the Center and its affairs are vested in an Advisory Committee. The Advisory Committee is headed by the Dean of the Graduate School and consists of 15 faculty members appointed by the Dean of the Graduate School in consultation with the Director. Formal appointment includes provision for rotation for representatives from the various Schools, Departments, and Divisions having a vital interest in the work of the Center, by use of one, two, and three-year terms appropriately staggered. A Consulting Council composed of 19 representatives from organizations outside the University concerned with water resources counsels with the Director, assists in identifying needed research, assists in integrating and coordinating University research with projects outside the University, and provides public liaison. Consulting Council Representatives are appointed by the Director in consultation with Advisory Committee. Formal appointment includes provision for rotation of representatives by three-year terms appropriately staggered. The present roster of the Center is given in Table 1.

One of the purposes of the Center is the stimulation of educational offerings for students which will prepare them for careers in the field of water resources. In doing this, it is appropriate for the Center to review the educational programs available in the University, both graduate and undergraduate, and to suggest to Departments, areas in which new offerings may be useful or appropriate; this is particularly helpful in connection with interdepartmental or interdisciplinary programs. Moreover, there is an increasing number of potential students interested in the area of water resources. The Center is assisting in recruiting such students, in attracting them to the University by informing them of the opportunities the University can provide, and in guiding them into appropriate programs of study. During the school year ending June, 1968, there were about 98 students majoring in water resources related fields. About 44 water resources oriented students graduated in June, 1968. As shown in Table 2, a large proportion of these students used Center

CONSULTING COUNCIL

equipment and received financial support from the Center.

Between Fiscal Years 1964-68, the following 20 new courses bearing on water resources have been developed: Water quality investigation and research techniques; Groundwater hydraulics; Groundwater and surface water quality problems; Limnology; Groundwater geology; Advanced Limnology; Water conservation; Research methods for analysis of natural waters; Seminar-hydro-geology; The biology of algae; Ecology of Freshwater algae; Water quality research; Advanced hydrology-small watersheds; Methods for analysis of natural waters; Soil and water management and conservation; Engineering hydraulics II; and Water resources seminar-examination of laws bearing on water resources. More than 100 graduate courses directly concerned with some aspect of water resources are offered each year at the University of Minnesota. In addition, there are hundreds of other graduate courses available that are often needed to provide adequate training for the various water resources specialists. These include many courses in physics, chemistry, mathematics, statistics, micro-biology, etc., as well as courses that are not directly concerned with water problems in each of the departments listed. The Department of Geology and Geophysics in April 1966 announced a new graduate option in hydrogeology leading to the M.S. and Ph.D. degrees in geology. This option supplements the currently available Ph.D. programs in general geology and in mineralogy and petrology, and the program leading to the M.S. degree in geophysics. A program of Graduate Education in Water Resources at the University of Minnesota was announced in December, 1965, shortly after the Center was established. There are approximately 50 members of the graduate faculty qualified and interested in some facet of water resources. Each of these men is actively engaged in teaching or research or both involving water resources and is prepared to advise graduate students in his specific area.

Table 1. - Roster of Center (1968-69)

William C. Walton, Director
John J. Waelti, Assistant Director
Dagmar Tezla, Secretary

ADVISORY COMMITTEE

<u>Professor</u>	<u>Department, School, or Division</u>
Alvin G. Anderson	St. Anthony Falls Hydraulic Lab.
Ward J. Barrett	Department of Geography
Richard G. Bond	School of Public Health
Alan J. Brook	Dept. of Ecology & Behavioral Biology
Bryce Crawford, Jr.	Graduate School
William J. Hueg, Jr.	Agricultural Experiment Station
Philip W. Manson	Department of Agricultural Engineering
John J. Waelti	Department of Agricultural Economics
William P. Martin	Department of Soil Science
Orville C. Peterson	Department of Public Administration
George J. Schroepfer	Dept. of Civil Engineering & Hydraulics
Paul K. Sims	School of Earth Sciences
Arnett Mace	School of Forestry
Thomas F. Waters	Dept. of Entomology, Fish, & Wildlife
Herbert E. Wright	Limnological Research Center, School of Earth Sciences.

<u>Representative</u>	<u>Organization</u>
David B. Anderson	U.S. Geological Survey, Water Res. Div.
Douglas W. Barr	Consulting Hydraulic Engineer
Arthur D. Belmont	Research Division, Control Data Corp.
Charles R. Collier	U.S. Geological Survey, Water Res. Div.
John Dobie	Minn. Dept. of Conservation, Div. of Game and Fish
Harry M. Major	U.S. Dept. of Agriculture, Soil Conservation Service
Gene Gere	Minn. Dept. of Conservation, Div. of Waters, Soils, and Minerals
Raymond Haik	Attorney, Minneapolis
Richard J. Hesse	U.S. Army Corps of Engineers
Eugene A. Hickock	Consulting Hydrologist
Samuel E. Jorgensen	U. S. Bureau of Sport Fish. & Wildlife
Del Krenik	Minn. Association of Soil & Water Conservation Districts
Dale S. Bryson	Federal Water Pollution Control Admin.
Lyle Smith	Minn. Pollution Control Agency
Joseph H. Strub	U. S. Weather Bureau
F. W. Thorstensen	Minn. State Department of Highways
C. A. Van Doren	U.S. Dept. of Agriculture, Agricultural Research Service
Erling Weiberg	Minn. Water Resources Board
Robert W. Merz	U.S. Department of Agriculture, Forest Service

Table 2. - Support of Students by Center

<u>Category of Students</u>	<u>No. Using Center Equipment, Supplies, etc.</u>	<u>No. Receiving Part time Employment or other Financial Support through Center Programs</u>
<u>Fiscal Year 1966</u>		
Undergraduates	24	20
Master's students	15	12
Doctoral students	10	4
Postdoctoral students	3	2
Total	52	38
<u>Fiscal Year 1967</u>		
Undergraduates	42	23
Master's students	21	13
Doctoral students	13	4
Postdoctoral students	4	5
Total	80	45
<u>Fiscal Year 1968</u>		
Undergraduates	30	25
Master's students	20	12
Doctoral students	15	11
Postdoctoral students	2	2
TOTAL	67	50

Twenty-one new faculty members with an active interest in water resources have been added to the University staff between Fiscal Years 1964-68; six faculty members have left the University.

The Center started in Fiscal Year 1965 with 7 research projects in progress; an average of 14 research projects have been in progress during each of FY's 1966-1969 (See figure 1). Principal Investigators have completed 17 research projects. The title of research projects in progress or completed are given in table 3. As indicated in figure 2, most research projects are concerned with the physical and biological aspects of the water cycle, water quantity management and control, and water quality management and protection. Only two research projects are concerned with the social-economic aspects of water resources planning. Sixteen reports published during Fiscal Years 1964-68 are related to research projects (see table 4). In addition to the Center's program, there were 91 ongoing water resources research projects within the University during FY 1968 with a dollar support exceeding \$500,000 from 30 granting agencies. A Memorandum of Agreement between the Regents of the University of Minnesota and St. Mary's College, Winona, Minnesota has been executed. The Agreement permits the collaboration of St. Mary's College with the Center, in conducting a Matching Grant Research project entitled "A study of techniques for determining changes in phytoplankton population in clouds of fluorescent dye moving in the Mississippi River" financed by the Office of Water Resources Research.

The Center continuously compiles information on needed and neglected water resources research areas with the assistance of its Advisory Committee and Consulting Council. The selection of research projects to be sponsored gives due regard to research needs of the State and is approached on an interdisciplinary basis. During the winter months of 1966, about 350 people having an interest in water resources research in Minnesota were solicited by the Water Resources Research Center for information concerning needed areas of water resources research. Based on the results of a questionnaire and considering water resources problems in Minnesota, additional research is needed most in areas bearing on social-economic aspects, water pollution, and floods, about in that order. The Center conducts interdisciplinary seminars to acquaint students, faculty, and others with the broad aspects of water resources and it sponsors short courses and conferences. The Center publishes Bulletins presenting results of research projects. Mimeographed Information Circulars and Quarterly Newsletters are distributed to about 500 people in Minnesota.

Research projects are sponsored with funds made available to the Center by the Office of Water Resources Research, U.S. Dept. of the Interior in connection with Title I of the Water Resources Research Act of 1964. There are authorized to be appropriated to the Secretary of the Interior for the FY 1965 and each subsequent year thereafter sums adequate to provide \$75,000 to each of the several States in the first year, \$87,500 in each of the second and third years, and \$100,000 each year thereafter to assist each participating State in establishing and carrying on the work of a competent and qualified water resources research center. There is further authorized to be appropriated to the Secretary of the Interior for the fiscal year 1965 and each subsequent year thereafter sums not in excess of the following: 1965, \$1,000,000; 1966, \$2,000,000; 1967 \$3,000,000; 1968, \$4,000,000; and 1969 and each of the succeeding years, \$5,000,000. Such moneys when appropriated, shall be available to match, on a dollar-for-dollar basis, funds made available to centers by State or other non-federal funds used by the Center to match federal funds consist of the fair value of the services of the faculty members and associated indirect costs and fringe benefits.

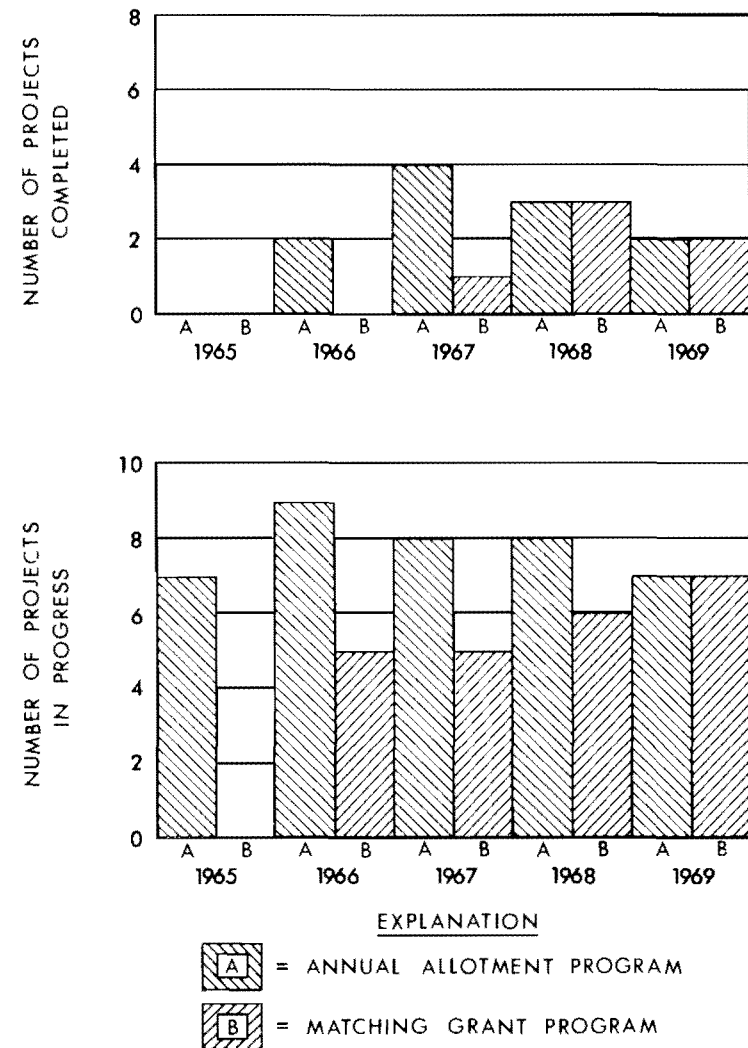


FIGURE 1 NUMBER OF CENTER OWRR RESEARCH PROJECTS IN PROGRESS AND COMPLETED, FY 1965 - 1969.

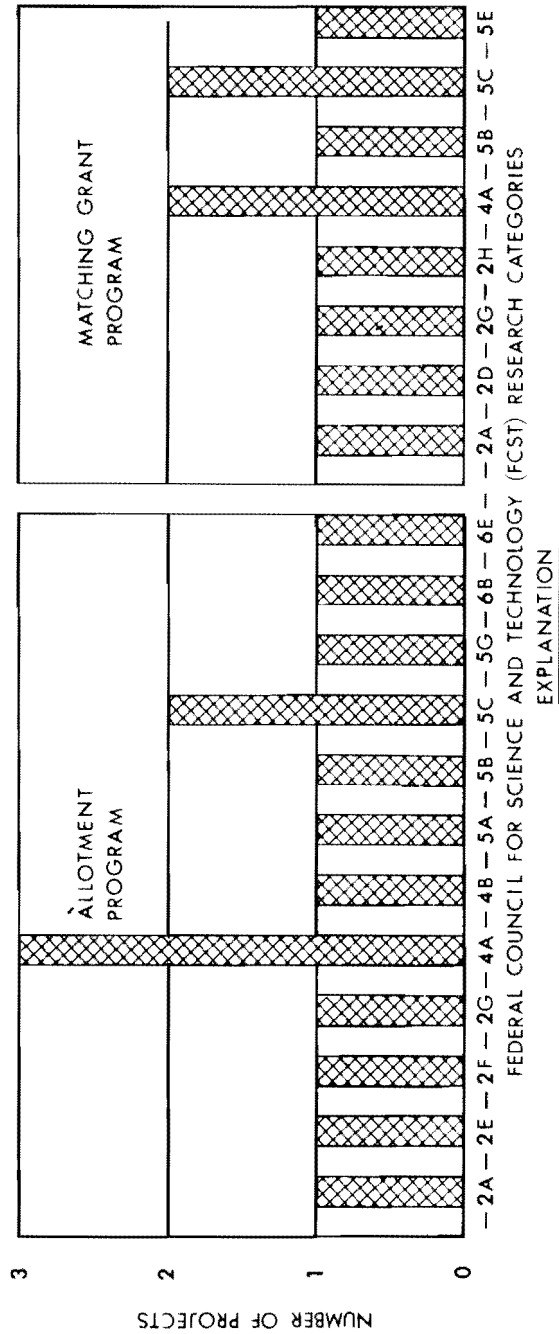


FIGURE 2 NATURE OF CENTER OWRR RESEARCH PROJECTS, SUBDIVIDED BY FCST CATEGORIES.

Table 3. - Titles of Research Projects in Progress or Completed

- The effect of pothole drainage upon groundwater resources.
- Factors influencing soil freezing in forests and the importance of their effect on surface runoff.
- Water absorption and its interactions with clay and quartz.
- Studies on the use of planktonic desmids as indicators of the tropic status and water quality in freshwater lakes.
- Water quality, organic productivity, and the distribution of organisms in Minnesota lakes.
- Groundwater contribution of streamflow and its relation to hydrogeologic basin characteristics and recharge rates to aquifers in Minnesota.
- Analysis of factors affecting aquifer test results under induced stream-bed infiltration conditions with electric analog computers.
- A study of the open water distribution and abundance of net-plankton as an index of the eutrophication in Lake Superior.
- Review and analysis of precipitation & runoff data for selected watersheds in Minnesota.
- Recharge from induced infiltration under varying stream stage and aquifer water level conditions.
- Diatoms and zooplankton in Minnesota lakes.
- The effect of the natural sealing of potholes upon water movement and groundwater resources.
- Storage and movement of water in soils as related to spacial and time changes in the clay-quartz matrix.
- Vertical migration of moisture in the soil induced by winter thermal gradients and its influence upon spring water resources.
- Study of factors affecting the channel phase of runoff from small watersheds by mathematical modeling.
- Hydrologic aspects of water laws in Minnesota.
- Primary productivity of Minnesota lakes.
- Effects of areal and time distribution of runoff supply on watershed hydrographs.
- Methodology for integrating water quality management with the management of the total water resources in Minnesota.
- Relation of phosphorus in lake-bottom deposits and pollutional history of Minn. lakes.

Study of techniques for determining changes in phytoplankton populations in clouds of fluorescent dye moving in the Mississippi River.

Economics of water quality control in the Upper Mississippi River, Minn.

Evaluation of selected computer programs in hydrology.

Development of a mathematical model to predict the role of surface runoff and groundwater flow in overfertilization of surface waters.

Reduction of water stress in crop production by mist irrigation.

Characteristics of the soil matrix that affect water storage and movement.

Table 4. - Research Project Related Publications (Fiscal Years 1964-68)

1965. Federal, State and local agencies concerned with water resources research in Minnesota. Bulletin No. 1, Water Resources Research Center, University of Minnesota. (Prepared by a Task Group of the Consulting Council).

Walton, W.C. and E.A. Ackroyd

1966. Effects of induced streambed infiltration on water levels in wells during aquifer tests. Bul.No.2, Water Resources Research Center, U.of Minn.

Olson, T.A., T.O. Odlaug and W.R.Swain

1966. The continuous plankton recorder--areview of the literature. Bul. No.3, Water Resources Research Center, U. of Minn.

Walton, W.C.

1967. Lists of references and selected books bearing on water resources in Minnesota. Bul. No. 4, Water Resources Research Center, U. of Minn.

Water Resources Research Center, U. of Minn.

1967. Water resources research and education needs in Minnesota. Bul. No. 5, Water Resources Research Center, U. of Minn. (Prepared by a Task Group of the Consulting Council).

Walton, W.C., D.L. Hills, and G.M. Grundenen.

1967. Recharge from induced streambed infiltration under varying ground-water level and stream-stage conditions. Bul.No.6, Water Resources Research Center, U. of Minn.

Megard, R.O.

1967. Limnology, primary productivity & carbonate sedimentation of Minn. lakes. Limnological Research Center, U. of Minn. Interim Report No. 1.

1968. Planktonic photosynthesis and the environment of calcium carbonate deposition in lakes. U. of Minn., Limnological Research Center, Interim Report No. 2.

1966. A mobile limnological laboratory. Limnology and Oceanography. Volume 11, No. 3, July 1966. Pages 420-422.

Bright, R.C.

1968. Surface-water chemistry of some Minnesota lakes with preliminary notes on diatoms. U. of Minn., Limnological Research Center. Interim Report No. 3.

Ackroyd, E.A., W.C. Walton, and D.L. Hills.

1966. Groundwater contribution to streamflow and its relation to basin characteristics in Minnesota. Minn. Geo. Survey Report of Investigation 6.

Olson, T.A. and T.O. Odlaug

1966. Limnological observations on western L. Superior. Proceedings, Int'l. Conference on Great Lakes Research, Publ.No.15. Great Lakes Research Div., U. of Michigan.

Blake, G.R. and J.B. Swan.

1967. New dimensions for soil and water conservation. Minn. Science, Resource Development Issue, Vol. 23, No. 3, pages 18-19.

Anonymous

1967. Papers presented during conferences on water and related land resources planning in Minnesota. Minn. State Planning Agency, Water Resources Coordinating Committee, Bul. 1.

Theses

Machmeier, Roger E.

1966. The effect of runoff supply rate and duration on runoff time parameters and peak outflow rates. Ph.D. thesis. U. of Minn., Dept. of Agric. Eng.

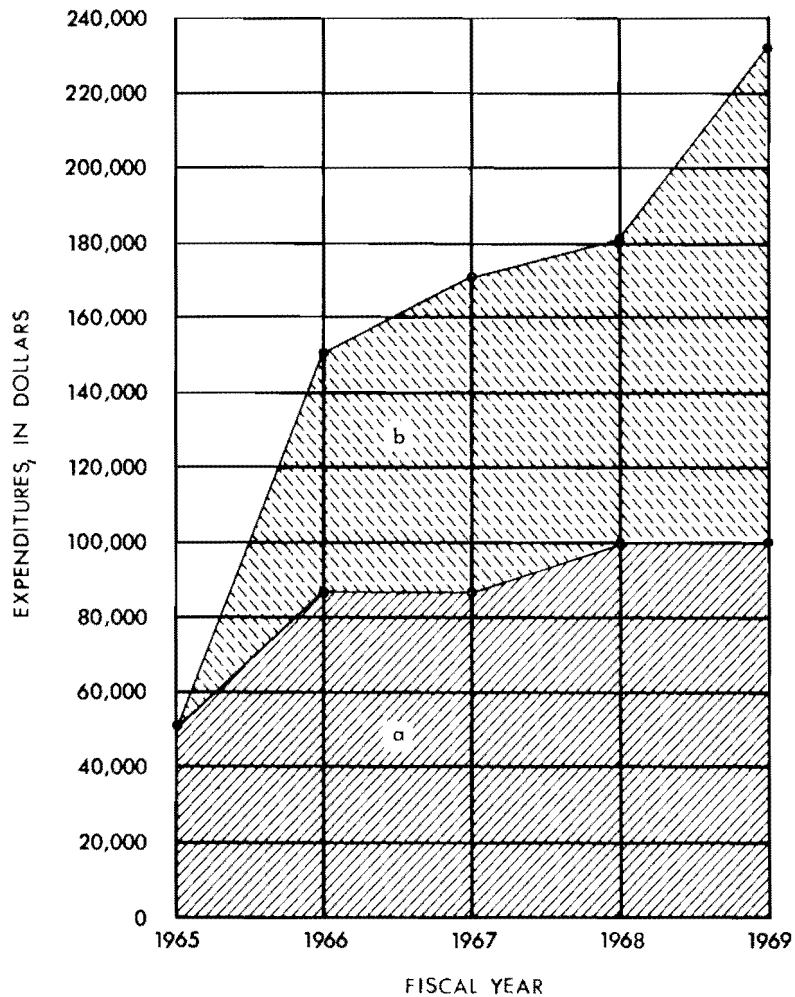
Lin, Shen Maw

1967. Porosity and pore size distribution of soil aggregates. M.S. thesis. UM

Reinke, J.W.

1968. The hydrology of a typical ice block glacial lake, M.S. thesis. U. of Minn., Dept. of Agric. Eng.

As shown in fig. 3, Office of Water Resources Research grant expenditures by the Center have increased from \$52,297 in Fiscal Year 1965 to \$236,236 in Fiscal Year 1969, largely as the result of steadily increasing Matching Grants. In FY 1965, 72% of the Water Resources Research Centers in the Nation received less funds than did the U. of Minn. from the Office of Water Resources Research, whereas, in FY 1969, 82% of the Centers received less funds than did the U. of Minn. (see fig. 4). As indicated in fig.5, less than 24% of the Center's Annual Allotment has been used to defray Center Director's office expenditures connected with administering the Office of Water Resources Research programs.



(a) ANNUAL ALLOTMENT PROGRAM
 (b) MATCHING GRANT PROGRAM

FIGURE 3 CENTER OWRR GRANT EXPENDITURES, SUBDIVIDED BY PROGRAM, FY 1965-1969.

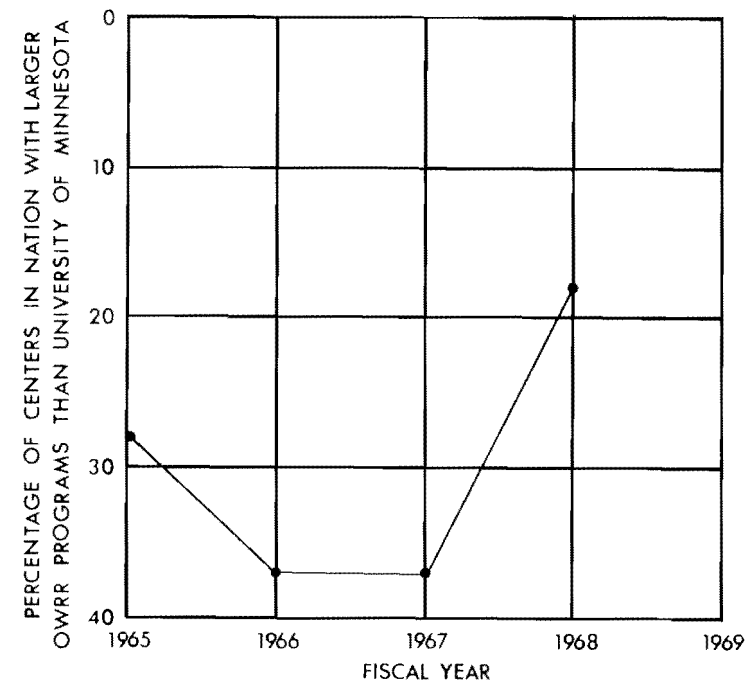


FIGURE 4 RELATION BETWEEN UNIVERSITY OF MINNESOTA CENTER'S OWRR PROGRAM AND THOSE OF OTHER CENTERS IN THE NATION, FY 1965 - 1968.

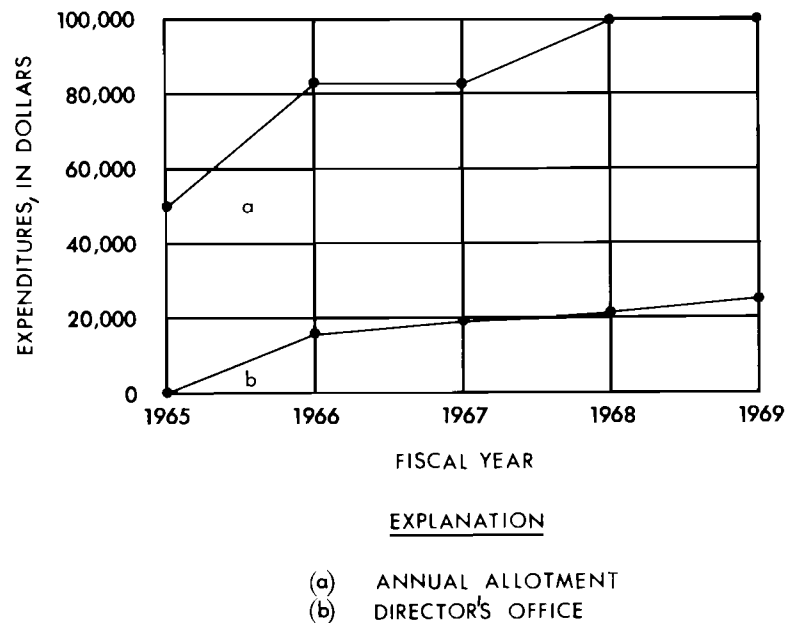


FIGURE 5 CENTER OWRR GRANT DIRECTOR'S OFFICE EXPENDITURES, FY 1965 - 1969.

In FY 1969, 65% of expenditures were for salaries and wages; 8% of expenditures were for non-expendable property and expendable materials and supplies; and 27% of expenditures were for other costs including indirect costs and fringe benefits (see fig. 6). During the period FY 1965-69, about \$79,000 has been encumbered for non-expendable property assigned to Divisions of the University. As shown in fig. 7, expenditures for salaries and wages have been about equally divided between the categories of Principal Investigators and Director; Research Associates and Fellows; Graduate Students, and Undergraduate Students, Technical Assistants, and Clerical Assistants.

Office of Water Resources Research funds have been allocated by the Center to the following Divisions of the U. of Minnesota and St. Mary's College: Dept. of Botany, Limnological Research Center, Grad. School, Dept. of Agric. Eng., School of Forestry, Dept. of Soil Science, School of Public Health, Minn. Geo. Survey, St. Anthony Falls Hydraulic Lab., Dept. of Agric. Econ., and Dept. of Horticultural Science (see fig. 8). The largest cumulative expenditures are associated with Matching Grants.

Fig. 9 shows in FY 1969 about 68% of the manpower effort was expended by Graduate and Undergraduate students and Technical and Clerical Assistants; 21% was expended by Research Associates and Fellows; and 11% was expended by the Director and Principal Investigators. The average annual total cost man years of effort is 15 for the period FY 1965-69 and the average annual cost per man year of effort is \$8,200. Expenditures for individual Annual Allotment research projects range from \$2,737 to \$14,839 per year and average \$8,500 per year. Expenditures for individual Matching Grant research projects range from \$5,574 to \$31,844 per year and average \$16,200 per year.

It should be pointed out that expenditures cited are not final but only approximate. Complete effort and cost data were not available at the time this information was prepared.

The University of Minnesota through its Water Resources Research Center has demonstrated its interest and its capability during the past five years, and it is willing to further develop a truly outstanding water resources research facility for Minnesota. It has provided the mechanics for unifying water resources research throughout the state.

The Graduate School provided \$500, in Fiscal Year 1969 to cover part of the Center's office expenses. The University provides office space (350 square feet) for the Center's office operations in room 107, Hubbard Building, 2675 University Avenue, St. Paul, Minn., at a total cost of \$1,800 per year.

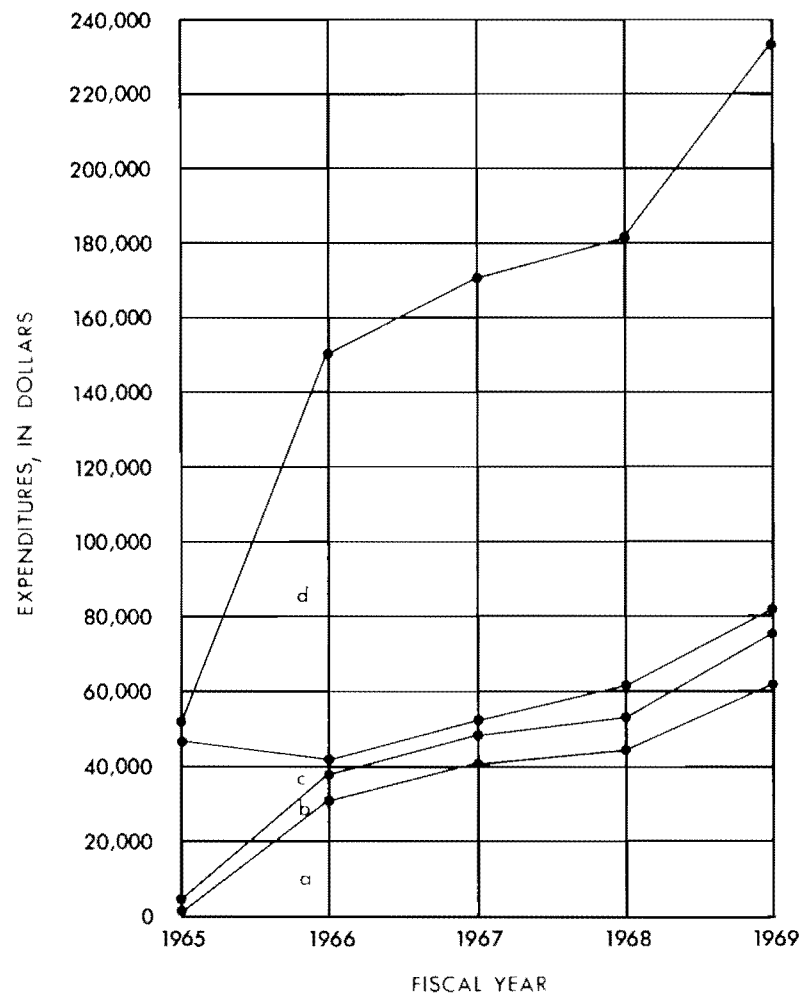


FIGURE 6 CENTER OWRR GRANT EXPENDITURES, SUBDIVIDED BY COST CATEGORY ITEMS, FY 1965-1969.

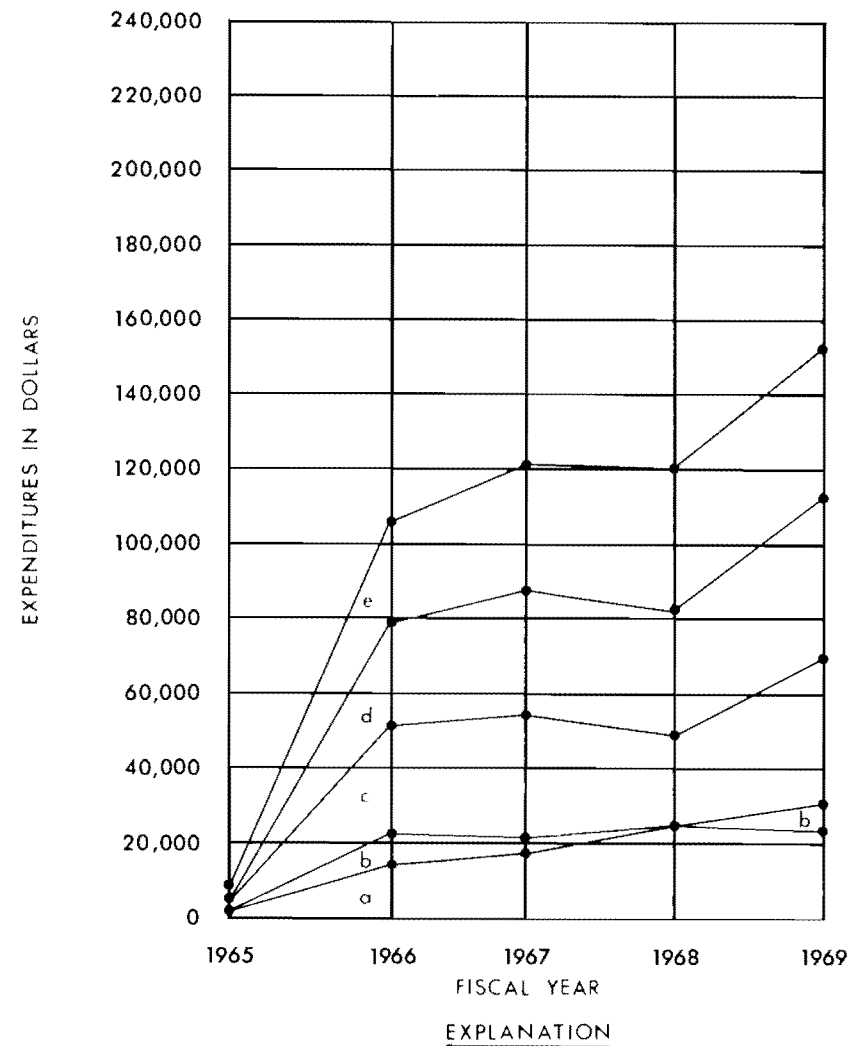
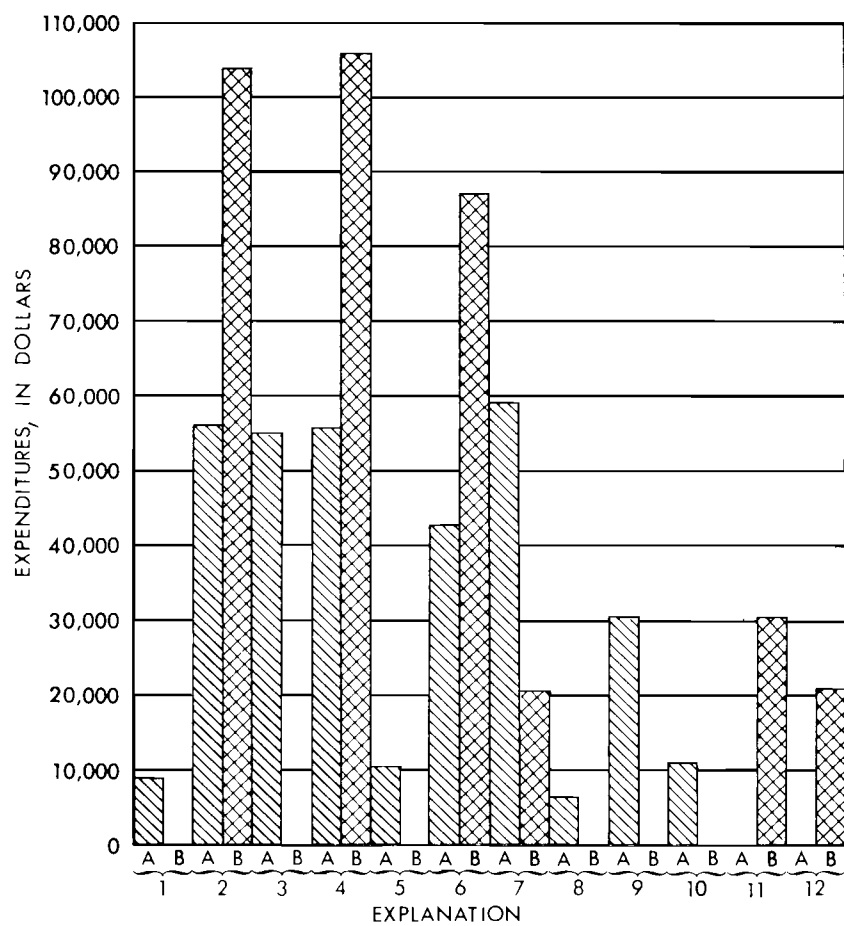


FIGURE 7 CENTER OWRR GRANT SALARIES AND WAGES EXPENDITURES, SUBDIVIDED BY PERSONNEL CATEGORY ITEM, FY 1965-1969.





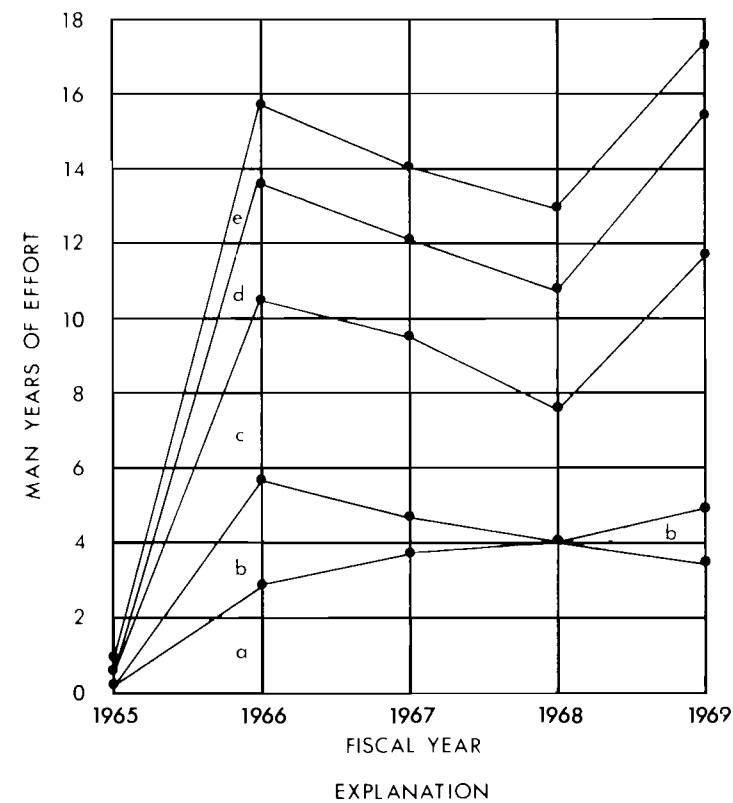
-  = ANNUAL ALLOTMENT PROGRAM
  = MATCHING GRANT PROGRAM
- | | |
|--|--|
| 1 Department of Botany | 7 School of Public Health |
| 2 Limnological Resources Center | 8 Minnesota Geological Survey |
| 3 Graduate School | 9 St. Anthony Falls Hydraulic Laboratory |
| 4 Department of Agricultural Engineering | 10 Department of Agriculture Economics |
| 5 School of Forestry | 11 Department of Horticulture Science |
| 6 Department of Soil Science | 12 St. Marys College |

FIGURE 8 CENTER OWRR GRANT EXPENDITURES, SUBDIVIDED BY UNIVERSITY DIVISIONS AND PROGRAMS CUMULATIVE FY 1965 - 1969.



- (a) TECHNICAL AND CLERICAL
 (b) UNDERGRADUATE STUDENTS
 (c) GRADUATE STUDENTS
 (d) RESEARCH ASSOCIATES AND FELLOWS
 (e) DIRECTORS AND PRINCIPAL INVESTIGATORS

FIGURE 9 CENTER OWRR GRANT MANPOWER EFFORT, SUBDIVIDED BY PERSONNEL CATEGORY ITEMS, FY 1965 - 1969.

Director's Brief Summary Report

Brief Description of the Current and Anticipated Water Problems of the State.

Past development and management practices in Minnesota, as substantial as they are, have not kept pace with the steadily growing demands placed upon water and related land resources. Many undesirable and serious, but not critical, problems have emerged associated with pollution, water-oriented recreation, floods, water supply, navigation, and land use. With the prospect that within 50 years water and related land resources demands and needs may approach or exceed the availability of resources and existing facilities in some areas, the State cannot expect to continue to avert critical problems without an acceleration in resource development and management. However, Minnesota has sufficient water and related land resources which with proper development and management will satisfy future demands.

What the Main Thrust of the Center's Program is and will likely be in the next 5 years.

The main thrust of the Center's program in FY 1969 was directed toward: establishing a practical baseline of water quality for L. Superior through the use of the continuous plankton recorder technique (A-011-Minn); the analysis and interpretation of existing Federal, State, and local water resources legislation and court decisions and ways and means for improving water laws in Minnesota (A-015-Minn.); ascertaining the physiological and ecological requirements of the algal species responsible for severe blooms on lakes scattered throughout the State to assist in controlling the excessive productivity of polluted lakes (A-016-Minn); determining methods for rainfall-runoff predictions which are based on the physical characteristics of ungaged small watersheds and rainfall characteristics of ungaged small watersheds and rainfall characteristics (A-017-Minn); reconciling and integrating water quality management with the ecological and social-economic objectives of the total water resources of Minnesota (A-018-Minn); formulation of an economic optimizing model for water quality and sewage disposal on selected stretches of the Upper Mississippi River (A-019-Minn); investigation of programs that appear to have special merit relative to hydrologic analysis for determination of design floods and for design of spillways and related structures (A-020-Minn); investigation of soil dynamic changes when interacting with water to assist in solving water problems such as infiltration, water spreading and flow properties in soils (B-005-Minn); determination of runoff-time distribution for a variety of watershed sizes and slopes (B-007-Minn); determining the role of bottom sediments in the phosphorus cycle for lakes of different types to assist in devising corrective measures for overfertilized lakes (B-009-Minn); development of techniques that will pinpoint polluted areas in reaches of the Upper Mississippi River where algacides might be profitably administered to control pollution (B-010-Minn); investigation of mist irrigation as a method of reducing water stress in potato crop production and thereby reducing transpiration (B-013-Minn); and investigation of the mechanics of soil moisture movement and retention to assist water resources developers and managers in estimating recharge to groundwater reservoirs and the effect of soil moisture movement on surface water runoff (B-015-Minn).

The main thrust of the Center's program during the next five years is likely to be directed to wards: inventorying, appraising, and evaluating water resources administration in Minnesota to provide background information for legislative action concerning reorganization of State

Water Resources Agencies (A-021-Minn); biomass determinations and productivity measurements in the west end of L. Superior to assess the extent of eutrophication of the west end of L. Superior (A-022-Minn); investigation of the ecology of the periphyton in the wavewashed and near-shore areas of the west end of L. Superior for detection of advancing eutrophication in the Lake (B-020-Minn); study of citizens groups involved at the grass roots to improve the water resources environment in the Minneapolis-St. Paul, Miami and environs, and two other metropolitan areas and environs in the USA (B-031-Minn); determining existing ecological conditions in the Mississippi R. near Monticello, Minn. before operation of a large nuclear power plant and monitoring environmental changes due to the thermal discharge from the power plant generator (B-032-Minn) simulating alternative strategies in locating and financing water recreation projects in growing and distressed areas in Minnesota; evaluating the impact of water quality and other factors in recreational use of water areas; integrated study of the littoral vegetation and invertebrate fauna which when combined with data on the physical and chemical properties and primary productivity of lake waters in the State and data on historical development to understand the trophic status and the effects of pollution lake metabolism; studies on the behavior of snow packs to provide estimates of snowmelt run-off; sociological studies concerning behavior toward water pollution control in Minnesota; devising methods for reduction of irrigation water losses; studies concerning the properties of aquifers and associated deposits; determining the effects of agricultural practices on the quality of surface and groundwaters; study of the use of State lakes; determining the effects of urbanization on water resources; and completion of research projects ongoing in FY 1969.

Examples of completed research and how results are being used to solve water problems or improve water management.

The results of research projects A-009-Minn "Groundwater contribution to streamflow and its relation to hydrologic basin characteristics and recharge rates to aquifers in Minnesota", "A-001-Minn "The effect of pothole drainage upon groundwater resources", and B-002-Minn "The effect of natural sealing potholes upon water movement and groundwater resources" have assisted the Minn. Dept. of Conservation, State Planning Agency, and the US geological Survey in estimating the rates of recharge to aquifers, vertical leakage through pothole beds, and the potential yields of groundwater reservoirs and in preparing framework water and related land resources regional and statewide plans. Information pertaining to research projects A-007-Minn "Studies on the use of planktonic desmids as indicators of the trophic status and water quality of freshwater lakes, "A-008-Minn "Water quality, organic productivity, and the distribution of organisms in Minn. lakes, "A-011-Minn "A study of the open water distribution and abundance of net plankton as an index of eutrophication in Lake Superior," and B-001-Minn, "Diatoms and Zooplankton in Minnesota Lakes" has improved knowledge concerning primary productivity in lakes throughout the State and the usefulness of certain organisms as indicators of pollution. Background data has assisted State, Local, and Federal agencies, and other Principal Investigators in devising methods to control excessive productivity of polluted lakes; the results of research projects A-010-Minn "Analysis of factors affecting aquifer test results under induced streambed infiltration conditions" and A-014-Minn "Recharge from induced streambed infiltration under varying streamstage and aquifer water-level conditions" have been used by several private

consultants and public agency personnel in various parts of the U.S. and England to evaluate the potential yields of aquifers receiving recharge from streams; the U.S. Army Corps of Engineers have been assisted in the development of peak rates of runoff design criteria and flood routing procedures through the results of the research project A-013-Minn "Review and analysis of precipitation and runoff from selected watersheds in Minnesota"; and the U.S. Weather Bureau has been assisted in its flood forecasting activities in Minnesota by the information generated by the research project B-005-Minn "Vertical migration of moisture in the soil induced by winter thermal gradients and its influence upon spring water resources."

Other Aspects of the Center's Programs

The Center has been helpful in developing 20 new courses bearing on water resources, a new graduate option in hydrogeology, and a program of graduate education in water resources at the University of Minnesota.

Members of the Center's Advisory Committee and Consulting Council having participated in the Federal - State and Statewide framework water and related land resources planning activities of the State Planning Agency. The Center Director has served as Governor LeVander's representative on Federal - State planning organizations.

The University of Minnesota has experienced some difficulty in diverting a sufficient number of graduate students into the water resources educational program, partly because of the almost total lack of courses dealing with the Social-Economic aspects of water resources. The center has to date been able to generate only a small amount of interest in expanding Social - Economic educational offerings and research proposals.

Minnesota has provided on the average about \$30,000 per year to defray overhead and indirect costs associated with the Center's Annual Allotment programs. The State has continuously provided non-federal funds to match federal funds associated with the Center's Matching Grant programs. Non-federal funds provided in Fiscal Year 1968 amounted to about \$49,000. In addition, the University has provided office space for the Center.

The government, management, and control of the Center and its affairs are vested in an Advisory Committee. The Advisory Committee is headed by the Dean of the Graduate School and consists of 15 faculty members from 12 Schools, Departments and Divisions of the University. A Consulting Council composed of 20 representatives from organizations outside the University concerned with water resources counsels with the Center, assists in identifying needed research, assists in integrating and coordinating University research with projects outside the University, and provides public liaison.

Faculty Research Bearing on Water Resources, 1967-68, in Addition to Center's Program

Water resources research has been carried on at the University of Minnesota for many years. The following list of faculty research conducted during the 1967-1968 academic year is suggestive of the substantial character of ongoing research activities in addition to the Center's program.

AGRICULTURE, INSTITUTE OF

AGRICULTURAL EXPERIMENT STATIONS

Support

NORTHWEST SCHOOL AND EXPERIMENT STATION, Crookston	
Soine, Olaf C., Soil heat and moisture characteristics related to evaporation from crop land	U
SOUTHWEST EXPERIMENT STATION, Lambertton	
Nelson, Wallace W., Soil heat and moisture characteristics related to temperature and moisture and evaporation from crop land.	D/U
AGRICULTURAL ECONOMICS	
Blank, O. Uel, Economic impact of Crow Wing Canoe Trail Economic of tourism-recreation industry.	-- AEC
Raup, Philip M. Economic problems in use, allocation and pricing of water.	AES
-Dissertation supervision: Economic investigation of water quality management in upper Mississippi-Twin Cities area.	
AGRICULTURAL ENGINEERING	
Allred, Evan R., Supplemental irrigation in Minnesota Treatment and disposal of animal wastes.	HA AESR/CSRS
Larson, Curtis L. Drainage of agricultural land: design criteria Hydrologic characterization of small watersheds	AES/CSRS
- Dissertation supervision: Mechanics of raindrop and splash erosion Time distribution of runoff from small watersheds	
Machmeier, Roger E., Engineering phases of soil and water management Erosion control Hydrologic characterization of small watersheds	AES/GAR GS AES/CSRS
Manson, Philip W., Concrete drain and irrigation pipe Specification for concrete pipe	ACPA/CDMA ACPA/CDMA
ENTOMOLOGY, FISHERIES AND WILDLIFE	
Smith, Lloyd L., Commercial fish investigations of Red Lake Early life history of northern pike Effect of paper fibers on fish Investigation of Lake Superior commercial fishes	USDI AEC USDI --
-Dissertation Supervision: Commercial perch population dynamics Early life history of herring Effects of detergents on blue gills Life history studies of stizostetion	
Waters, Thomas F. Dynamics of stream invertebrate populations	AES/NSF
-Dissertative supervision: Effect of temperature on drift of stream invertebrates Production rate of stream trout populations.	

SOIL SCIENCE

Baker, Donald G., Characterization of agricultural climate HA
 Regional solar radiation reception GAR
 Soil Heat and moisture characteristics related to evaporation from cropped land GAR/HA
 Urban versus rural climatology GAR/HA
 -Dissertative supervision:
 Evapotranspiration
 Minature radiometer
 Net radiation
 Blake, George R., Soil Structure: Formation and alteration GAR/HA/U
 Storage and movement of water in soils USDI
 Water absorption by clay and quartz USDI
 -Dissertative Supervision:
 Pore size distribution in soil aggregates
 Quartz dilution of soil and mechanical properties
 Soil amelioration under heavy traffic

BIOLOGICAL SCIENCES, COLLEGE OF

BOTANY

Corham, Eville, Chemistry of Irish bog waters and peats --
 Cycles of major and minor elements in lakes and wetlands GS/NSF
 Periodical coverage in limnology --
 Productivity of sedge fans NRCC
 Sedimentary pigments as indices of lake productivity GS/NSF
 Tritium as tracer for water masses in wetlands and lake sediments GS
 -Dissertative supervision:
 Computerized study of wetland vegetation by objective methods
 Development and breakdown of leaf pigmentation
 Ecology of peatlands of northern Minnesota

ECOLOGY AND BEHAVIORAL ECOLOGY

Brook, Alan J., Algal & bacterial microstratification in Minn. lakes GS
 Ecological and taxonomic studies of algae of Red Lake Bog, Minnesota --
 Ecology, morphogenesis and taxonomy of Caulerpa
 Polymorphism and taxonomy of Staurastrum --
 Terrestrial algae on roofs --
 -Dissertative supervision:
 Biology of Oscillatoria agardii with special its microstratification
 Ecology of algae of iron-rich springs
 Growth studies of planktonic desmids in nature and culture
 Polymorphism in Staurastrum Chaetoceras

ZOOLOGY

Huver, Charles W., Age and growth in yellow perch of Gull Lake KBS
 Control of alewife in Great Lakes MIDC
 Fertilization in Teleost eggs GS/LF
 Host-parasite relations between acanthocephalan & centrarchid fishes KBS
 Introduction of coho salmon to Great Lakes MIDO
 Sex differentiation in American eel SX

-Dissertation supervision:

Ecologic effects of heated effluents
 Microinjection study of fertilization in teleosts

DULUTH, UNIVERSITY OF MINNESOTA

SCIENCE AND MATHEMATICS, DIVISION OF

Odlaug, Theron O. (Biology) Continuous plankton recorder studies USDI
 Lake Superior periphyton in relation to water quality USDI

SOCIAL SCIENCES, DIVISION OF

Larsen, Arthur J. (History), Great Lakes-St. Lawrence Waterway Ass'n.
 Olson, Dale W., (Political Science), Political, administrative --
 and legal aspects of federal & state environmental pollution --
 control programs --
 Political concerns for economic development in Minn. --

LIBERAL ARTS, COLLEGE OF

GEOGRAPHY

Barrett, Ward J., Dissertation supervision:
 Consumptive water use of Denver and suburbs
 Draining wet prairies of southern Minnesota
 Borchert, John R., Changes in intensity & location of lakeshore development in Minnesota MORRC
 Geographic Evolution of U.S. Metropolitan areas --
 -Dissertation supervision:
 New lands program in Soviet Union

TECHNOLOGY, INSTITUTE OF

CIVIL ENGINEERING AND HYDRAULICS (Engineering, College of)
 Johnson, Walter K., Nitrogen removal from waste waters USDI
 Maier, Walter J., Removal of colloidal matter by biological processes USDI
 Susag, Russell, Mississippi R. investigations increasing waste water assimilation capacity MSSD

GEOLOGY AND GEOPHYSICS (Earth Sciences, School of)

Bright, Robert C., Fossil vertebrates in Minnesota MNH/MORRC
 Geology of area in southeast Idaho --
 Paleocology of lakes in Wyoming LRC
 Shapiro, Joseph, Water chemistry USDI
 Swain, F.m., Coastal and freshwater ostracoda NSF
 Ostracoda of Atlantic Coastal Plain USGS
 Walton, William C., Hydrologic aspects of water law in Minn. USDI
 Wright, H. Jr., Diatoms in lakes and lake sediments NSF
 Late Pleistocene vegetation history and limnology NSF
 Paleocology of Mycenean Greece HFF
 Vegetation, hydrology and stratigraphy of patterned wetlands NSF
 -Dissertation supervision:
 Geomorphology of Ellsworth Mountains, Antartica
 Peat stratigraphy of Red Lake Bog, Minnesota

ST. ANTHONY FALLS HYDRAULIC LABORATORY

Anderson, Alvin G., Design of erosion-resistant channels for high-way drainage

NAS

Experimental design: metropolitan water district of southern California		HEC
Free streamline flow over boundary discontinuities		NSF
Hydraulic design: Laurence Avenue sewer system, Chicago		HEC
-Dissertation supervision:		
Acoustic effects in sediment transport		
Air-water interface in high velocity open channel flow		
Bowers, C. Edward, Breakwater for Interstate 35 at Duluth		HNTB/MHD
Mathematical model of storm runoff		MSSD
Hayden, John W., Dispersion in turbulent pipe flow		HEC
-Dissertation supervision:		
Effect of submerged long constriction		
Equilibrium depth of scour in open channels		
Ripken, John F., Disk friction reduction		USN
Flow meter studies		AuCC
Water tunnel studies		NSF
-Dissertation supervision:		
Influence of injected polymers on boundary friction		
Influence of polymer additives on disk friction		
Silberman, E., Dispersion in turbulent flow in pipeline		HEC
Mixing in stratified flow		USDI
-Dissertation supervision:		
Experimental and theoretical studies of supercavitating jet flapped hydrofoils		
Influence of electrokinetic phenomena on hydraulic and electro-osmotic permeability of uniform very fine sand		
Song, Chieh-Shyang, Flutter of supercavitating hydrofoils		USN
Subcritical Taylor instability		USN
Unsteady forces on supercavitating hydrofoils		USN
-Dissertation supervision:		
Viscous effect on cavitation separation		
Wetzel, J.M. Experimental investigation of boundary layer characteristics for dilute polymer flows		NSRDC/USN
<u>Sources of Support</u>	LRC	Limnological Research Center, U of M
-- No Granting Agency Reported	MDA	Minnesota Dept. of Agriculture
ACPA American Concrete Pipe Assoc.	MDC	Minnesota Dept. of Conservation
AEC Atomic Energy Commission	MDPH	Minnesota Dept. of Public Health
AES Agricultural Experiment Sta. University of Minnesota	MGS	Minnesota Geological Survey
AESR Agricultural Exper. Sta. Rosemount, Minn.	MORRC	Minnesota Outdoor Recreational Resources Commission
	MRC	Minnesota Resources Commission
AGI American Geological Inst.	MSSD	Mpls.-St. Paul Sanitary District
AXS Agricultural Ext. Service, University of Minnesota	MWF	McGraw Wildlife Foundation
	NF	National Foundation
CDMA Minnesota Concrete Drainage Manufacturers Association	NSF	National Science Foundation
D Department or Division of researcher is a member	U	University of Minnesota

GAR	General Agricultural Research Funds	USDI	US Dept. of the Interior
GS	Graduate School, U of Minn.	USFS	United States Forest Service
HA	Hatch Act Funds	USFWS	US Fish and Wildlife Service
HEC	Harza Engineering Company	USFS	US Geological Survey
HFF	Hill Family Foundation	USN	United States Navy
IT	Inst. of Technology, U of M		

Involvement in Academic Activities and Public Affairs

The Center sponsored three interdisciplinary seminars concerned with the results of water resources research during Fiscal Year 1969. Attendance at the seminars ranged from 57 to 25 and included faculty members; graduate students; Federal, State and Local agency personnel; and private Consultants and citizens. The Center has had numerous requests to continue and expand the seminar series next Fiscal Year. A list of the titles of papers and authors of papers presented during the seminars is given below:

<u>Title of Paper</u>	<u>Author</u>
Research on Water Law in Minn. . .	.R.A. Haik, Attorney, Law Firm of Popham, Haik, Schnobrich, Kaufman and Doty.
Water & Related Land Resources Planning in Minnesota. . . . .	.William C. Walton, Univ. of Minnesota
Computer Control and Mathematical Modeling of Urban Water Resources	C.E. Bowers & A.F. Pabst, St. Anthony Falls Hydraulic Laboratory & J.J. Anderson, Mpls.-St. Paul Sanitary District.
Surface Chemistry of Some Minn. Lakes, With Preliminary Notes on Diatoms. . . . .	.R.C. Bright, Limnological Research Center and Bell Museum of Nat. History
Preliminary Studies on Zooplankton Distribution in the Great Lakes..	.W.R. Swain, Dept. of Public Health Biology, School of Public Health
Mathematical Watershed Models for Studying Surface Runoff	C.L. Larson, Dept. of Agricultural Engineering, Inst. of Agriculture

The Advisory Committee's Subcommittee on Educational Programs in Water Resources was reactivated in FY 1968 for the purpose of reviewing and recommending changes in the educational program in Water Resources at the Univ. of Minn. Topics being reviewed include available coursework in water resources, the possibility of formulating an interdisciplinary graduate program in water resources, and continuing education in water resources. Reports concerning these topics were prepared by Sub-committee members representing 3 major areas; social sciences, biological science, and physical sciences. These reports are being assembled into a main report which will be reviewed by the entire Subcommittee and will serve as the basis for recommendation concerning the water resources program at the University. The following Faculty members are serving on the Subcommittee: C.L. Larson, Dept. of Agric. Eng. (Chairman); E.R. Allred, Dept. of Agric. Eng.; C.E. Bowers, St. Anthony Falls Hydr. Lab.; A.J. Brook, Dept. of

Ecology and Behavioral Biology; D.L. Graven, Dept. of Law; P.K. Sims, School of Earth Sciences; & J.J. Waelti, Dept. of Agric. Econ.

A Task Force of the Consulting Council was organized in FY 1968 for the purpose of summarizing past and present effort on water resources research in Minn. by private enterprise, educational institutions, and by local, State and Federal government. Emphasis was on research performed within the State even though the area of application may be more general. Emphasis was on the period 1963-69. During the past year, a large body of data on water resources research was assembled. For every research project identified, information was sought on title, date, principal investigator, performing agency, funding agency, effort in terms of dollar cost. Projects are being categorized by subject matter area. A draft of a report summarizing research projects is being completed. The following people are serving on the Task Force: J.J. Waelti, Dept. of Agricultural Econ. (Chairman), C.A. VanDoren, U.S. Dept. of Agriculture, Agric. Research Service; John Dobie, Minn. Dept. of Conservation, Div. of Game and Fish; Douglas W. Barr, Consulting Hydraulic Engineer; D.B. Anderson, U.S. Geological Survey, Water Resources Division; G.H. Hollenstein, Minn. Dept. of Conservation.

The report will be patterned after the document "Federal Water Resources Research Program for FY 1969" prepared by the Federal Council for Science and Technology.

On July 1, 1968, the Minn. State Planning Agency entered into a cost reimbursement contract with the University which included provisions for the Director on an indefinite basis to spend 30% of his time serving as Water Resources Planning Director. Through the Director, several faculty members of the University have been retained by the State Planning Agency as consultants to prepare material for statewide and Federal-State water and related land resources planning activities. Members of the Center's Advisory Committee and Consulting Council have participated in planning activities by supplying information and by reviewing and commenting on planning documents. Faculty members active in the Center's affairs have been exposed to a large amount of water resources information. Interest in water and related land resources planning in Minn. has greatly increased. The need for additional research in the planning field has been brought to the attention of potential principal investigators. The relationship between faculty members and the State and Federal Agency employees has improved. Because water and related land resources planning involves many disciplines, the need for interdiscipline research is now more fully appreciated by faculty members.

Serving as Governor LeVander's representative on Federal-State Planning organizations has made it possible for the Director with the council of faculty members to influence State water resource policies and to assist the State in strengthening its position in the water resources field. The director has also been requested on several occasions to advise Governor LeVander on such matters as water pollution.

Publications

During Fiscal Year 1969, the Center distributed to about 350 people interested in water resources in Minnesota mimeographed Information Circulars covering the following subjects:

Information Circular No.	Title
89 . . . . .	.State Comprehensive Planning: Progress and Problems 1967
90 . . . . .	.Economic Analyses of Alternative Flood Control Measures
91 . . . . .	.Water Resources Education and Training
92 . . . . .	.Hydrology vs. Water Allocation in the Eastern United States
93 . . . . .	.Evaluation of Investments in Water Res. Manage.
94 . . . . .	.Water & Related Land Res. Planning in Minn.
95 . . . . .	.Programs of the Water Res. Research Center, University of Minn., FY's 1965-69
96 . . . . .	.Research Project Proposals Submitted by the Center to Office of Water Resources Research for possible funding starting in FY 1970.

The Center also distributed quarterly newsletters to about 350 people interested in water resources in Minn. Bulletings published by the Center during FY 1969 are listed in the section of this Annual Report entitled "Publications and Theses."

The Center has had many requests for copies of its Bulletins, Newsletters, Annual Reports, Information Circulars, and Brochures. A few excerpts from letters expressing appreciation for the Center's publications are given below:

Dear Mr. Walton:

Your third annual report is an excellent summary of water research activities in Minnesota. We noticed in this report (p.27) that you completed June 1966 a project (OWRR Project No.: A-009-Minn.) whose results, I believe, will be of interest to us. Ground water's contribution to streams is a subject that is continually being explored and needs serious consideration by the hydrologist. A number of our districts are involved in determining the relation of ground water to surface water. Because of the complexity of the subject, we are interested in any findings made in the research field. Therefore, we would certainly like to receive a copy of the report, if any, prepared by Ackroyd. If the results of the project have not been formally released and published, we would like to have in brief summary form a statement of Ackroyd's findings and recommendations. If only a file copy of the findings is available, could you let us have for a brief time on loan basis these results. Your cooperation in this matter would be greatly appreciated.

FOR THE REGIONAL HYDROLOGIST:

A.N. Turcan, Jr.
U. S. Dept. of the Interior
Geological Survey
Rm. 1252, Federal Building
1520 Market Street
St. Louis, Missouri

Gentlemen:

Thank you for your recent submittal of the Water Resources Research Center Information Circular No. 94 on Water and Related Land Resources Planning in Minn. as of Nov., 1968. It appears that your Water Resources Coordinating Committee has performed a monumental and commendable task in a short period of its existence.

I note, with particular interest, the comments on Federal-State regional planning and the complexity of trying to coordinate the activities of the four regional planning organizations. Oregon, with but two such organizations, the Pacific Northwest River Basin Commission (PNWRBC) and the Pacific Southwest Inter-Agency Committee (PSIAC), appears to be in an enviable position. The Columbia-North Pacific Type I Study, under the Commission, covers all of Oregon except the Klamath Basin. A portion in southeastern Oregon in the Great Basin and Minor drainages in southwestern Oregon are all included in the PSIAC Type I Study for the Southwest Region. It would be appreciated if you would address further correspondence or publications mailed to the board to Mr. Donel J. Lane, Director, State Water Resources Board, 500 Public Service Bldg., Salem, Oregon 97310.

Sincerely yours,

DONEL J. LANE, DIRECTOR
By Fred D. Gustafson, Chief Engr.
State of Oregon
State Water Resources Board
500 Public Service Bldg.
Salem, Oregon 97310

Dear Mr. Walton:

I have Bulletin 9 from the Water Resources Research Center entitled, "Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota." This looks useful to me. Would it be possible to procure two additional copies for the library here at the College as this certainly is a useful document for some of the papers that will be written in the future on water management matters by students here the Technical College. If there is a charge for these, I am sure we can arrange for appropriate payment. Thank you.

Cordially yours,
B.E. Youngquist, Superintendent
University of Minnesota
Northwest Experiment Station
Crookston, Minnesota

Dear Bill:

Thank you for the copy of the "Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota." This is a very worthwhile and useful document, and I appreciate receiving it.

Yours very truly,
Richard J. Lebens, Manager
Northern States Power Company
Minneapolis, Minn.

Dear Mr. Walton:

This is to acknowledge receipt of your recent publication, "Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota." I have scanned this bulletin and find it to be a thorough compilation of Minnesota Laws, Legislative Enactments, and Local Laws bearing on Water and Related Land Resources. This work is an important tool to intelligent planning development and use of these resources in your particular state.

Sincerely yours,
Robert M. Tarbox, Brigadier Gen. USA
Division Engineer, Dept. of the Army
North Central Div., Corps of Engineers
536 So. Clark Street, Chicago, Illinois

Dear Dr. Walton:

I wish to acknowledge with my thanks, receipt of the bulletin with which you have recently provided me. Your generous cooperation in furnishing this valuable material is genuinely appreciated.

Very truly yours,
Henry C. Eichhorn, Research Biologist
Biological Research Laboratory
National Fisheries Center & Aquarium
U. S. Department of the Interior
Washington, D. C.

Gentlemen:

The C.Y. Thompson Library is appreciative of your courtesy in sending us the Water Resources Research Newsletter. We feel certain that this publication would form a valuable addition to our library resources and we would like to receive it regularly. Would it be possible for you to place us on your mailing list to receive future issues and the available back-file as well as those issues published since Dec. 1967? Thank you for your cooperation.

Sincerely,
Wayne R. Collings, Librarian
The University of Nebraska
C.Y. Thompson Library, East Campus
Lincoln, Nebraska

Gentlemen:

Thanks for the separate (bulletin 7) on PRELIMINARY STUDIES OF ZOO-PLANKTON DISTRIBUTION WITH THE CONTINUOUS PLANKTON RECORDER which came a short time ago; it is certainly appreciated, and will find use not only in my personal work but through me in some studies now going on through the Ohio Biological Survey, where I am now serving as Administrative Associate under Dr. Charles A. Dambach, the director of the new School of Natural Resources at the Ohio State University. In this connection I am supervising some projects where this sort of equipment may be very useful. Thanks again and I would appreciate being in contact with other such papers. I maintain a small office here at Wesleyan.

William F. Hahnert, Ph.D.
Dept. of Zoology, Ohio Wesleyan Univ.
Delaware, Ohio.

Project Related Reports Published during Fiscal Year 1969

Dear Mr. Walton:

Thank you for the set of Information Circulars issued by the University of Minnesota Graduate School which you recently furnished this office. If available, we should like to have another set for our Missouri River Basin Studies office in Billings, Montana. Following is a list of the Circulars in question: No. 84 - Concept, Preparation, and use of "A Ten-Year Program of Federal Water Resources Research", No. 85 - Effects of Urbanization; No. 86 - River Basin Comprehensive Planning; No. 87 - Objectives of Water Resources Planning; No. 88 - Flood Plain Management Policies. These reports are very informative and useful to our Division in our RBS program.

Sincerely yours,
Harry G. Anderson, Acting Regional Super.
Division of River Basin Studies
U.S. Department of the Interior
Bureau of Sport Fisheries and Wildlife
1006 West Lake Street
Minneapolis, Minnesota

Mr. Thomas M. Downs
Special Assistant Attorney General
Department of Water Resources
State Office Building
Annapolis, Maryland 21401

Dear Dr. Downs:

Your letter dated May 8, 1969, to Attorney General Douglas Head, requesting a copy of Minnesota's water laws has been referred to this office for reply.

The best publication compiling these laws is Bulletin Number 9 of the University of Minnesota's Water Resources Research Center. Their office has graciously agreed to send you a copy of the bulletin. You should be receiving it from them in the not too distant future.

Sincerely,
Philip J. Olfelt
Spec. Asst. Attorney General
Department of Conservation

Blake, G.R. and R.D. Gilman
1969, Thixotropic Aging of Synthetic Soil Aggregates.
Soil Science Proceedings (B-003-Minn)

Bowers, C.E. and A.F. Pabst.
1968. Review and Analysis of Rainfall and Runoff Data for Selected Watersheds in Minn. Water Resources Research Cntr. Bul.8. 70 p., 55 fig., 9 tab., 10 ref. (A-013-Minn)

Haik, R.A., W.C. Walton and D.L. Hills.
1969. Aspects of Water Resources Laws in Minnesota.
Minn. Water Resources Research Cntr. Bull. 11, 143 p. 9 ref. (A-015-Minn)

Machmeier, R.E. and C.L. Larson. 1968
Runoff Hydrographs for a Mathematical Watershed Model.
Jour. of the Hydr. Div., Amer. Soc. of Civil Engr., Vol. 94, No. HY 6, pp 1453-74.

Manson, P.W., G.M. Schwartz and E.R. Allred. 1968.
Some aspects of the Hydrology of Ponds and Small Lakes.
Agr. Exper. Sta.-Univ. of Minn. Tech. Bull. 257. 88 p. 55 fig., 40 tab., 14 ref. (A-001-Minn)

Megard, R.O. 1968
Algae and Phosphorus in Lake Minnetonka.
Limnological Research Cntr.-Univ. of Minn., Interim Rept. No. 4. 27 p., 9 fig., 3 ref. (A-016-Minn.)

Shapiro, J., W. Chamberlain and J. Barrett. 1969.
Factors Influencing Phosphate Use by Algae.
Water Research 2. 12 p. (B-009-Minn)

Swain, W.R., T.A. Olson, T.O. Odlaug. 1968.
Preliminary Studies of Zooplankton Distribution with the Continuous Plankton Recorder.
Minn. Water Resources Research Cntr. Bull. 7. 21 p., 14 fig., 12 ref. (A-011-Minn.)

Thorud, D.B. and D.A. Anderson. 1969.
Freezing in Forest Soil as Influenced by soil Properties, Litter and Snow.
Minn. Water Resources Research Cntr. Bull. 10. 41 p., 20 fig., 16 tab., 19 ref. (A-004-Minn.)

Waelti, J.J. 1969.
Understanding the Water Quality Controversy in Minnesota.
Agr. Extension. Bull. No. 349. 28 p.

Walton, W.C., R.A. Haik and D.L. Hills. 1968.
Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota.
Minn. Water Resources Research Center Bull, 9. 640 p. (A-015-Minn.)

Director's Activities

During Fiscal Year 1969, the Director attended the following water resources meetings: July 3, conference with Harza Engineering concerning State Planning Agency water and related land resources report, Chicago, Ill.; July 10-11, conference of State and Federal Water Officials, Council of State Governments, Detroit, Michigan; July 18-19, meeting Great Lakes Basin Commission, Duluth, Minn.; July 22-24, Meeting Souris-Red-Rainy-Rivers Basin Commission, Hibbing; Aug. 12, described activities of Center to Dept. of Agr. Economics faculty, St. Paul; Aug. 14-16, meeting of the Work Group N, Souris-Red-Rainy-Rivers Basin Commission, Moorhead; Aug. 22-23, meeting to discuss 4-State Compact, Madison, Wisconsin; September 11 and 12, Great Lakes Basin Commission Planning Conference, Ann Arbor, Mich.; Sept. 17-18, Upper Mississippi River Comprehensive Basin Study Coordinating Committee meeting, Madison, Wisconsin; Sept. 24-26, Souris-Red-Rainy River Basins Commission meeting, Minot, North Dakota; Oct. 2, presented a paper on water and Related Land Resources Planning during annual meeting of North Central Section of American Water Works Association, St. Paul; Oct. 10-11, meeting of Great Lakes Basin Commission, Erie, Pennsylvania; Oct. 16-18, meeting of Interstate Conference on Water Problems, New Orleans, Louisiana; Oct. 29-30, met with North Dakota State Officials to discuss Souris-Red-Rainy-River Basins Commission, Bismarck, North Dakota; Nov. 18-19, meeting of Great Lakes Commission, Toledo, Ohio; Nov. 20-23, Conference on "The Sea and the States: Mutual Problems and the Solutions," Miami, Florida; Dec. 2, quarterly meeting of Upper Mississippi River Comprehensive Basin Study Coordinating Committee meeting, St. Louis, Missouri; Dec. 10-11, quarterly meeting of Missouri Basin Inter-Agency Committee meeting, Lincoln, Nebraska; Dec. 12-13, visited Waterways Experiment Station, Vicksburg, Mississippi; Dec. 15-17, meeting of U.S.G.S. Advisory Committee on Water Data for Public Use, Miami Beach, Fla.; Dec. 18-19, Souris-Red-Rainy River Basins Commission Plan Formulation Work Group Meeting, Moorhead; Jan. 9-10, meeting of Great Lakes Basin Commission, Detroit, Michigan; Jan. 14-16, meetings of Souris-Red-Rainy River Basins Commission, Moorhead; Jan. 27-29, 4th Annual meeting of Water Resources Research Directors (OWRR), Washington, D.C.; Feb. 12-14, presented lectures on groundwater resource evaluation, Hydrologic Center, U.S. Army Corps of Engr., Davis, California; Feb. 20, Plan Formulation Work Group meeting, Souris-Red-Rainy River Basins Comm., Moorhead; Feb. 25-26, Upper Mississippi River Comprehensive Basin Study Coordinating Committee meeting, Mpls.; Feb. 27, presented paper on planning, Red River Valley Shows, Crookston; Mar. 3, appeared before the House Metropolitan and Urban Affairs Comm. and presented information concerning a bill to finance groundwater investigations in the Mpls.-St.Paul area, St. Paul; Mar. 6, presented paper on Water Resources Planning to Toastmasters Club of Mpls., Mpls.; Mar. 12, appeared before the House Appropriations Subcommittee on Semi-State Agencies to present information pertaining to River Basin Commissions, St. Paul; Mar. 14, Work Group N Meeting of Souris-Red-Rainy River Basins Comm., Moorhead; Mar. 17, meeting of Great Lakes Basin Commission, Cleveland, Ohio; Mar. 26-27, Work Group N meeting of Souris-Red-Rainy River Basins Commission, Moorhead, Minn.; April 8-9, meeting w/ SRRRBC Citizens Advisory Council in Mahanomen Minn.; April 10-11, meeting of Mid-Continent Water Resources Research Center Directors, Kansas City, Missouri; April 23-25, American Geophysical Union Conf., Washington, D.C.; April 29-30, SRRRBC Plan Formulation Work Group meeting, Moorhead, Minn. and lectures at No.Dakota State Univ., Fargo, No.Dakota; May 2, meeting of Standing Committee for Framework Plan, Missouri Basin Inter-Agency Committee, Omaha, Neb. May 5, Gustavus Adolphus College, Guest AGU Visiting Lecturer, St. Peter, Minn.; May 7, Wisc. State Univ. and Winona State College, Guest AGU Visit.Lecturer, LaCrosse, Wisc. and Winona, Minn.; May 20-21, Great Lakes Basin Comm. meeting, Niagara Falls,

N.Y.; May 22, Souris-Red-Rainy Rivers Basin Comm. meeting, Moorhead, Minn.; June 5, Minn.-Wisc. Boundary Area Comm. meeting, LaCrosse, Wisc.; June 6, Mississippi R. Research Consortium Conf., LaCrosse, Wisc.; June 9, mtg. with U.S. Army Corps of Engrs., Chicago, Ill.; June 18, Souris-Red-Rainy Rivers Basin Comm. mtg., Moorhead, Minn.; June 23-25, Interstate Conf. on Water Problems, Salt Lake City, Utah; June 30-July 2, Univ. Council on Water Resources Annual Mtg., Reno, Nevada.

Fiscal Year 1969 Budget

The Fiscal Year 1969 OWRR budget summary is given below:

<u>Annual Allotment Program</u>	<u>Federal Funds</u>
Center Director's Office	\$ 23,720
Projects Continuing from Fiscal Year 1968	
A study of the open water distribution and abundance of net plankton as an index of eutrophication in Lake Superior - Olson, School of Public Health (A-011-Minn)	\$ 9,000
Hydrologic aspects of water laws in Minnesota - Walton, Graduate School (A-015-Minn)	\$ 16,225
Primary productivity of selected Minnesota Lakes - Wright, Limnological Research Center (A-016-Minn)	\$ 11,850
Effects of areal and time distribution of runoff supply on watershed hydrographs - Larson, Dept of Agricultural Engineering (A-017-Minn)	\$ 5,800
Methodology for integrating water quality management with management of the total water resources in Minnesota - Straub, School of Public Health (A-018-Minn)	\$ 13,254
New Projects	
Economics of Water Quality Control in the Upper Mississippi River, Minnesota - Waelti, Department of Agricultural Economics	\$ 12,384
Evaluation of Selected Computer Program in Hydrology - Bowers, St. Anthony Falls Hydraulic Laboratory	\$ 7,767
Annual Allotment Program Total	\$100,000

Matching Grant Program

	<u>Fed. Funds</u>	<u>Non-Fed. Funds</u>	<u>Total</u>
Projects Continuing from Fiscal Year 1968			
Storage and movement of water in soils as related to spatial and time changes in the clay-quartz matrix - Blake, Department of Soils Science (B-003-Minn)	\$ 9,060	\$ 9,060	\$ 18,120
Study of factors affecting the channel phase of runoff from small watersheds by mathematical modeling - Larson, Department of Agricultural Engineering (B-007-Minn)	\$ 3,900	\$ 3,900	\$ 7,800
Relation of phosphorus in lake-bottom deposits and pollutional history of Minnesota Lakes - J, Shapiro, Limnological Research Center (B-009-Minn)	\$15,913	\$15,913	\$ 31,826
A study of techniques for determining changes on phytoplankton populations in clouds of fluorescent dye moving in the Mississippi River - McNabb, St. Mary's College (B-101-Minn)	\$ 3,948	\$ 3,948	\$ 7,896

New Projects

Development of a mathematical model to predict the role of surface runoff and ground water flow in overfertilization of surface waters - Straub, School of Public Health	\$ 11,365	\$ 11,365	\$ 22,730
Influence of mist irrigation on moisture stress, growth, yields and quality of potatoes and other vegetable crops - Nylund, Department of Horticultural Science	\$ 15,434	\$ 15,434	\$ 30,868
Characteristics of the soil matrix that affect water storage and movement - Blake, Department of Soil Science	\$ 8,498	\$ 8,498	\$ 16,996
Matching Grant Program			
Total	\$ 68,118	\$ 68,118	\$136,236

Expected Results from Projects Initiated in FY 1970

OWRR Project No.: B-020-Minn. Project Title:
Pollution and the Ecology of nearshore
periphyton of Lake Superior
Principal Investigator:
T.A. Olson, School of Public Health
Project Began: July 1, 1969 FCST Category: V-A
Scheduled Completion: June 30, 1972

Representative areas of the North Shore and other adjacent waters of Lake Superior will be examined for the purpose of characterizing the periphyton which prevails in shallow water areas and at the shore-water interface; for comparison, concurrent samples of periphyton will be collected from deeper waters. In addition, simultaneous field and laboratory experiments will be conducted to ascertain the growth response of the periphyton community as affected by contamination or enrichment of the water. The research will investigate more fully the ecology of the periphyton in the wave-washed and near-shore areas of the western end of Lake Superior. Such a study will provide base-line information on the present make-up of this near-shore ecological association as contrasted to the deeper-water periphyton. Thus, a body of knowledge will become available which may be valuable for detection of advancing eutrophication in the lake.

OWRR Project No.: B-031-Minn. Project Title: Participatory Ecology: A
study of citizens groups involved at the
grass roots to improve the water
resources environment.
Principal Investigator:
Luther P. Gerlach,
Department of Anthropology

Project Began: July 1, 1969 FCST Category: VI-B
Scheduled Completion: June 30, 1972

The objective of this project is to study by interview, observation and questionnaire, and to film, Participatory Ecology groups in Mpls.-St. Paul, in Miami and environs, and two other metropolitan areas and environs in the USA. Major research objectives are to: 1a) Identify and analyze structure, function and process in Participatory Ecology groups in each of the above areas using 5-factor and other models;; 1b) determine linkages with other Participatory Ecology groups across the country, and also with other groups engaged in social action-human rights; 1c) determine processes in movement formation, or impending factors. 2) Determine the extent to which the ideology and activities of Participatory Ecol. constitutes an attempt to redefine man's relationship with the water resources environment. 3) Assess the adaptive significance of Participatory Ecol. in promoting ecological thinking and improving the quality of the water resources environment, particularly of urban areas, by such means as a) influencing power elite, b) involving people at grass roots, c) experimenting through trial and error in water resource environmental problem solving. 4) Expand knowledge about social movement structure, function, process, capability and limitation.

OWRR Project No.: B-032-Minn. Project Title: Mississippi River Ecology
Associated with Heated Power Plant Effluent
Principal Investigator:
Alfred J. Hopwood, Dept. of Biol., St. Cloud State College, St. Cloud, Minn.
56301
Project Began: July 1, 1969
Scheduled Completion: June 30, 1972 FCST Category: V-C

Construction of a large power plant on the Mississippi R. near Monticello, Minn., is scheduled for completion in Feb., 1970. Heated water will be discharged from the plant during operation, causing changes in the environment with subsequent alterations in aquatic life. The study described herein, is designed to determine existing ecological conditions in the Mississippi R. before operation of the plant and to monitor the environmental changes due to thermal discharge from the generator. The above purposes can best be served by attainment of the following objectives:

A. Prior to operation, Feb., 1970:

1. Determine existing physical and chemical factors of water quality.
2. Determine existing species, and temporal and seasonal abundance.
3. Determine general physical condition, food habits, life cycles, and energy relations of species in the river ecosystem.

B. During operation:

1. Compare physical and chemical water quality with that which was present before plant operation.
2. Compare species structure and abundance with data collected prior to operation.
3. Observe physical condition, food habits, life cycles and energy interactions of all species.

OWRR Project No.: A-021-Minn. Project Title: Water Resources Adminis-
tration in Minnesota
Principal Investigator:
W.C. Walton, Graduate School
Project Began: July 1, 1969
Scheduled Completion: June 30, 1972
FCST Category: VI-E

The research project will inventory, appraise, and evaluate water resources administration in Minnesota. The application of water laws, resources and methods used in working for institutional goals, nature of each institution's involvement in water resources activities, coordination between units of government, rigidities in administrative arrangements, and institutional factors which have influenced water resource development and management will be examined. This research project will provide comprehensive background information required for effective future action in the important and increasingly complex field of water-resource administration in Minnesota.

OWRR Project No.: A-022-Minn. Project Title: Zooplankton Biomass and
Incipient Eutrophication in Lake Supr.
Principal Investigator:
T.A. Olson, School of Public Health
Project Began: July 1, 1969
Scheduled Completion: June 30, 1972
FCST Category: V-C

The research project will involve biomass determinations and productivity measurements in the west end of Lake Superior just off the Duluth-Superior Harbor area, in the Larsmont area, and in the Grand Marais-Isle Royal region. Samples will be taken with Clarke-Bumpus Nets, Miller High Speed Samplers, Hardy Plankton Recorders and determinations will be made of the organic matter of the biomass. The investigations, focusing on zooplankton biomasses, should be helpful in assessing the extent of eutrophication of the west end of Lake Superior. Knowledge concerning the effects of pollution on the growth response, species replacement, and productivity of flora and fauna in the aquatic habitat of the west end of Lake Superior should be useful. Information concerning eutrophication will assist the State in enforcing water quality standards.

Annual Allotment Program

Narrative Progress Reports

OWRR Project No.: A-011-Minn. Annual Allotment Agreement No.: 14-01-
Project Title: A Study of the Open Water Distribution & Abundance of Net Plankton as an Index of Eutrophication in Lake Superior 0001-1843

Prin. Invest.:	T.A.Olson	Degree:	Ph.D.	Discipline:	Public Health
Student Assistants:		Degree:		Discipline:	
	Jonathan Vomachka		Undergrad.		Public Health
	Carolyn Anderson		"		"
	Sandra McNeil		"		"
	Gregory Foley		"		"
	James Hanko		"		"
	Wayland Swain		M.S.		"
	William Parkes		"		"
	Robert Nelson		"		"

Name & Location of University Where Project is Being Conducted:
Univ. of Minnesota, Minneapolis, Minn. 55455

A. Description of research performed & any findings, results or conclusions relating PART I. CARBON-14 PRODUCTIVITY STUDIES ON L.SUPERIOR, MICH., HURON & ERIE (There to:

INTRODUCTION: In an affluent society such as we enjoy in the U.S. great technological advances are being made which are undoubtedly reflected in the rise of industrial production, operations, and income. The workmen are enjoying the benefits of these advances in the form of reduction in the work-day and subsequent increase in leisure time, and increased annual incomes. One of the unfortunate results of this affluence however, is an ever increasing contamination of the environment.

The Great Lakes have not escaped this process of contamination caused by man's activities, and much concern is presently being expressed involving the enrichment and resultant productivity of this chain of lakes. Although much discussion has been and is presently being conducted concerning the signs of eutrophication in the Great Lakes with the exception of L. Erie, very little information regarding the seasonal productivity rates in the Great Lakes is generally available. There are various techniques available for the determination of such productivity in an aquatic environment. The carbon-14 method was chosen for this study because it is highly sensitive and presents fewer logistical problems than other available techniques. The carbon-14 project described here, was designed to attain the following objectives: 1. To obtain base lines of primary productivity of surface waters for the lakes investigated. 2. To determine the effects of seasons; that is, does productivity increase or decrease, and to what degree, as the season progresses? 3. To determine whether or not differences in productivity exist in various water masses along longitudinal lake transects. 4. To make comparisons of the productivity levels of the lakes under investigation.

MATERIALS AND METHODS

The field portion of the project was completed during the 1967 and 1968 summer seasons through the cooperation of the US Steel Corp. and Hanna Mining Co., who graciously supplied laboratory space and quarters aboard their ore carriers.

Samples for carbon-14 analysis were collected at 2-hour intervals and at points approximately every 35 mi. The entire lake was sampled along the course followed by the ore carrier. On board incubation involving constant light and temperature was used to determine photosynthetic rates.

The necessary associated chemical analyses were also done aboard ship as was the filtration of samples. Final preparation of the samples and subsequent determination of the activity present was carried out at the Lake Superior Research Station. An Ansitron II liquid scintillation counter was used to determine the activity present in the samples, which were counted to a 1% standard error.

RESULTS

All carbon-14 productivity data obtained from scintillation counting is processed, and reported in terms of milligrams carbon fixed, per liter of surface water. A multiple regression was used in the statistical evaluation of all primary productivity data. The following general statement can be made concerning the productivity rates of those Lakes studied:

1. Lake Superior was found to be the least eutrophic lake of the lakes sampled. Lake Huron, Michigan, and Erie, in that order were found to be more eutrophic, with L. Erie being more than 4 times as productive as any of the other lakes sampled.
2. The degree of eutrophication noted in the lakes sampled increased progressively as the more southerly latitudes were reached.
3. The mean seasonal productivity of the lakes sampled increased progressively as surface water temp. increased, with the exception of L. Michigan. In the latter case a longer sampling season, including the cold fall months was involved, and the mean temp. was lowered.
4. The productivity rate on each of the lakes increased as the season advanced during the 1967 sampling period. A similar rate was observed only near the end of the 1968 summer period.

During the 1967 investigations, L. Superior and L. Michigan were extensively sampled, but in 1968, it was L. Superior and Huron which received primary attention. The sampling trip was made to L. Erie. The following represents the mean seasonal productivity range for the lakes sampled:

1. L. Superior, 1967: 2.6 - 8.8 mg C/L/4 hrs.
2. L. Michigan, 1967: 8.1 -17.5 mg C/L/4 hrs.
3. L. Superior, 1968: 4.9 -12.0 mg C/L/4 hrs.
4. L. Huron, 1968: 4.9 -12.0 mg C/L/4 hrs.
5. L. Erie, 1968:30.6-127.7 mg C/L/4 hrs.

A more comprehensive report, which will present in more detail the results of this project is at press.

PART 2. CONTINUOUS PLANKTON RECORDER STUDIES ON L. SUPERIOR, MICHIGAN & HURON

INTRODUCTION

No attempt is made in this report to discuss all the ecological factors affecting the distribution of crustacean plankton. It is clear from the data presented that a variety of parameters must be thoroughly examined before adequate commentary can be made, and the causes of a given ecological distribution can be understood. An effort has been made, however, within the limits of the method employed to present a biogeographical synopsis of organism distribution at a single sampling depth for three of the Great Lakes. Since the use of a continuous transect sampling method such as was employed in this study, had been tried only one other time in the Great Lakes (Beeton, unpublished data) the data acquired in these tows yielded information on organism distribution in both space and time that was previously unavailable.

MATERIALS AND METHODS

In this study, made with the Continuous Plankton recorder, a series of lakelong transect tows were made in three of the Great Lakes; Superior, Michigan and Huron. The Recorder concentrated, on a mile per mile basis, an entire lake transect onto 18-1/2 ft. of silk netting. This silk effectively filtered out planktonic crustaceans which could be subsequently enumerated and identified. All tows were made at a depth of ten meters with either #60 mesh Grit Gauze or #15 mesh Silk Bolting Cloth.

In July of 1967 and Aug. of 1968 a series of replicate tows were made in L. Superior for the purpose of determining the optimum towing depth for Recorder runs. These replicate tows were made with Hardy Plankton Indicator, sequentially stacked at various depths along the towing line. The runs were made from the Knife River, Minn. Station, to two Harbors, Minn., and returned. Analysis of the data acquired in these studies showed rather conclusively that if a single depth of tow is mandatory, the depth of 10 meters is at least as good as, if not better than, any other single depth that could have been chosen.

Throughout the study, towing depths were determined graphically, based on charts constructed for marine use by the Scottish Marine Biological Station of Edinburgh, Scotland. To confirm these depths for the freshwater situation, a recording device, a Bathykymograph, was utilized to plot depth of tow against time. A period of 12 consecutive hours could be plotted with this device. The use of this instrument confirmed that the Recorder running at the prescribed depth of ten meters in tows in the Great Lakes. Remarkably little variation in depth of tows was noted.

From the alternate 10 mi. blocks of data utilized in analysis, information was obtained on organism distribution in both space and time. A series of biogeographical charts of distribution have been prepared which show clearly the density and distribution of ecologically related groups in the plankton.

RESULTS

Within the limitations of the method, variations based on several factors were observed. Net mesh size greatly influenced the numbers of organisms taken in size specific ranges. It was apparent that the use of #60 mesh Grit Gauze induced a selective bias in favor of the larger planktonic constituents. From the data some influence of the trophic status of the various bodies of water sampled was made. It is evident that as one of the three lakes is compared with the others, L. Superior is certainly the most oligotrophic, L. Huron the most Eutrophic and L. Michigan more nearly mesotrophic. Marked variations are seen from lake to lake and from one year to another. As one examines the data, marked seasonal variations are also noted. In general, low vernal densities were observed, with a sharp autumnal increase occurring in late fall. This peak was followed by a decline in population. The seasonal pattern was so regular in occurrence throughout the 3 yr. study that it was regarded as an annual cycle.

The phenomenon of patchiness was seen on numerous occasions. It gave an irregular appearance to the histograms of data from the tows. Marked variations in both the numbers and species of organisms were evident in all three of the lakes. The influence of environmental factors doubtlessly affected the distribution and densities of these various forms. One such factor was light. Marked diurnal variations in species and concentration was noted on most of the runs. These changes are attributed to the influence of vertical migration of the crustaceans.

This comprehensive transect study of the second trophic level served to accomplish the following:

1. Determination of the zooplankton occurrence and distribution in the Great Lakes;
2. Demonstration of the applicability of the Continuous Plankton Recorder in fresh-water research programs;
3. Assessment of the water quality, utilizing zooplankters as index organisms and some inference as to the nature of the standing crop of planktonic organisms;
4. Acquisition of information on the effects of patchiness of distribution of zooplankters in the Great Lakes;
5. Determination of the ecological distribution of zooplankters from which ecological baselines for studies relating to pollution, eutrophication, and the like can be made;
6. Provided a basis for the construction of biogeographical charts of organism distribution which provides a basis for judging relative water quality.

This study represented an ecological approach to the question of water quality. Further, a useful method for establishing practical baselines by analysis of the second trophic level has been demonstrated utilizing lake-long transects of water. A more comprehensive report, which will present in more detail the results of this project is at press.

B. Project Related Publications

- a. Olson, T.A. and T.O. Odlaug, 1966. "Limnological observations on western Lake Superior." Proceedings International Conference on Great Lakes Research Pub. No. 15, Great Lakes Research Div., Univ. of Mich.: 109-118.
- b. Olson, T.A., T.O. Odlaug & W.R. Swain, 1966. "The Continuous Plankton Recorder, a review of the literature." Water Resources Research Cntr. Bul. 3, 221 p.
- c. Swain, W.R., T.A. Olson & T.O. Odlaug, 1968. "Preliminary studies of zooplankton distribution with the Continuous Plankton Recorder." Water Resources Research Center, Bul. 7, 20 pp.
- d. Fox, J.L., T.A. Olson, & T.O. Odlaug, 1967. "The collection, identification, and quantitation of epilithic periphyton in L. Superior." Proceedings, 10th Conference on Great Lakes Research, 12-19
- e. Stokes, L.W., T.A. Olson & T.O. Odlaug, 1967, "Studies of chlorophyll and carotenoid pigments in L. Superior periphyton." Proceedings, 10th Conference on Great Lakes Research: 107-114.
- f. Swain, W.R., 1969 (Thesis). "Crustacea of L. Superior, Michigan & Huron, as determined by the Continuous Plankton Recorder technique."
- g. Parkos, W.G., 1969 (thesis). "Primary productivity studies with C-14 along shipping routes in L. Superior, Michigan, Huron, and Erie."

C. Statement of Project Work Remaining to be Accomplished: None

D. Project Progress Contemplated For Remainder of Calendar Year: None

E. Application of Research Findings

Contemporary reports in the literature emphasize an increasing concern about the effects of pollution on water quality and on the changes in trophic states of the Great Lakes. The carbon-14 productivity technique and Continuous Plankton Recorder investigations, as used in our investigations, have

been shown to be effective methods for the study of fauna and flora of the Great Lakes and for obtaining biological data relevant to the productivity of water in the Great Lakes basin.

The Continuous Plankton Recorder (CPR) has been used effectively for research in the marine environment and has been valuable for characterization of indigenous zooplankton associated with various saline water masses. It also has been employed for studies of fish spawning areas and for investigations of zooplankton migration. However, the CPR is a relatively new research tool in Great Lakes investigations.

Our CPR investigations on the Great Lakes have demonstrated the applicability of this method for fresh water work. Data accumulated in these studies indicate that sharply delineated regions of high zooplankton concentrations occur, confirming the hypothesis of non-uniform dispersal of organisms. Differences in species composition and members of organisms were evident when samples from water masses of Lakes Superior, Huron, and Michigan were analyzed. Definite seasonal differences in zooplankton were detected and a marked diurnal variation in species composition of the plankton has been noted also. Data collected from CPR tows through chemically polluted and enriched areas indicate that marked increase in zooplankton occurs in these regions as compared to lake areas that display a paucity of nutrients. Thus, the CPR technique provides a means for assessing the effect of pollution and ensuing eutrophication as reflected by studies of the second trophic level in a manner heretofore unobtainable in the Great Lakes.

Carbon-14 productivity studies of surface waters in L. Superior, Huron, Michigan, and Erie demonstrated that differences in primary phytoplankton production occurred in the water masses of the Great Lakes system. Lowest levels of productivity were found in the Central regions of L. Superior. Comparison of productivity from the four Great Lakes indicated a definite increase in phytoplankton carbon fixation activity of the lower lakes. Especially marked rises in primary production were found in lower Lake Michigan and in Lake Erie -- both regions where a high level of enrichment of the waters has undoubtedly developed because of massed populations and industry.

The results of the CPR studies and the carbon-14 productivity investigations have provided extensive data related to primary and secondary productivity in the great lakes. The research indicates that both methods are useful tools for the assaying of the biological response to pollutional effects in the aquatic environments. Data accumulated in these studies will furnish valuable reference levels for persons interested in rates of eutrophication, productivity and water quality of the Great Lakes in future years.

OWRR Project No.: A-015-Minn Annual Allotment Agreement No.: 14-01-0001-1843

Project Title: Hydrologic & Other Aspects of Water Laws & Major Court Decisions in Minnesota.

Principal Investigator: W.C. Walton Degree: B.S. Discipline: Civil Engineering
Student Assistant: D.L. Hills Degree: B.S. Discipline: Civil Engineering
Project Began: July 1, 1967 Scheduled Completion: June 30, 1969

Name & Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minn. 55114

A. Description of research performed and any findings, results or conclusions relating thereto:

The study had as part of its objective the determination of the extent to which statutory laws and court decisions reflect the existing scientific knowledge of the hydrologist. The present use of our water and related land resources and the expected increase in future water needs requires that court decisions have as their foundation the scientific knowledge which is or will be available concerning water resources. If the legal principles enunciated in legislation are to be effective in reconciling disputes over water use and also furnish a guide for the future development and management of water resources, it is essential that legislation adequately reflect the knowledge of the physical scientist. Other aspects of water laws with which the study was concerned include: areas of inconsistent regulation, extent to which water policy has been defined and developed by existing water laws, extent to which priorities of use have been established by existing water laws, effectiveness of existing water laws in dealing with specific problems and water law obstacles to effective water resource development and management.

The study indicates the direction in which State water law is moving, and offers suggestions concerning areas where legislative efforts might be placed with respect to hydrologic and other important aspects of water law. This compilation should be an excellent source reference for legislators, lawyers, engineers, governmental officials, and others interested in water resource development and management.

During FY 1968, the numerous legislative enactments bearing on water and related land resources that are contained in the codified laws of Minnesota were collected and processed for publication in a report. In addition, selected uncodified legislative enactments and ordinances of villages and cities bearing on water and related land resources which have the force and application of law were compiled. All pertinent uncodified laws enacted during the 1965 Legislative Session are presented in the report together with selected uncodified laws of other Legislative Sessions to provide the reader with an insight into the nature and scope of uncodified laws in the field of water and related land resources. The offices of selected villages and cities in Minnesota with varying water problems were visited during FY 1968 and a sampling of local water use regulations was compiled. The local ordinances presented in this report indicate the extent to which the development and management of water resources presently resides in local units of government.

During FY 1969 the study was concerned with the analysis and interpretation of existing Federal, State, and local legislation and court decisions bearing on water and related land resources in Minnesota. A second report contains a compilation of major court decisions in Minnesota, a compilation of major rules and regulations of selected State agencies, a compilation of county ordinances, a list of all Federal legislation and major court decisions outside Minnesota, discussions on various aspects of water laws, and recommendations concerning ways and means for improving water laws. Some of the subjects which the second report discusses include: the relative spheres of Federal and State water laws, legislation concerning Federal projects and activities, water policies as expressed in Minnesota's water laws, problems associated with differing scientific and legal classification of water, diffused surface water law, groundwater law, water diversions, provincialism and precedent in court decisions, water law and changing conditions, insecurity of existing water rights, the adequacy of current legislation regulating water permits by the Dept. of Conservation and pollution control by the Pollution Control Agency, flood plain regulations, tax laws, definition of public waters, and adequacy of riparian permit of water allocation.

B. Project-related Publications:

Walton, W.C., R.A. Haik and D.L. Hills, 1968.
Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota.
Bulletin 9.
Minnesota Water Resources Research Center.

Walton, W.C., R.A. Haik, and D.L. Hills, 1969.
Hydrologic and Other Aspects of Water Laws and Major Court Decisions in Minnesota.
Bulletin No. 11.
Minnesota Water Resources Research Center. At Press.

C. Statement of Project Work Remaining to be Accomplished:

None

D. Additional Project Progress contemplated for the remainder of calendar Year 1968:

None.

OWRR Project No.: A-016-Minn. Annual Allotment Agreement No.: 14-01-0001-

1843

Project Title: Primary Productivity of Selected Minnesota Lakes

Principal Investigator: H.E. Wright Degree: Ph.D. Discipline: Geology

Student Assistants: Kathleen Baker Degree: M.S. Discipline: Botany
John Joyce Degree: M.S. Discipline: Ecology

Project Began: July 1, 1967 Scheduled Completion: June 30, 1970

FCST Category: V-C

Name & Location of University Where Project is Being Conducted:
University of Minnesota, Minneapolis, Minnesota 55455

A. Description of research performed and any findings, results, or conclusions relating thereto:

Algal abundance and daily rates of algal photosynthesis have been measured periodically in 18 lakes in 3 different physiographic regions of Minn. Four of the lakes are in northeastern Minn., in a region where bedrock is relatively insoluble. The salinity of lake water is low and most lakes are unpolluted and oligotrophic. Ten of the lakes are in central Minn. in a region where the lake basins are in calcareous glacial drift; the water salinity is moderately high, and most lakes are moderately or highly eutrophic. Several receive drainage from agricultural land and municipal sewage. The other four lakes are in southwestern Minn., also in a region of calcareous glacial drift, but water salinity is high because the climate is more arid than elsewhere in the state and all lakes are eutrophic. These lakes are in a fertile agricultural region.

The objective of the project is to rank the lakes on the scale of eutrophication, to provide a context for interpreting geochemical and biological data obtained in other studies, and to develop diagnostic procedures for use in designing nutrient abatement programs. Average daily gross photosynthesis ("algal growth rates") range from 0.4 grams carbon/m²/day in the oligotrophic lakes of the northeast to more than 3 grams carbon/m²/day in polluted, very eutrophic lakes. Procedures developed and used in the regional survey have been modified for the purpose of diagnosing lake pollution. They have been used to measure the photosynthetic capacity of algae in two lakes that receive municipal sewage. Measurement of algal photosynthetic capacity indicate that phosphorus is the critical nutrient that limits algal growth during the summer in L. Minnetonka, a large lake that is almost surrounded by suburbs of Mpls. An intensive analysis of the nutrient budget of this lake has now been undertaken in cooperation with watershed management groups to design a comprehensive nutrient-abatement program.

B. Project-related Publications:

Megard, R.O., 1968, Algae and Phosphorus in Lake Minnetonka, University of Minnesota, Limnological Research Center, Interim Report 4, 27 p.

C. Statement of project work remaining to be accomplished:

For the final field season of the project, summer 1969, emphasis will be to obtain additional data from the S.W. and N.E. lakes, which thus far have received the least attention. The balance of the year will be spent

on preparing the data for publication.

D. Additional project progress contemplated for the remainder of calendar year 1969:

The field studies will be completed in 1969, and the date will be tabulated in preparation for interpretation and further publication.

OWRR Project No.: A-017-Minn Annual Allotment Agreement No.: 14-01-0001-1843

Project Title: Effects of Areal & Time Distribution of Runoff Supply on Watershed Hydrographs.

Principal Investigator: Degree: Discipline:
Curtis L. Larson Ph.D. Agricultural Engineering

Student Assistants: Degree: Discipline:
Pinhas Golany M.S. Agricultural Engineering
Tsong C. Wei M.S. Agricultural Engineering
Russell Mein M.S. Agricultural Engineering

Project Began: July 1, 1967 Scheduled Completion: June 30, 1970

FCST Category: II-A

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minnesota 55101

A. Description of Research performed & any findings, results, or conclusions related thereto:

Procedures have been developed and incorporated in the watershed model that will accommodate a time-varying input (runoff supply) to the model. Procedures have also been worked out for varying the areal distribution of runoff throughout the watershed. Studies of how these factors vary have been made and used as a basis for establishing patterns to be used in experiments with the watershed model. A method of varying watershed slope without changing watershed area was selected for use in the study.

A substantial portion of this year's effort has been devoted to further study and development of the numerical routing procedures being used in the study. Serious difficulties with unstable solutions were encountered when the backwater effect was combined with a trapezoidal channel. This was quite unexpected since the procedure worked very well when these two conditions were taken separately. An iterative solution by the characteristic method was adopted and is giving improved results. However, for the complete watershed model it requires considerably more computer time.

B. Project-related Publications: None

C. Statement of project work remaining to be accomplished:

The remaining work includes parts of Salient Points (1), (2), (4), and (5) of the original Project Proposal. In each case, the necessary improvements of the model have been completed. The actual experiments have not, but are expected to get underway during the month of July, 1969.

D. Additional project progress contemplated for the remainder of calendar year 1969:

It is expected that the experimental portions of the project, as indicated in Salient Points (1), (2), (4), will be completed during 1969 and that the remaining time on the project will be devoted to analysis and preparation of reports.

OWRR Project No.: A-019-Minn Annual Allotment Agreement No.: 14-01-0001-1843

Project Title: Economics of Water Quality Control in the Upper Mississippi River-Minn.

Principal Investigator: Degree: Discipline:
John J. Waelti Ph.D. Agricultural Economics

Student Assistants: Degree: Discipline:
Robert C. Lewis B.S. Agricultural Economics
Richard Hoelner B.S. Agricultural Economics

Project Began: July 1, 1968 Scheduled Completion: June 30, 1971

FCST Category: VI-B

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minnesota 55101

A. Description of research performed & any findings, results, or conclusions relating thereto:

Background work was performed including literature review and information sources, especially relative to costs of waste treatment and sources of physical data. Arrangement was made with the Minnesota Pollution Control Agency to utilize physical data on dissolved oxygen fuels in the Minnesota and Mississippi Rivers under varying flow, effluent, and load conditions. Work was begun on a M.S. thesis by Robert C. Lewis to be entitled "The Marginal Costs of Attaining Water Quality Standards Under Alternative Treatment Strategies."

Relevant information pertaining to technical, economic, and political aspects of water quality was integrated in a publication described in item B.

B. Project-related Publications:

"Understanding the Water Quality Controversy in Minnesota," by John J. Waelti, Agricultural Extension Bulletin No. 349, July 1969, 28 pages.

C. Statement of project work remaining to be accomplished:

A model combining physical and economic data needs to be formulated. The cost of attaining successively higher degrees of dissolved oxygen will be estimated under varying conditions of flow and degree of treatment at alternative locations. A report must be prepared.

D. Additional project progress contemplated for the remainder of calendar year 1969.

It is expected that the model mentioned in item C. will be formulated and perhaps some preliminary computer runs performed. This will be a portion of the work involved in a M.S. thesis by Robert C. Lewis.

OWRR Project No.: A-018-Minn Annual Allotment Agreement No.: 14-01-0001-1843

Project Title: Methodology for Integrating Water Quality Management with Management of the Total Water Resources in Minnesota

Principal Investigator: Degree: Discipline:
Conrad P. Straub Ph.D. Public Health

Student Assistants: Degree: Discipline:
Prem Kishor Saint M.S. Public Health

Project Began: July 1, 1967 Scheduled Completion: June 30, 1970

FCST Category: V-G

Name and Location of University Where Project is Being Conducted:
University of Minnesota, Minneapolis, Minnesota 55455

A. Description of research performed and any findings, results, or conclusions relating thereto:

Additional information was obtained concerning water pollution control activities with a view to establishing the existing situation relative to water quality and total water resources planning within the State. On-the-spot studies were made of water resources management in the Delaware R. Basin, the responsible agency there having been described by Messrs. Kneese and Bower in their recent book "Managing Water Quality:..." as the only agency in the U.S. "authorized to develop a unified approach to water quality management as part of over-all water resources management." A similar study was made of the operations of the Ohio R. Valley Sanitation Comm. (ORSANCO). Literature on water resources management practices in other states (Wisc. for example) and in other countries (Canada, Germany, France and the United Kingdom) has been researched with a view to determining the national and international approaches and establishing the available alternatives that might be considered for application in Minn.

Mr. Gibson, Research Fellow on the project, participated in a workshop on "Applications of Analog Computers in Sanitary Engineering" sponsored by the American Assoc. of Professors in Sanitary Eng. and the School of Eng., Vanderbilt Univ., Tenn. last summer. He also attended a 2-week course on "The Use of Systems Analysis in Water Resources Planning, Development and Management" at the Univ. of California at Los Angeles, that summer. He was associated with the Principal Investigator in organizing and running a workshop on "Applications of Computers in Sanitary Engineering" for State Sanitary Engineers of the Central U.S. during May, 1969. Applications to Water Quality Management and Water Resources Management were given considerable attention.

B. Project-related publications: None.

C. Statement of project work remaining to be accomplished:

The development of methodology for improving the integration of water quality management with that of the total water resource management in the state. The preparation of a report.

D. Additional project progress contemplated for the remainder of calendar year 1969:

The development of methodology mentioned in item C.

OWRR Project No.: A-020-Minn Annual Allotment Agreement No.: 14-01-0001-1843

Project Title: Evaluation of Selected Computer Programs in Hydrology

Principal Investigator: Degree: Discipline:
C.E. Bowers M.S. Civil Engineering

Student Assistants: Degree: Discipline:
C. Henningsgard B.S. Civil Engineering
J. Muller B.S. Civil Engineering
P. Pundarikathan M.S. Civil Engineering
J. Peterson Undergrad. Civil Engineering

Project Began: July 1, 1968 Scheduled Completion: June 30, 1971

FCST Category: II-E

Name and Location of University Where Project is Being Conducted:
University of Minnesota, Minneapolis, Minnesota 55455

A. Description of research performed & any findings, results, or conclusions relating thereto:

The objective of the study proposed herein is an evaluation of some existing computer programs and mathematical models relating to the analysis of storm runoff and flood routing.

Currently, many individuals and organizations are developing new models and programs. While this is commendable, there appears to be a lack of application of these developments to applied hydrologic problems. This is due in part to (1) a lack of communication between the research and design groups, (2) failure to make some developments available in readily usable form, and (3) reluctance on the part of designers to depart from established techniques.

At the recent International Hydrology Symposium at Fort Collins, considerable concern was indicated on the part of consulting engineers as to the lack of communication between the researchers and the practicing engineers. While the results of research are usually published, they may not be readily usable for design purposes. Further, considerable work is necessary to compare various programs, arrive at the selection of one which might be used for specific design problems, and develop confidence in the applicability of the program or method to critical design problems. As a result, the application of research lags very far behind the current research efforts.

In some instances, government agencies have prepared programs for specific areas in which they are interested, and have made them available to cooperating organizations. Examples of this are the Hydrologic Engineering Center of the Corps of Engineers, the Bureau of Public Roads, and the Soil Conservation Service. In some instances, the primary effort has involved preparation of digital computer programs to assist in the solution of established hydrologic procedures. In others, the established methods may be involved, with optimization techniques used to assure the best solution. In still others, new procedures are developed. Relative to the present project, during the past year the primary effort has been devoted to the following: (a) Review of the literature and published information on programs in hydrology and hydraulics, (b) Contacting of organizations and individuals relative to program listings and source decks, (c) Review and study of programs received, and (d) Use of selected programs to assist in evaluating their characteristics. As a result of these efforts, approximately 25 programs have been accumulated. The

primary source of programs in this area has been the Hydrologic Center of the Corps of Engineers, with other contributions from the Soil Conservation Service, the U.S. Geological Survey, the Bureau of Reclamation, the Tennessee Valley Authority, and several universities including the University of Minnesota.

As a result of recommendations by the Water Resources Council for the use of a "Uniform Technique for Determining Flood Flow Frequencies," based on the log Pearson Type III theory, a number of computer programs have been developed. Included among these are programs by the USGS, the Bureau of Reclamation, and the University of Minnesota. Copies of the first two have been obtained and are presently being prepared for use on the CDC 6600 computer. Modification and improvement of the University of Minnesota program was also continued and a description and listing prepared.

Work has continued on four Corps of Engineers programs with the objective of obtaining experience in their use.

B. Project-related publications:

None.

C. Statement of project work remaining to be accomplished:

Approximately 20 per cent of the overall effort remains to be completed. This will consist primarily of use and evaluation of programs on hand but efforts to acquire new programs will continue. A report must be prepared.

D. Additional project progress contemplated for the remainder of calendar year 1969:

During the period July 1, 1969 to December 31, 1969 selected programs will be compiled and used on typical problems.

MATCHING GRANT PROGRAM

Narrative Progress Reports

OWRR Project No.: B-003-Minn Matching Grant Agreement No.: 14-01-0001-889

Project Title: Storage and Movement of Water in Soils as Related to Spatial and Time Changes in the Clay-quartz Matrix.

<u>Principal Investigator:</u>	<u>Degree:</u>	<u>Discipline:</u>
George R. Blake	Ph.D.	Soils Science

<u>Student Assistants:</u>	<u>Degree:</u>	<u>Discipline:</u>
Victor Fuentes	B.S.	Soil Science
Lalit Arya	B.S.	Soil Science
Jiwan Palta	B.S.	Soil Science
James Spicker	Undergrad.	Forestry
Dennis Thompson	Undergrad.	Agronomy
Kenneth Vowels	Undergrad.	Mathematics
Vivian Liden	Undergrad.	Journalism

Project Began: January 1, 1966 Scheduled Completion: February 28, 1969

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minnesota 55101

A. Description of research performed & any findings, results, or conclusions relating thereto:

Soils consist of particles ranging from perhaps 0.1 micron to 2 mm diameter (gravelly soils are an exception). These particles of varying sizes are grouped into domains called aggregates that impart porosity important in storage and movement of water within the soil matrix. The stability of aggregates and thus of the whole matrix is an important consideration for infiltration, runoff, and hence also erodability. Agricultural practices that maintain stable structure are practiced meticulously by careful farmers. Nevertheless, stability is a dynamic property that changes with time because constructive and destructive forces are constantly in process.

In this project two aspects of aggregate stability were studied: (a) Effects of time on reestablishment of interparticle bonding between soil particles pulverized by shearing and formed into synthetic aggregates, and (b) Effect on aggregate stability of quartz in the matrix of synthetic aggregates.

Increase in relative stability of artificially prepared aggregates held at constant water content followed a pattern analogous to a thixotropic sol-gel transformation and strength aging of packed soil. Aggregates were not perceptibly stable to wet sieving at time of formation. Matrix stability of aggregates increased at a rate dependent on water content at which aggregates were stored, on soil type and on storage temperature. High relative stabilities were commonly attained in 24-48 hours at intermediate water contents and at 25°C. Extent of slaking resistance was dependent on aging from time of aggregate formation rather than from time of wetting pulverized soil in preparation for pressing into aggregates. The aging phenomenon was independent of organic matter content and of a viable microflora. Data are compatible with the explanation that orientation of water molecules and associated cation equilibrium, and spontaneous shifting of clay particles to positions of lowered potential

energy account for the build-up during aging.

Silica is found in all soils in varying quantity, but usually in amounts greater than 20% by weight. Sodium silicate is known to be a powerful soil stabilizer even in small quantity. There are indications that on the silica surface there exists a readily soluble monolayer of silicic acid that could be a strong bonding agent in soil aggregates. The extent of this cementing effect was measured on synthetic aggregates made from soil and silica particles. Variables included the quantity, particle size and particle shape of added silica.

Relative stability of synthetic aggregates to which silica was added decreased as the amount of silica increased. The larger the silica particles the greater the decrease. The relationship between these was found to be

$$Y = 0.49 - 0.0002X_1 - 0.009X_2$$

where Y is relative stability, X_1 is size of added quartz and X_2 is percent by weight of added quartz. It is believed that possible long term effects could enter if systems were maintained for periods of perhaps a year or longer but these were not measured. Particle shape of silica had little effect on stability in like amounts and sizes.

B. Project-related Publications:

Blake, G.R. and R.D. Gilman. 1969. Thixotropic Aging of Synthetic Soil Aggregates. Soil Science proceedings.

Chye-Sheng Hwang. M.S. thesis. Role of quartz in clay-quartz bonding in soil aggregates.

C. Statement of project work remaining to be accomplished:

None.

D. Additional project progress contemplated for the remainder of calendar year 1969:

None.

OWRR Project No.: B-007-Minn Matching Grant Agreement No.: 14-01-0001-890

Project Title: Study of Factors Affecting the Channel Phase of Runoff from Small Watersheds by Mathematical Modeling.

Principal Investigator: Curtis L. Larson Degree: Ph.D. Discipline: Agricultural Engineering

Student Assistants:
Pinhas Golany Degree: M.S. Discipline: Agricultural Engineering
Tsong C. Ulei Degree: M.S. Discipline: Agricultural Engineering
Russell Mein Degree: M.S. Discipline: Agricultural Engineering

Project Began: January 1, 1966 Scheduled Completion: February 28, 1969

FCST Category: II-A

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minnesota 55101

A. Description of research performed & and findings, results, or conclusions relating thereto:

A portion of the time during the past year was devoted to completing the calculated routings for junction tests performed in the lab. previously. The procedure developed for this purpose was described in last year's annual report. It involved explicit solutions of the different equations applicable to the unsteady flow, as developed by Stoker, and a series of six simultaneous equations at the channel junction. The input hydrographs to the small rectangular laboratory channels were quite varied in terms of magnitude and relative timing.

The computed hydrographs below the channel junction were found to agree quite closely with the measured hydrographs, both in magnitude and timing, including several cases where reverse flow was produced by backwater. Computer plots of the hydrographs were made for all tests for direct, visual comparison. Stage graphs at selected points and water surface profiles were less accurate but satisfactory. A separate report is being prepared on this phase of the project.

A major part of the year's work was devoted to work with the watershed model. The elementary or first order unit is 0.05 sq. in., which combines with four others of similar size, etc., up to a sixth order watershed of 282 sq. mi. All orders or sizes are geometrically similar, giving an adequate basis for comparing the effect of watershed size from about one sq. mi. to 282 sq. mi. The principal is the same as that used in the Machmeier watershed model but the model itself has been completely reconstructed.

Despite the good results obtained with the explicit routing method for the laboratory channel, major difficulties were encountered when the same procedure was incorporated in the watershed model. The solution of the equations became very sensitive and often unstable, apparently due to the combination of a trapezoidal channel, backwater effects, and the natural sensitivity of the equations. Other investigators have incorporated backwater effects in tidal investigations but only for the case of a rectangular channel.

It was therefore necessary to modify the watershed model further, incorporating a form of the method of characteristics suggested by Lister. This involves an iterative solution with successive approximations for the position of the backward and forward flood waves or characteristic lines. This increases the computer time requirement considerably but appears to be necessary for the trapezoidal channels of the model watershed. Elimination of the backwater effect would, of course, enable one to use the simpler solution. However, the backwater process must be included in the model to determine whether its effect is of any consequence.

B. Project-related Publications:

- (a) R.E. Machmeier and C.L. Larson "Runoff Hydrographs for a Mathematical Watershed Model", Journal of the Hydraulics Division, American Society of Civil Engineers, Vol.94, No.HY6, Nov., 1968, pp 1453-1474.
- (b) Manuscript in preparation "Calculated and Observed Hydrographs for Laboratory Channels Above and Below a Channel Junction".

C. Statement of project work remaining to be accomplished:

None.

D. Additional Progress Contemplated for the remainder of calendar year 1969:

Experiments with the watershed model will be completed, using a steady input and running until the watershed approaches equilibrium to determine, in

each case, the time required to reach virtual (97%) equilibrium, mean travel time and similar parameters indicating watershed response time. A series of tests will be run for each of several channel characteristics to determine its effect on the time parameters. A comprehensive report of these results will then be prepared.

OWRR Project No.: B-009-Minn Matching Grant Agreement No.: 14-01-0001-1515

Project Title: Relation of Phosphorus in Lake-bottom Deposits and Pollutional History of Minnesota Lakes.

Principal Investigator: Joseph Shapiro Degree: Ph.D. Discipline: Zoology

Student Assistant: Stephen Taryschak Degree: M.S. Discipline: Limnology

Project Began: July 1, 1967 Scheduled Completion: June 30, 1970

FCST Category: V-C

Name and Location of University Where Project is Being Conducted: University of Minnesota, Minneapolis, Minnesota 55455

A. Description of research performed & any findings, results or conclusions relating thereto:

The work on a new analytic procedure for evaluating individual fractions of phosphorus rather than phosphorus as a whole was continued. The phosphorus fractionation studies have been extended and applied to other lakes, including studies on samples from Lake Washington, near Seattle, which were supplied to us by Professor W.T. Edmondson. Although this is not a Minnesota lake, it has been studied very intensively and it is felt that findings on Lake Washington relative to its recent history will be of value in interpreting results in Minnesota lakes where the history is less well documented.

In analyzing phosphorus fractionation data, it is becoming increasingly clear that the only fraction that seems to be mobile, i.e. that is likely to influence the productivity of lakes, is the acid soluble fraction, for it is only from this fraction that phosphorus is released upon reduction. In addition, not all of this fraction is mobile, the percentages varying from about 40 percent to 100 percent. In an attempt to determine the reason for this variability, the Principal Investigator tried to use soil fractionation schemes for iron phosphate, calcium phosphate, and aluminum phosphate, but with little success. Currently he is approaching the problem in a more indirect fashion, by determining the dependence of the percentage phosphorus that can be released from the acid soluble fraction, on the total content of Fe, Ca, and Al. A large series of lakes was selected with varying concentrations of these elements and samples are being collected and analyzed.

B. Project-related publications:

Shapiro, J., W. Chamberlain and J. Barrett. 1969. Factors influencing phosphate use by algae. *Water Research* 2: 12 pp.
Chamberlain W. and J. Shapiro. On the biological significance of phosphate analysis - two methods for its improvement. Submitted to the

Journal of Limnology and Oceanography.

C. Statement of project work remaining to be accomplished:

Further work will include studies of phosphorus profiles and their relation to the pollution history of lakes, as well as reduction studies to determine the availability of phosphorus to a lake from its bottom sediments under various conditions. A report must be prepared.

D. Additional project progress contemplated for the remainder of calendar year 1969:

The next few months will be devoted mostly to further analyses of Fe released by reduction vs. Ca, Al, Fe content of bottom sediments.

OWRR Project No.: B-010-Minn Matching Grant Agreement No.: 14-01-0001-1516

Project Title: A study of techniques for determining changes in phytoplankton in clouds of fluorescent dye moving in the Mississippi R.

Principal Investigator: C.D. McNabb Degree: Ph.D. Discipline: Botany

Project Began: July 1, 1967 Scheduled Completion: June 30, 1969

FCST Category: V-C

Name and Location of University Where Project is Being Conducted: St. Mary's College, Winona, Minnesota 55987

A. Description of research performed & any findings, results, or conclusions relating thereto:

A cloud of Rhodamine WT fluorescent dye was released from a stable platform in the Mississippi River channel. Its resulting changes in geometrical configuration were plotted utilizing a boat with a continuous flow Turner Fluorometer. A mathematical model of the cloud was derived using three-dimensional parameters readily ascertained from fluorometer readings, sonar depth readings and aerial photogrammetry. Population dynamics, within the cloud as it traveled downstream, were determined by sampling from within the homogeneous main body of the cloud with the aid of membrane filter counting techniques originated by one of the investigators during previous work. Having a working estimate of the changes in cloud volume allows for analysis of the changes in plankton populations as a water mass moves downstream. Statistical analysis of these data show that the mean concentration of individuals within the tagged population varied proportionately with the populations within the diluting water. Cloud expansion into well mixed water masses along a course of travel influences mean densities of populations as they move from one marked transect to another. Three organisms were under investigation simultaneously. Population dynamics of *Melosira*, *Stephanodiscus*, and *Cyclotella* were ascertained in each run. The techniques derived allow for insights regarding the dynamics of moving plankton populations not previously applied in limnological literature. Potential applications of results are the determination of plankton contributions into channels as indicators of productivity of the sloughs; determinations of die-off rates of bacteria from varying pollution sources; effects of introduced pollutants on plankton and bacterial populations in transit UNDER FIELD CONDITIONS. The investigators feel that other poten-

tial uses will arise as future investigators use the technique.

B. Project-related publications:

Research findings will be published in a formal report later during the current year. The paper is nearing completion and will be submitted to the Journal of Limnology and Oceanography.

One Master's degree thesis will result from this investigation. A copy will be presented to OWRR upon completion within the next eight weeks.

C. Statement of project work remaining to be accomplished:

None.

D. Additional project progress contemplated for the remainder of calendar year 1969:

None.

OWRR Project No.: B-012-Minn Matching Grant Agreement No.: 14-01-000-1914

Project Title: Development of a mathematical model to predict the role of surface runoff and groundwater flow in overfertilization of surface waters.

Principal Investigator: Degree: Discipline:
Conrad P. Straub Ph.D. Public Health

Student Assistants: Degree: Discipline:
Alan Tupy Undergrad Chemistry
Kirk English Undergrad Civil Engineering
Jack Johnson M.S. Public Health

Project Began: July 1, 1968 Scheduled Completion: June 30, 1970

FCST Category: V-B

Name and Location of University Where Project is Being Conducted:
University of Minnesota, Minneapolis, Minnesota 55455

A. Description of research performed & any findings, results, or conclusions relating thereto:

A 23 square mile watershed at New Prague has been selected as the prime test watershed and has been fully instrumented at two sites. These sites are instrumental with a continuous stream stage recorder and one of the automated samplers which collects 600 ml samples daily and at 4-inch intervals of stream stage change. One fully instrumented site is at the watershed outlet and this site also has a continuous rain gage installed. The other instrumented site is at Sta. 34 on the urban fork of the creek. In addition, several sites are sampled by hand with the depth integrating sediment sampler, and streamflow is normally determined at the same time. Agricultural tile drains are also sampled. To date, approximately 100 samples have been analyzed and they are presently being collected at a rate of 20 to 40 samples weekly. Although there has been no actual development on the model, per se, approximately 400 documents have been catalogued and are being reviewed as possible data sources. In addition, several investigators have been

contacted and it is anticipated that some unpublished data will be made available.

B. Project-related publications:

None.

C. Statement of project work remaining to be accomplished:

The mathematical model to describe the nutrient output must be developed, programmed into the analog-digital hybrid computer, and tested against the New Prague data. A report must be prepared.

D. Additional project progress contemplated for the remainder of calendar year 1969:

It is expected that data collection will be complete; several hydrologic models describing surface runoff will be selected and tested against the 9 years of available precipitation-streamflow records; sediment yield models will be tested, and nutrient yield parameters will be documented.

OWRR Project No.: B-013-Minn Matching Grant Agreement No.: 14-01-0001-1914

Project Title: Influence of mist irrigation on moisture stress, growth yields, and quality of potatoes and other vegetable crops.

Principal Investigator: Degree: Discipline:
Robert E. Nylund Ph.D. Horticulture

Student Assistants: Degree: Discipline:
Douglas Sanders M.S. Horticulture
Edgardo Quisumbing M.S. Horticulture
James Brown ---- General College
Carolyn McWilliams Undergrad Home Economics

Project Began: July 1, 1968 Scheduled Completion: June 30, 1971

FCST Category: V-B

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul Minnesota 55101

A. Description of research performed & any findings, results or conclusions relating thereto:

The influence of mid-day mist irrigation on the reduction of environmental water and temperature stresses and on growth and development of potato plants were studied. Air temperatures throughout the plant canopy, plant temperatures, and soil temperatures were recorded at one-half hour intervals daily principally between the hours 0700 and 2100. Soil moisture was recorded thrice weekly. While the results of these measurements are still being evaluated, it can be reported that mist irrigation reduced leaf temperatures by 2 to 16°C.

The reduction of temperature and moisture stresses by mist irrigation resulted in increased potato plant growth and increased total yields of tubers. Tuber defects such as hollow heart, growth cracks, and secondary growths were increased by misting but in spite of these defects yields of

U.S.#1 grade tubers were higher than from non-misted plants. Chipping quality of tubers was decreased, an effect that is being studied further.

The influence of mist irrigation on nutrient content of potato leaves and petioles was studied. Zinc concentration was found to be greatly increased in both leaves and petioles. An explanation for this response is being sought by further studies.

Results of a $^{14}\text{CO}_2$ feeding study indicates that misted plants have a higher photosynthesis rate. Analysis of the experimental plants indicate that reduction of moisture stress by misting results in greater free amino acid production.

B. Project-related publications:

None

C. Statement of project work remaining to be accomplished:

Growth and developmental responses of the potato to reduction of moisture and temperature stress by mist irrigation will be studied in greater detail. Studies will be conducted to determine the specific cause(s) for increased zinc content of leaves, reduced chip quality and increased yields of tubers. Further growth responses at the cellular level will be studied. Changes in the micro-environment of the plant that result from mist irrigation will be characterized.

D. Additional project progress contemplated for the remainder of calendar year 1969:

Work will primarily consist of completion of the evaluation of data at hand and that which will be collected during the current summer.

OWRR Project No.: B-015-Minn Matching Grant Agreement No.: 14-01-0001-;0;6

Project Title: Characteristics of the Soil Matrix that Affect Water Storage and Movement.

<u>Principal Investigator:</u>	<u>Degree:</u>	<u>Discipline:</u>
George R. Blake	Ph.D.	Soil Science

<u>Student Assistants:</u>	<u>Degree:</u>	<u>Discipline:</u>
Victor Fuentes	B.S.	Soil Science
Lalit Arya	B.S.	Soil Science
Jiwan Palta	B.S.	Soil Science
James Spicker	Undergrad	Forestry
Dennis Thompson	Undergrad	Agronomy
Kenneth Vowels	Undergrad	Mathematics
Vivian Liden	Undergrad	Journalism

Project Began: January 1, 1969 Scheduled Completion: December 31, 1972

FCST Category: II-G

Name and Location of University Where Project is Being Conducted:
University of Minnesota, St. Paul, Minnesota 55101

A. Description of research performed & any findings, results, or conclusions relating thereto:

sions relating thereto:

Apparatus was acquired and partly fabricated to precisely measure thixotropic aging effects on soil moisture tension in pressed soil briquets on aging. The measuring system consists of a miniature tensionmeter, the porous ceramic cylinder being 6 mm. O.D. by 30 mm length. Water connection to a pressure transducer is via polyvinyl tubing 0.063 inch O.D. The micro-volt output of the transducer is wired to a Kipp recorder. The pressure transducer itself is a Dynisco model PT-25 with a very low temperature sensitivity. At its maximum excitation potential of 6 volts we can read pressures from zero to minus 232 mb with a precision of 2.3 mb. Range can be extended by using a higher voltage but there is a concomitant decrease in precision.

Pulverized, remoistened soil is pressed in a brass chamber by an air-actuated rubber piston at 3.44 kg/cm² for one minute. Pressure stress is then removed from the soil and the moisture tension recorded on the transducer-recorder system with time. In practice twelve tensiometers are handled by the recorder system by running them through a zero displacement valve. A synchronous motor switches the solenoid-actuated valve each 3 minutes thus allowing the pressure on each tensiometer to reach the transducer-recorder the 3 minutes out of each 36 minutes. Three sensors are placed in each pressed soil sample; the remaining are placed in water reservoirs of known pressure head with respect to the recording system. Though there has been very little instrument drift with time, these interspersed readings at known pressures allow correction for the pressures recorded in the soil briquet. Initially there were difficulties in maintaining air free connecting tubes. But these have been overcome by use of de-aired water and maintenance of equipment at constant temperature. Measurements of matric potential during thixotropic aging using this measuring system are in progress.

Earlier research (OWRR Project No. B-003-Minn., terminated February 28, 1969) has shown a thixotropic matric stability increase with time after formation of synthetic soil aggregates. In order to test practical implications of this fact, we hypothesized that shearing of soil by plowing might weaken matric stability temporarily. Portable testing equipment was assembled and a number of trips to different soil areas was made the months of April and May 1969. Aggregates were collected by sieving immediately upon plowing. They were stored against water loss for various times and stability to wet sieving determined. On four soil types relative stability of freshly sheared aggregates did indeed increase with time. Analysis of data and testing of other aspects of the phenomenon are proceeding. The fact has a number of practical implications to be explored and elaborated.

B. Project-related publications:

None

C. Statement of project work remaining to be accomplished:

This project was actuated only 6 months ago. Objectives are to investigate:

- (a) water storage and release from the soil as related to the matrix characteristics, and
- (b) reactions occurring between water, clay and quartz during initiation, growth and stabilization of domains in the soil matrix that affect the storage and movement of water.

These research objectives will be pursued by continuation of studies on water potentials in thixotropically aging soil briquets, by investigations of practical implications of matric stability related to shearing by the plow and by measurements of the effectiveness of asphalt moisture barriers in reducing irrigation need or in increasing efficiency in use of natural rainfall on sandy soils.

D. Additional progress contemplated for the remainder of the calendar year 1969:

Time dependent changes in soil water potential in soil briquets will be determined and summarized and a thesis will be written.

Study of effects of plow shearing on matric stability will be completed and a thesis will be written.

A second year of data on water needs of four vegetable crops with and without an asphalt moisture barrier and its effects on production and vegetable quality will be obtained.

A beginning on the measurement of hydraulic characteristics of soils altered by layering will be made.

Training And Educational Aspects
Of Program

University of Minnesota

New Courses Developed

School of Public Health

Although no new courses were developed during the fiscal year 1968-1969, revisions were made to update the three existing courses (Public Health 233, Public Health 234, and Public Health 200). During the summer sessions instruction was provided for 19 full time students and 3 Visiting Scientists.

Among other groups who benefited from the summer program at Duluth were the following:

1) A group of 25 graduate students (chemists, biologists, and engineers) in the School of Public Health spent a two-day session at the Lake Superior Research Station for orientation to aquatic biology and water pollution problems.

2) A total of 73 students (in groups ranging from 18 to 30 persons) from Bemidji State College, St. Cloud State College, and the Wisconsin State College system, Pigeon Lake Station. Each group spent a one-day session at the Lake Superior Research Station to learn about water quality investigation techniques and water pollution studies.

3) A group of eight chemists, mining engineers, and laboratory personnel from Reserve Mining Company visited the laboratory for discussion of techniques.

4) Smaller groups of interested persons also have made visits to learn of the research program at Duluth. Among these were Dr. Richard Myshak, Director, Environmental Science Center of Golden Valley, Minnesota, and his associate, Dr. John Staba. Graduate students from the University Department of Pharmacognosy also visited the laboratory.

Civil Engineering

Civil Engineering 169, Lake, Reservoir and Ocean Hydrodynamics. Transport and dispersion of mass, momentum and heat in large natural bodies of water. Hydrodynamics and design of water withdrawal and recharge facilities. (3 cr.) Dr. Heinz Stefan.

Limnology

Field course in advanced limnology, emphasizing organic productivity, will be offered by Dr. R. O. Megard at the University of Minnesota Biological Station at Itasca State Park.

Agricultural Engineering

Agricultural Engineering 10, Water Supply and Irrigation in Developing Countries, (3 cr.) (New course, intended primarily for nonengineers)

Mechanized Agricultural Engineering 84, Hydrology, Water Control, (3 cr.) (Revision of existing course to place greater emphasis on water resources)

Mechanized Agricultural Engineering 106, Agricultural Waste Management, (3 cr.) (New course)

New Staff Members Added

R.O. Megard, Ph.D., Assistant Professor, Department of Geology and Geophysics - received salary from P.L. 88-379 funds.

R.C. Bright, Ph.D., Assistant Professor, Department of Geology and Geophysics - received salary from P.L. 88-379 funds.

B.G. Crewdson, Extension Specialist in Resource Development

School of Public Health

No new faculty members were added to the school. However, two visiting lecturers were brought to Duluth to supplement the teaching program. One of these was Dr. Wolfgang Fuhs, Senior Water Pollution Scientist, Division of Laboratories and Research, New York State Health Department. The other lecturer was Dr. Hugh D. Putnam, Associate Professor, Department of Environmental Engineering, University of Florida.

Staff members employed to replace those who retired, died or moved

None

New research and training facilities other than research equipment items

Completion of the newly constructed Life Sciences Building on the University of Minnesota, Duluth Campus has provided additional laboratory space and lecture facilities in the current fiscal year. Temperature controlled rooms for algal and invertebrate culture and a new radioisotope laboratory are included in these facilities now available to the Lake Superior Research Station.

Interdepartmental, interuniversity or regional agreements consummated with respect to improved research and training capabilities.

Arrangements for St. Cloud State College to Participate in Center's Program:

The Center and the University will enter into a written agreement with St. Cloud State College, St. Cloud, Minnesota, to permit that Institute to participate in the work of the Center should the matching grant proposal from that Institute be approved by your office. The Business Administration Office of St. Cloud College will be responsible to the Business Administration Office of the University of Minnesota in fiscal matters. The Center will assume responsibility for planning, work performance, and reporting on its entire program, including St. Cloud's project. The Vice President, Business Administration, is the officer of the University concerned with the fiscal responsibility and accounting of the Center. The Director has the responsibility for reporting on the technical and scientific aspects of the program of the Center. According to the Rules and Regulations, St. Cloud State College will not have the status of a subordinate contractor, but rather will have the status of a participant in the Center eligible for support through the allotments and/or matching grants.

The Memorandum of Agreement given below will be executed should the matching grant proposal be approved for funding.

MEMORANDUM OF AGREEMENT BETWEEN

REGENTS OF THE UNIVERSITY OF MINNESOTA AND ST. CLOUD STATE COLLEGE

WHEREAS: The Regents of the University of Minnesota with the collaboration of St. Cloud State College with the Water Resources Research Center, University of Minnesota, in conducting a research project entitled "Mississippi River Ecology Associated with Heated Power Plant Effluent"

AND

WHEREAS: St. Cloud State College is willing to cooperate with the University of Minnesota Water Resources Research Center in carrying out this research.

THEREFORE: Subject to the award of grant funds from the U.S. Department of the Interior, Office of Water Resources Research in support of the study, the collaboration between the parties to this agreement during the period from July 1, 1969 through December 31, 1972, will be governed by the terms and conditions as follows:

1. Integration of the research with that of the Center: In keeping with the spirit of the law under which the Center was established, the proposed program has been selected for inclusion in the activities of the Center upon the recommendation of the Center Director, in consultation with the Advisory Committee of the Center. Further planning and work performance in connection with the study will be coordinated through the Center Director's Office.
2. Institute responsibility for the planning, work performance, and reporting of the project: The Center Director or his authorized representative will conduct periodic site visits to consult with the principal investigator and furnish such advice and assistance as will best promote the purposes of the Center program.

St. Cloud State College will provide the University of Minnesota with annual progress and financial reports and other periodic reports as required in accordance with the Rules and Regulations pursuant to the Water Resources Research Act.

Grant funds will be forwarded to St. Cloud State College, pursuant to its vouchers, on a quarterly basis only in such amounts as are required to liquidate liabilities connected with the research due and payable during the time period to which the voucher pertains.

Expenditures of grant funds shall be made in accordance with the Rules and Regulations pursuant to the Water Resources Research Act.

ST. CLOUD STATE COLLEGE

REGENTS OF THE UNIVERSITY OF MINNESOTA

Signature _____

Signature _____

Name and Title of Official _____

Name and Title of Official _____

_____ Date

Student enrollment in water-related fields during period July of last year (summer term) through June of this year (spring term)

	No. Enrolled		No. Graduating		Total
	not appli- cable	With OWRR Support	Without OWRR Support		
(1) Juniors	---	---	---	---	---
(2) Seniors (Bachelor's degree candidate)	25	3	17		20
(3) Master's degree students	36	4	14		18
(4) Doctoral degree students	26	3	10		13
(5) Postdoctoral degree students	0	0	0		0

Number of students using equipment and supplies purchased wholly or in part with P.L. 88-379 funds.

Category of Students	No. Using Equipment, Supplies, etc.
(1) Undergraduates	15
(2) Master's students	10
(3) Doctoral students	15
(4) Postdoctoral students	2

Number of students receiving employment through the P.L.88-379 program. (Include only those students paid wholly or in part with P.L.88-379 funds.)

Category of Students	No. by Scientific Discipline or Major Field of Study (Engineering, Biology, Economics, etc.)	
(1) Undergraduates	Soil Science	4
	Civil Engineering	3
	Public Health	7
	Agricultural Economics	2
	Horticulture	2
(2) Master's Students	Civil Engineering	3
	Soil Science	3
(3) Doctoral students	Public Health	5
	Geology and Geophysics	3
	Horticultural Science	2
	Agricultural Engineering	3
	Horticulture	2

Employment status of major in water-related fields who graduated during the school year ending about June

EMPLOYMENT STATUS	CATEGORY OF SCHOOL YEAR GRADUATES BY DEGREE OBTAINED			
	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
No. employed in water-related positions in:				
Federal Agencies- - - - -		1	0	1
		3	2	5
State Agencies- - - - -		1	0	1
		2	1	3
Colleges & Universities - - - - -		0	2	2
		2	5	7
Other-Such as Private - - - - -		0	1	1
		1	2	3
		2	0	2
No. graduates returning to school for advanced degree - - - - -		5	0	5
No. going into military service - - - - -		0	0	0
		1	0	1
No. unemployed or working in other fields- - - - -		0	0	0
		0	0	0
No. status unknown - - - - -	3	0	0	3
	17	0	0	17
Totals - - - - -	3	4	3	10
	17	14	10	41

Note: Graduates who received OWRR support above dotted line, and those who received no financial support from OWRR below the dotted line.

Type of employment of those school year graduates known to have gone into water-related positions.

No. of Graduates engaged in water-related work in:	CATEGORY OF SCHOOL YEAR GRADUATE BY DEGREE OBTAINED			
	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
University or College:				
Teaching Primarily-----		0	0	0
		2	0	2
Research Primarily-----		0	0	0
		0	0	0
Research & Teaching-----		0	2	2
		0	5	5
Agency or Private Water Resources Research-----		1	1	2
		2	3	5
Operations and Management-----		1	0	1
		2	1	3
Planning-----		0	0	0
		1	1	2
Other Water Resources Work:				
Unknown-----	3	0	0	3
	17	1	0	17
TOTALS-----	3	2	3	8
	17	8	10	35

Note: Graduates who received OWRR support above dotted line and those who received no financial support from OWRR below dotted line.

Identify by name and discipline and briefly describe instances, if any, in which the institute program, in the past year, has resulted in individuals, other than students, doing research or teaching in the water resources field who, previously, were not involved in water work.

None

Cite any instances you know of in which individuals who previously served as student research assistants on P.L.88-379 projects, are now serving as professional investigators of P.L.88-379 projects following graduation. Do not include individuals reported in this category last year or before.

None