

Eleventh 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
During the Fiscal Year Ending
June 30, 1975

Water Resources Research Center
University of Minnesota
1975

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

July 1975

Minneapolis, Minnesota

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

CONTENTS

	page
Preface	ii
Director's Section	1
Introduction	1
Director's Summary Statement, 1975	13
Examples of Selected Research Findings and Their Actual or Potential Application to Water Resources Problems	15
Compliance with Consultation and Collaboration Provisions of Section 100(b) P.L. 88-379 as Amended by P.L. 92-175	17
Information Dissemination	22
Information Concerning Research Project Proposals Submitted to OWRT by Center, FY 1976	28
Fiscal Year 1975 OWRT Budget	30
Annual Allotment Program	32
Narrative Progress Reports	32
Matching Grant Program	51
Narrative Progress Reports	51
Title II Grant Program	73
Narrative Progress Report	73
Program Under P.L. 88-379	75
Project Related Reports and Theses Published During 1975. .	79

PREFACE

This is the Eleventh 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, 1974, and ending June 30, 1975, with funds provided by the Graduate School and the Office of Water Research and Technology 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 extend 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.

This Bulletin is related to the Center Director's Office fiscal year 1975 program and to OWRRC Annual Allotment Agreement No.: 14-31-0001-5023.

FCSIT-COWRR Research Category: 00-D

Publication Abstract:

The fiscal year 1975 budget of the Center was \$378,584. The Center supported 12 research projects involving 9 faculty members. These research projects were concerned with: developing a water resources research plan for Minnesota; developing indices for establishing water supply quality status and trends in Minnesota; analyses of organic carbon as a pollution index in Minnesota; spatial and temporal variation of precipitation in Minnesota; forecasting rainfall and snowmelt floods; determining the geochemical and biostratigraphic record of natural and pollution eutrophication of Minnesota lakes; bio-manipulation of Minnesota lakes for elimination of blue-green algae; determining the thermal pollution and second trophic level fauna in Lake Superior; social trends of water quality status and trends in Minnesota; assessment of water quality status and trends in Minnesota by remote sensing techniques; and hydronomic analysis of forest management alternatives for environmental quality. About 37 students received employment through the Center's program. During fiscal year 1975, there were 26 reports generated through research projects.

Publication Descriptors: *Research/ *Water Resources/ *Minnesota/ Education/ Projects/ Expenditures Manpower/ Water Management/ Water Pollution/ Water Resources Research Act

Publication Identifiers: *Researchers/ *Applied Research/ *Basic Research/ Physical-Biological-Economic-Social Aspects/ Faculty

WATER RESOURCES RESEARCH CENTER UNIVERSITY OF MINNESOTA GRADUATE SCHOOL

Annual Report to
Office of Water Resources Research (OWRR)
for Fiscal Year ending June 30, 1975
Part I - Narrative Progress Reports

DIRECTOR'S SECTION

INTRODUCTION

The origin, history, organizational structure, functions, goals, objectives and programs of the Water Resources Research Center are described below.

Origin and History

One of the most significant recent changes in higher education is the phenomenal growth of offices, bureaus, centers, laboratories and institutes. Developed in response to increased demands for the application of academic research to the social and technical problems of the nation, more than 5,000 institutes and centers are now in operation at universities and colleges.^{1/} No easy description of these additions to the academic landscape is possible. They carry out a bewildering variety of purposes, use many different organizational models, are supported at widely disparate levels of investments, are sometimes housed in obscure corners of the campus, and are found at all levels of the organizational hierarchy. Most institutes and centers began their work since World War II.

The growing demands for research and public service, as well as education have undoubtedly contributed to the proliferation of institutes and centers. Recognition that research was not only useful but perhaps essential to progress in this scientifically and technologically advanced age resulted in a dramatic increase in governmental and other support for university-based research. Changing societal needs and the growth of organized research in universities were accompanied by the expectation of sponsors that efforts would be task-oriented rather than discipline-oriented. The task, in turn, frequently required cross-disciplinary collaboration of individuals and a different organizational environment which maximized coordination and offered less professional autonomy than did the typical academic department.

Some degree of support from three sectors - agencies outside the university, the faculty and university administrators - was usually present in the formation of an institute or center. Increased Federal support, in combination with the growing reliance on universities by State governments, private foundation, business and industry, contributed very substantially to a major redefinition of the role of research in the university. The

^{1/} Ikenberr, S.O. and R. C. Friedman. 1972. Beyond Academic Departments. Jasssey-Bass Inc., Publishers. San Francisco, Washington and London

emergence of research centers reflects, in part, attempts of universities to accommodate this newly defined mission.

The Water Resources Research Center at the University of Minnesota was established on September 1, 1964 directly as a result of Federal legislation. The Center was created shortly after the Federal Water Resources Research Act of 1964 was approved on July 17, 1964. That Act called for the establishment of one Water Resources Research Center or Institute in each State to be located at the land-grant college or university. Continuing financial support was pledged to the newly established centers under Title I of the Act. It was the purpose of the Act to stimulate, sponsor, provide for, and supplement existing programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and of resources which affect water. Emphasis was placed on cross-discipline task or problem-oriented research and training.

Concern about a Water Resources Research Center at the University of Minnesota started on May 31, 1962 as a consequence of a letter from Senator Clinton P. Anderson to University of Minnesota President O. Meredith Wilson requesting information on water related research which could be used to appraise the need for Federal legislature leading to the passage of a Water Resources Research Act. During the period May 31, 1962 through August 3, 1964, numerous meetings were held on the campus involving many university officials and faculty members. The purposes of the meetings were to: formulate purposes, objectives and organizational arrangements for a Center, make preparations for a Center to participate in the programs associated with the Water Resources Research Act of 1964, and to retain a Center Director. On August 4, 1964 a proposal for the establishment of a Water Resources Research Center was agreed upon by various ad hoc committees, the Dean of the Graduate School and the Vice President for Academic Administration. A Director was retained to establish the Center on September 1, 1964. The Center has functioned during the period September 1, 1964 through June 30, 1975 following, in general, the provisions of the proposal.

Organizational Structure

The contract model adopted by the Federal government is largely responsible for the adaptive organizational structure of the Water Resources Research Center. The Center undergoes a continuous process of initiating and terminating projects; it has only a small managerial staff. The professional staff for research projects is drawn from the faculties of the University of Minnesota and State and Private Colleges. The Center has a small office of its own; it does not have a laboratory or library nor does it house any research equipment. Professional staff members do not have any long-term career identification with the Center. The Director, with the assistance of an Advisory Committee, is responsible for the effective operation of the Center. The organizational structure of the Center is designed to maintain flexibility in personnel commitments, space, equipment and other resources sufficient to make major changes in the tasks pursued as well as in the procedures followed. The

desire to strengthen graduate education and research programs figures prominently in having the Water Resources Research Center function as a unit of the Graduate School. The Center is effective in generating needed external income for graduate education and research. Some have likened the university to a federation, composed of departments, colleges, schools, institutes, and centers, each going its own way and following its own interests. Much of the strength of the university as well as much inefficiency and vulnerability result from these conditions. The Center provides one means of preserving the strengths of this federated diversity among departments and individual faculty members while reducing the negative consequences through increased cross-departmental communication and coordination in the field of water resources.

The Center has functioned with a part-time Director, an Assistant Director, Research Accountant, Property Accounting Officer, and a full-time Secretary. As of October 1, 1974, upon the resignation of the Director, the Assistant Director assumed duties as Acting Director. The Acting Director has a 12-month academic appointment as an Associate Professor in the Department of Agricultural and Applied Economics.

A Research Accountant in the Research Accounting Department of the University's Business Office serves on a part-time (10 percent) basis as the Center's Accountant. A Federal Property Specialist in the Property Accounting Department of the University's Business Office serves on a part-time (5 percent) basis as the Center's Property Accounting Officer. The Vice President for Finance, Planning, and Operations is the officer of the University concerned with the fiscal responsibility and accounting of the Center.

The Center does not have a research personnel nor does it have research facilities. It plans and arranges for faculty members in units of the University of Minnesota and State and Private Colleges to conduct research. Thus, the Center strengthens research activities in existing units of the University of Minnesota and State and Private Colleges and assists in expanding cross-disciplinary, multi-disciplinary and interdisciplinary research. Research equipment is assigned by the Center to units of the University of Minnesota and State and Private Colleges. All research personnel are housed in academic units.

In October 1964, the Water Resources Research Center established an Advisory Committee and a Consulting Council. The Advisory Committee consisted of 15 faculty members from 15 Schools, Departments and Divisions of the University of Minnesota; the Consulting Council was composed of 19 representatives from organizations outside the University. The Advisory Committee counseled with the Center Director, helped identify research needs, assisted in selected research projects the Center sponsored, assisted in identifying needed research, assisted in integrating and coordinating University research with water resources projects outside the University, assisted in acquainting the Center with water resources activities in the State, and provided public liaison.

During the period October 1964 through August 1965, the Advisory Committee met once a month. The Advisory Committee met once every three months during fiscal years 1966 and 1967; twice a year during fiscal years 1968, 1969, and 1970; once a year during fiscal years 1971 and 1972; twice during fiscal years 1973 and 1974; and once during fiscal year 1975.

Joint meetings of the Advisory Committee and Consulting Council proved to be successful and it was deemed appropriate that the Center consolidate the Committee and Council into a single new Advisory Committee. The membership of the new Advisory Committee, activated in fiscal year 1973 and expanded in fiscal years 1974 and 1975, reflects the need for greater representation from the social sciences, State and Private Colleges, Interest Groups, and State Agencies. Changes in the Advisory Committee membership were made to improve coordination between faculty members and Federal, State and Private organizations, and to assure that the Center programs are developed in close coordination and collaboration with leading water resources officials within the State. Advisory Committee members are appointed by the Center Director in consultation with the Dean of the Graduate School. The new Advisory Committee generally meets twice a year; rotation of some members will occur every three years to provide widespread representation. The Advisory Committee reviews the Center's programs and makes recommendations concerning activities and research needs and priorities; assists the Center in coordinating its programs with water resources programs of other organizations within the State; provides public liaison; and assists the Center in information dissemination.

Functions

Many functions are carried out by the Water Resources Research Center emphasizing the application of knowledge and the solutions of problems. The special ability of the Center to facilitate cross-disciplinary, multi-disciplinary and interdisciplinary research collaboration is regarded as one of the prime justifications for its existence. Several factors have contributed to the growing emphasis on multi-disciplinary research. The so-called knowledge explosion contributed to the fragmentation of disciplines into new and important specialties and to the emergence of new cross-disciplinary relationships. The second major push toward interdisciplinary collaboration has been the increased demand for applied knowledge to solve scientific, technical and social problems. Problem-solving cannot necessarily be restricted to disciplinary boundaries.

The nature of the Center's interdisciplinary involvement and the extent of interdisciplinary collaboration in the Center's programs can be described as follows. The Center involves faculty members from different disciplines; individuals tend to work independently on separate aspects of a larger problem. There is an overall, integrative design to the total enterprise, but substantial autonomy is granted each researcher in the design and direction of separate phases of the effort.

Center resources are distributed among the functions of research, public service, and instruction. Research and public service are the primary or predominant functions. Estimated distribution of resources among functions are: research - 93 percent, public service - 6 percent and instruction - 1 percent.

The Center does not perform research, it administers and facilitates research. The Center is administratively responsible for the research carried out under its sponsorship; the research is actually "produced" in various academic departments. The principal task is to coordinate efforts and ensure accountability to funding agencies. Research programs on the problems of water quantity and quality require competencies from several disciplines, and as problems shift over time, the specific professional talent, equipment and facilities required also change. As a result, the Center supports faculty members from several departments, all of whom maintain their principal identification with their departments. The task of maintaining and coordinating these complex interpersonal and organizational relationships is considerable. The Center facilitates research by referring sponsors of disciplinary research to departments, providing statistical and research design consultation assistance, making available research equipment, and helping move good research ideas into proposal form.

The Center is not involved in the administration of public service, it is involved in the performance and facilitation of public service. The Center publishes and distributes Bulletins, Information Circulars and a Newsletter and sponsors seminars and conferences. The primary purpose of the Center's public service is to disseminate information concerning the Center's programs and the results of its research projects. The Center facilitates public service by offering guidance and technical advice

to agencies which provide direct delivery of public service like the Cooperative Extension Division.

The Center does not perform or administer instruction but it does facilitate instruction. The Center facilitates graduate and undergraduate education programs by providing employment for students.

Goals and Objectives

The successes or failures of the Center can be appraised by comparing the Center's goals and objectives and the results of its programs. The Center's goals and objectives as of June 30, 1975 were as follows:

- * Apply academic water resources research to the social and technical problems of the State and nation.
- * Stimulate University of Minnesota and State and Private College water resources research through administration of funds associated with the Federal Water Resources Research Act of 1964.
- * Coordinate Center research programs with programs of local, State and Federal agencies and private organizations throughout the State and nation.
- * Disseminate information concerning the Center's programs and the results of its research projects.
- * Facilitate cross-disciplinary, multi-disciplinary and interdisciplinary water resources research collaboration.
- * Strengthen water resources research programs of academic departments by referring sponsors of disciplinary research to academic departments, providing statistical and research design consultation assistance, making available research equipment, and helping move good research ideas into proposal form.
- * Facilitate graduate and undergraduate water resources education programs by providing employment for students and stimulating educational offerings.

Programs

Funds to support the Center's research, public service, and instruction programs have been obtained from the Office of Water Resources Research (OWRR), U. S. Department of the Interior and the State through the University of Minnesota and State and Private Colleges. With the exception of a small amount of continuing support funds from the Graduate School, all of the funds are associated with the Federal Water Resources Research Act of 1964. The Office of Water Resources Research administers funds connected with that Act.

The purpose of the Act was to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and of resources which affect water in order to assist in assuring the nation at all times of a supply of water sufficient in quantity and quality to meet the requirements of its expanding population. In part, the Act makes available, on a cost-sharing basis, Federal funds for research programs carried out at universities. The Water Resources Research Center has received funds in connection with Title I of the Act (Annual Allotment and Matching Grant research projects).

The Center's budgets for fiscal years 1965 through 1975 are shown in the table below. The sources of funds are also indicated.

Source of Funds

Fiscal Year	Center's Budget \$	Fed. (OWRR) \$	U of M \$	St. Col. \$	Private Col. \$	Grad. School U of M \$
1965	84,564	52,297	7,474	0	0	24,793
1966	195,362	106,980	78,336	0	0	10,046
1967	214,767	113,333	92,567	0	0	8,867
1968	220,525	135,396	78,054	0	6,575	500
1969	262,819	166,508	91,044	0	3,867	500
1970	328,160	180,930	123,055	20,795	0	3,200
1971	338,872	192,846	109,022	29,403	4,011	3,500
1972	432,477	240,856	156,126	27,622	4,473	3,700
1973	373,672	199,256	151,835	14,813	4,268	3,500
1974	441,680	255,179	180,969	0	2,032	3,500
1975	388,584	229,636	145,448	0	0	3,500

Research Program

The number of ongoing projects associated with the Center's research program varied from 7 in fiscal year 1965, to 20 in fiscal year 1972, and 12 in fiscal year 1975, as shown in the table below.

Fiscal Year	Total Number of Ongoing Research Projects
1965	7
1966	14
1967	13
1968	14
1969	14
1970	14
1971	17
1972	20
1973	17
1974	16
1975	12

Research conducted through the Center is relevant to water resources problems in Minnesota and the nation. Research efforts in the 10 water resources research categories used by the Committee on Water Resources Research, Federal Council for Science and Technology (FCST²) are identified in the table below to provide information on the nature of the Center's research projects.

FCST Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
I. Nature of Water	0	0	0	0	0	0	0	0	0	0	0
II. Water Cycle	2	3	3	4	6	5	4	4	4	3	2
III. Water Supply Augmentation and Conservation	0	0	0	0	0	0	0	0	0	0	0
IV. Water Quantity Management and Control	2	6	5	4	0	0	0	1	1	1	0
V. Water Quality Management and Control	3	5	5	5	6	4	3	3	2	6	8
VI. Water Resources Planning	0	0	0	1	2	5	10	11	9	6	1
VII. Resources Data	0	0	0	0	0	0	0	1	1	0	1
VIII. Engineering Works	0	0	0	0	0	0	0	0	0	0	0
IX. Manpower, Grants and Facilities	0	0	0	0	0	0	0	0	0	0	0
X. Scientific and Technical Information	0	0	0	0	0	0	0	0	0	0	0

Research effort has been consistently high in the following 4 categories: II. Water Cycle, IV. Water Quantity Management and Control, V. Water Quality Management and Protection, and VI. Water Resources Planning. Little effort has been devoted to category VII. Resources Data, and there has been no research in the following 4 categories: I. Nature of Water, III. Water Supply Augmentation and Conservation, VIII. Engineering Works, IX. Manpower, Grants and Facilities, and X. Scientific and Technical Information.

For several years the Center has known that the need for research concerned with the social-economic-political aspects of water resources is great. However, in fiscal year 1967, not a single research project proposal concerned with these aspects was submitted to the Center. In contrast, the Center's fiscal years 1972 and 1973 programs included 7 socio-economic-political research projects whose support constituted about 32 percent of the Center's total budget, (see table below).

Broad Aspects	Fiscal Year										
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Physical Sciences	4	11	10	8	7	5	7	8	6	7	3
Biological Sciences	3	3	3	4	4	5	4	5	4	5	6
Social Sciences	0	0	0	2	3	4	6	7	7	4	3

This trend of increased emphasis of the Center's research program on social-economic-political aspects of water resources is expected to continue. Most of the research the Center has supported or will support in the future can be broadly classified as environmental research.

The man-years of effort associated with the Center's research program is summarized in the table below.

Fiscal Year	Estimated Man-Years of Effort			Total
	Professional	Students	Clerks, etc.	
1965	0.83	0.75	0.29	1.87
1966	5.26	7.28	2.98	15.52
1967	4.43	6.00	3.70	14.13
1968	5.59	3.86	4.56	14.01
1969	6.12	7.61	3.49	17.22
1970	7.57	10.64	4.23	22.44
1971	6.90	10.43	2.93	20.26
1972	8.96	12.55	3.22	24.73
1973	5.27	10.12	5.13	20.51
1974	6.42	8.87	4.54	19.83
1975	5.22	9.37	2.26	16.85

During recent years, about 20 man-years of effort have been associated with the Center's research program involving 6 man-years of professional effort, 10 man-years of student effort, and 4 man-years of clerical and laboratory assistant effort. About 77 percent of man-years of student effort was by graduate students and about 23 percent was by undergraduate students.

Estimated administrative expenses incurred as part of the Center's Director's office budget for the Center's research program are listed below.

Fiscal Year	Center Director's Office Expenses \$	Research Program Administrative Expenses \$	Public Service Administrative Expenses \$	Instruction Administration Expenses \$
1965	14,000	11,000	3,000	0
1966	25,000	13,500	8,000	3,500
1967	30,000	14,000	12,000	4,000
1968	32,000	15,000	14,000	3,000
1969	38,500	20,000	16,000	2,500
1970	41,500	22,500	16,000	3,000
1971	51,500	24,000	24,500	3,000
1972	44,000	25,000	17,000	2,000
1973	47,800	27,500	17,300	3,000
1974	57,900	27,900	27,000	3,000
1975	59,900	30,500	26,400	3,000

The Center's Director's office expenses have averaged about 11 percent of the total Center's budget; research program administrative expenses have averaged about 7 percent of the total Center's budget.

Typically, expenditures for salaries and wages and associated indirect costs and employee fringe benefits constitute about 86 percent of the total Center's budget. Non-Federal contributions to the Office of Water Resources Research programs consist of the fair value of the services of faculty whose salaries are being paid with non-Federal funds and indirect costs and employee fringe benefits associated with total salaries and wages.

Expenditures through fiscal year 1975 for non-expendable equipment items associated with the Center's research programs total \$141,586. Title to non-expendable equipment purchased with Office of Water Research and Technology funds is vested in the University of Minnesota for the use and benefit of the Center. Upon project completion, equipment is retained by the research project Principal Investigator who gives due credit to the Office of Water Research and Technology for continued use of the equipment. Some of the major equipment items purchased with Center funds are: rain gauges, water level recorders, anemometers, evaporation pans, trucks, freezers, centrifuges, balances, boats, trailers, outboard motors, microscopes, mobile limnological laboratory, electronic apparatus, plankton recorders, hand winches, chain saws, office equipment, calculators, hygrothermographs, vertical illuminator, depth finders, fluorometer, pumps, samplers, and irrigation systems.

Funding of water resources research projects at the University of Minnesota increased from about \$788,400 in fiscal year 1965 to about \$1,293,200 in fiscal year 1973. The percentage of the total University of Minnesota water resources research supported by the Center has steadily increased from about 9 percent in fiscal year 1965 to about 28 percent in fiscal year 1973. The Center research expenditures in fiscal year 1972 exceeded the water resources research expenditures of all other individual units of the University.

Total funding of water resources research projects conducted in Minnesota has increased from about \$1,226,600 in fiscal year 1965 to about \$3,940,000 in fiscal year 1973. Recent annual Federal and State expenditures for all water resources programs in the State total about \$110,000,000. Thus, expenditures for water resources research constitute only about 3.5 percent of total expenditures for all water resources programs in the State. The Center supported about 10 percent of the total water resources research conducted in Minnesota in fiscal year 1973. On a nationwide basis, the Center has received a high proportion of Title I funds from the Office of Water Research and Technology.

Funds to support research projects have been distributed by the Center to various units of the University of Minnesota, St. Mary's College, St. Cloud State College, Bemidji State College, and Gustavus Adolphus College as shown below.

Cumulative Funds Associated
with Center's Research
Program Through Fiscal
Year 1975 \$

University or College and
Unit Performing Research

University of Minnesota	2,574,792
Institute of Agriculture	943,509
Department of Agricultural Engineering	287,112
School of Forestry	131,621
Department of Soil Science	290,597
Department of Agricultural & Applied Economics	152,399
Department of Horticultural Science	81,782
Institute of Technology	603,462
St. Anthony Falls Hydraulic Laboratory	259,522
Limnological Research Center	283,016
Geological Survey	9,523
Department of Geology & Geophysics	54,596
Department of Civil & Mineral Engineering	31,205
Health Sciences	266,120
School of Public Health	298,011
Department of Pharmacognosy	68,109
College of Liberal Arts	259,753
Department of Anthropology	71,494
Department of Sociology	188,259
College of Biological Sciences	142,219
Department of Ecology & Behavioral Biology	51,304
Department of Botany	71,915
Graduate School	198,556
Medical School - Duluth	61,173
State and Private Colleges	219,147
St. Mary's College	20,597
Department of Biology	20,597
St. Cloud State College	107,833
Department of Biology	107,833
Bemidji State College	64,472
Center for Environmental Studies	64,472
Gustavus Adolphus College	26,245
Department of Geography	26,245

Public Service Program

Increased attention is being given to making available to the public, governmental agencies and the research community the information produced by the Center's programs. The Center has published and distributed to 700 people throughout the State 40 quarterly Newsletters and 156 Information Circulars in an effort to disseminate information concerning water resources. Research projects supported by the Center have generated 202 Technical reports and theses. Upon request, the Center has distributed about 140 copies of its publications per month to people throughout the State and Nation. The Center has widely distributed 55,000 copies of 80 Bulletins describing the results of research projects.

Public service administrative expenses have averaged about 5 percent of the total Center's budget.

Instruction Program

One of the purposes of the Center is the stimulation and review of education offerings for students which will prepare them for careers in the field of water resources. The Center assists in recruiting students and in guiding them into appropriate programs of study. The Center has been helpful to the University of Minnesota in developing 53 new courses bearing on water resources, a new graduate option in hydrogeology, and a program of graduate education in water resources.

The number of students receiving part-time employment as research project assistants through the Center's recent research program has averaged 40. Sixty-three students have graduated with M.S. and Ph.D. degrees in water resources related fields and received Center financial support.

Instruction program administrative expenses have averaged about 1 percent of the total Center's budget.

Minnesota generates the popular image as a haven for water-based outdoor recreational activities. The quality of Minnesota's environment is a significant factor in making the state a desirable place in which to live and work. Minnesotans jealously guard against deterioration of this environment. This concern has been manifested in a long list of environmentally related legislation (summarized in WRRC Bulletin No. 76, Project No. B-054-Minn).

While concern such as this has done much to maintain Minnesota's unique water based natural environment, prudence dictates that we do not become complacent, for old problems and controversies persist, and new problems arise with dramatic suddenness. Therefore, there is a continuing need for maintaining an ongoing research program. New research programs cannot be turned on and off like a water spigot - rather, the expertise must be kept on line, and in operation to be effective.

Research made possible by the Water Resources Research Act of 1964 has already been helpful in public decisions in Minnesota Water Problems. For example, results from projects A-009-Minn. on groundwater contribution to streamflow, A-001-Minn. on effect of pothole drainage upon groundwater resources, and B-002-Minn. on effect of natural sealing of potholes have assisted State and Federal agencies in evaluating groundwater recharge on a statewide basis. Information from projects A-007-Minn. on the use of planktonic desmids as indicators of pollution of lakes, A-008-Minn. on water quality and organic productivity of lakes, A-011-Minn. on abundance of net plankton as an index of eutrophication in Lake Superior, B-001-Minn. on diatoms and zooplankton in Minnesota, B-101-Minn. on techniques for determining changes in phytoplankton, A-016-Minn. on primary productivity of Minnesota lakes, and B-009-Minn. on phosphorus in lake-bottom deposits is assisting water managers in controlling excessive productivity of polluted lakes. Results from projects A-010-Minn. and A-015-Minn. on recharge from induced streambed infiltration have been used in the U.S. and England to evaluate potential yields of aquifers. The Corps of Engineers has been assisted in their analyses of peak rates of runoff and flood routing by the results of project A-013-Minn. on review and analysis of watershed precipitation and runoff data. The Weather Bureau has been assisted in flood forecasting activities by information from project B-001-Minn. on soil moisture and A-001-Minn. on soil freezing in forests. The results of project A-021-Minn. on water resources administration in Minnesota has assisted the Legislature and the Executive Branch in formulating an environmental policy for the State and in reorganizing State agencies.

The Center's program in FY 1975 was directed toward: Water quality status and trends in Minnesota - Indices for water supply and groundwater pollution (A-029-Minn); Analysis of organic carbon as a pollution index (A-030-Minn); Developing a Statewide water information system for Minnesota (A-031-Minn); Water quality status and trends in Minnesota - Social dimensions (A-032-Minn); Assessment of water quality status and trends in Minnesota by remote sensing techniques (A-033-Minn); A hydronomic analysis of forest management alternatives for environmental quality (B-053-Minn); Spatial and temporal variations of precipitation of a concentrated network in both urban and rural environments (B-068-Minn); Bio-manipulation of lakes

EXAMPLES OF SELECTED RESEARCH FINDINGS AND THEIR ACTUAL OR
POTENTIAL APPLICATION TO WATER RESOURCES PROBLEMS

for elimination of blue-green algae (B-087-Minn); The geochemical and biostratigraphic record of natural and pollutional eutrophication of Minnesota lakes (B-081-Minn); Thermal pollution and second trophic level fauna in Lake Superior (B-097-Minn); Feasibility of using iron-ore overburden material as a media for disposal of secondary sewage effluent in northeastern Minnesota (B-102-Minn); and Computer programs and simulation models in water resources: scope and availability (C-5111-Minn).

While this research has been helpful in formulating rational water policy, we cannot say that water problems have been totally "solved". Failure to totally resolve water problems cannot be construed as a "failure of research." A popular misconception is that research resolves problems on a "once and for all basis." In fact, there can be no "once and for all" resolution of water problems through research any more than there can be through enactment of a "once and for all" set of laws. Most water problems involve conflict of use or expenditure of public funds. These controversies are continuing, and research is essential to generate the knowledge necessary for rational public decisions regarding such problems.

In 1975 and beyond, the major water resources problems requiring additional attention are those involving water quality, including pollution of lakes, streams, and groundwater. A related problem is the controversy over preservation of wetlands for natural and wildlife purposes. Flood damages continue to be a problem. The increased demands for food and fiber have accentuated the conflict between drainage of marginal lands suitable for wildlife. These increased demands have also generated concern over cultivation of marginal lands subject to erosion, and increased the potential economic feasibility of irrigation. These problems and the need for legislation to deal with resulting conflict and controversy generates the need for increased research to provide a more rational basis for policy direction.

The Center has been helpful in developing new water resources courses, a graduate option in hydrology, a program of graduate education in water resources, and recruitment of new faculty members with an active interest in water resources. The following State and private colleges have participated in the Center's research program: St. Mary's College, St. Cloud State College, Bemidji State College, Winona State College, and Gustavus Adolphus College.

The Center has increased its information dissemination activities, initiating a new Public Report Series designed to make information available to the public on an "easy to understand" basis. The first two reports were primers on lakes and general Minnesota water resources. These reports are designed to be a useful point of departure both for citizen, and for governmental personnel wishing to upgrade their knowledge for their role in legislation and administration of water resource related programs.

The Center has an Advisory Committee composed of 46 members from the University of Minnesota; State and Private Colleges; State, local and Federal agencies; and Interest groups and private concerns. Members of the Center's Advisory Committee have participated in water and related land resources planning activities of the Minnesota State Planning Agency. The Center Director has served on several important State and national water resources committees.

First Example

OWRT Project No.: B-044-Minn. started July 1, 1970 embodies in the concepts, techniques and data for area economic analysis of water resource systems. A 14-county pilot-study area in West Minnesota was selected for study because of the diversity of its water resource problems and the difficulty of acquiring the public financing for water resource development. Nine of the 14-counties are organized into a multi-county Regional Development Commission (RDC). Research findings bear directly upon the work of the RDC and other resource development and planning organizations in the 14-county area.

Because of the many local organizations and financing sources considered in the study, the research findings relate to a variety of issues and institutions in water resource development including: water resource-related capital plant, settlement alternatives, development potentials, decision models, fiscal-ecological accounts, financing strategies, and community resource mobilization.

Project results are being used in educational programs and consulting in the study area and other resource planning areas in Minnesota. In addition, segments of the project were used in classroom activities on the University of Minnesota campuses. A summary of specific applications of project results includes: Public affairs programs and conferences for resource planning groups in outstate Minnesota; data and information services for local government planning and decision making in 14-county study area; consulting services for regional planning commissions, resource conservation and development project committees and other groups; undergraduate and graduate courses in resource development and planning; and continuing education classes for local government officials, staff members, community leaders, and others interested in financing water-resource development and related activities. The Principal Investigator has participated in two public affairs programs sponsored by the Minnesota Commission on the Humanities which pertained to issues and data of concern to the newly-organized Regional Development Commissions in two of Minnesota planning regions. The Principal Investigator has met with the West Minnesota Resource Conservation and Development Committee, community industrial development organizations and other groups about the local impacts of particular development proposals.

Second Example

Northern States Power Company constructed a 500-megawatt nuclear generator near Monticello, Minnesota. Operation of the plant started on January 23, 1971. Water from the Mississippi river is used for cooling and condensing purposes and returned to the river at a higher temperature. The ecological monitoring program related to OWRT Project No.: B-032-Minn. determined existing ecological conditions in the Mississippi river before operation of the plant and changes due to thermal discharge from the generator after operation. The activities and energy relationships of reptiles, birds, forage fishes, and aquatic plants were studied. These studies show that the effects of the heated discharge have been minimal since the power plant began operation.

Information generated by this project was used by the Atomic Energy Commission in the preparation of an environmental statement and recommendations for licensing referred to below:

United States Atomic Energy Commission, Directorate of Licensing.
May 1971. Draft Environmental Statement on the Northern States Power Company Monticello Nuclear Generating Plant. Washington, D.C. 170 p.

The results of the studies are being used by Federal and State agencies and individuals involved in the site selection, monitoring and regulation of power plants and power production, particularly the Power Plant Siting Task Force of the Governor's Environmental Quality Council.

Third Example

OWRT Project No.: B-054-Minn. started July 1, 1971, sought to examine the economic impact of alternative water policies in Minnesota. Several general policy areas were analyzed including flood damage reduction, navigation, and others.

A study was made of flood control alternatives in the Minnesota River Basin. These results were presented to the Minnesota River Basin Commission. The study in which the Minnesota Department of Natural Resources cooperated, led to the Graduate student who carried out the study being funded by the DNR for additional work on flood costs and policies for the State as a whole. This would not have occurred without OWRT funding for the initial project.

The navigation portion of the study resulted in a comprehensive report on the history and public policy aspects of commercial navigation on the Upper Mississippi river. The report examined the dredging issue and reviewed policy alternatives for dealing with the conflicts between environmental navigation interests. The report has generated much interest and has been widely used by interest groups, individuals, and policy makers who are concerned with use of the Upper Mississippi.

Another product of the project was a summary of Minnesota Legislation relating to water and land resources passed during the 1973 and 1974 sessions. This publication has been requested widely by those involved in various aspects of natural resource policy.

COMPLIANCE WITH CONSULTATION AND COLLABORATION PROVISIONS OF SECTION 100(b) P.L. 88-379 AS AMENDED BY P.L. 92-175

On December 2, 1971, the President approved P.L. 92-175 which amended certain sections of P.L. 88-379, the Water Resources Research Act of 1964. Among the amendatory provisions of Section 100(b) is the new requirement that: "The annual programs submitted by the State institutes to the Secretary for approval shall include assurance satisfactory to the Secretary that such programs were developed in close consultation and collaboration with leading water resources officials within the State to promote research, training, and other work meeting the needs of the State."

Information concerning the procedures and actions the Center has established or taken pertaining to compliance with consultation and collaboration provisions of Section 100(b) P.L. 88-379 as amended by P.L. 92-175 is given below.

A Water Resources Research Coordination and Information Dissemination Committee met on September 21, 1973 and October 30, 1973 to discuss the need for any water resources research coordinating arrangement other than the informal arrangement which exists. The Committee was composed of the following voluntary members: Gene Hollenstein, Department of Natural Resources; Lowell Hanson, University of Minnesota; Thomas Straw, University of Minnesota-Morris; Arthur O'Hayre, University of Minnesota; Walter Maier, University of Minnesota; Ed Ross, Department of Health; Ed Bowers, University of Minn; Arnett Mace, University of Minnesota; Bob Moline, Gustavus Adolphus College; Dennis Mathiason, Moorhead State College; Dennis Ferche, Senate Research Counsel; and Bill Walton, University of Minnesota. The Committee reviewed and critiqued alternative means of coordinating water resources research in Minnesota.

Specifically, the Committee discussed the possibility of establishing regional Water Resources Research Regional Councils (WRRRC's) throughout the State. However, after extensive consultation and discussion this idea was rejected as there seems to be little enthusiasm, either within the University of Minnesota, or other institutions or agencies for formally coordinating water resources research on a regional basis within the State. It was unanimously agreed that no additional arrangements other than those existing, are presently needed.

It was suggested that it would be helpful if the Water Resources Research Center could expand its Advisory Committee membership to include additional representatives from State and Private Colleges. The Water Resources Research Center was urged to explore the feasibility of providing leadership in making arrangements to hold an Annual Water Resources Conference. It was suggested that the Conferences should be co-sponsored by many organizations and focus on the discussion of water resources issues by speakers and Conference participants.

In response to Committee recommendations, the Water Resources Research Center in January 1974, expanded its Advisory Committee membership to include representatives from University of Minnesota-Duluth, University of Minnesota-Morris, St. Cloud State College, Southwest Minnesota State College, and Winona State College. Plans have been made for the Center to co-sponsor Conferences. The 1975 roster of the Center is as follows:

John J. Waelti, Acting Director
Elizabeth Hermansen, Secretary

Advisory Committee

University of Minnesota

A.G. Anderson	St. Anthony Falls Hydraulic Laboratory
D.A. Brown	Department of Geography
R.G. Bond	School of Public Health
K.W. Easter	Agricultural & Applied Economics
L.P. Gerlach	Department of Anthropology
L.D. Hanson	Department of Soil Science
K. Huston	Agricultural Experiment Station
W. Ibele	Graduate School
C.H. Larson	Dept. of Agricultural Engineering
A.C. Mace	School of Forestry
W.J. Maier	Dept. of Civil & Mineral Engineering
G.D. Rose	Institute of Agriculture
W.P. Martin	Department of Soil Science
R.E. Rickson	Department of Sociology
T.E. Straw	Div. of Science and Math (Morris)
W.R. Swain	School of Medicine (Duluth)
M.S. Walton	Minnesota Geological Survey
T.F. Waters	Department of Entomology
H.E. Wright	Limnological Research Center

State and Private Colleges

N. Baron	Dept. of Geography, Winona State College
A.J. Hopwood	Dept. of Biology, St. Cloud State College
C.H. Puchsmann	Center for Env. Studies, Bemidji State College
J. Jack	Dept. of Geography, Mankato State College
R.T. Moline	Dept. of Geography, Gustavus Adolphus College
T. Surdy	Dept. of Biology, Southwest Minnesota State College

State, Local and Federal Agencies

B.J. Breimhurst	Environmental Protection Agency
F. Lamm	Metropolitan Council
R.M. Dennistoun	Minn. Dept. of Agriculture
P.H. Geisenhoff	Minn. Dept. of Economic Development
G. Gere	Minn. Dept. of Natural Resources
C.A. Johannes	Minn. Pollution Control Agency
E.H. Ross	Minn. Dept. of Health
J.F. Sizer	Minn. State Planning Agency
E.M. Weiberg	Minn. Water Resources Board
J.H. Strub	National Weather Service

C.R. Collier	U.S. Geological Survey
M.W. Noah	U.S. Army Corps of Engineers
H.J. Major	U.S. Soil Conservation Service
J. Scott	U.S. Bureau of Sport Fisheries and Wildlife

Interest Groups and Private Concerns

D. Asmussen	Minn. Public Interest Research Group
D.W. Barr	Consulting Hydraulic Engineer
R.A. Haik	Attorney
H. Lykken	Sierra Club
J.T. Shields	Minn. Association of Commerce & Industry
P. Toren	Izaak Walton League of America
M. Watson	League of Women Voters

The Center maintains close liaison with the various Schools, Departments and Divisions of the University of Minnesota, State and private research firms and Consultants and voluntary organizations through its Advisory Committee and through its membership on the All-University Council on Environmental Quality at the University of Minnesota.

A research project (OWRF Project No.: A-028-Minn) entitled "Developing a Water Resources Research Plan for Minnesota" was started on July 1, 1972 and was completed on June 30, 1974. The objective of this project was to develop comprehensive guidelines for water resources research programs in Minnesota.

Needed water resources research topics identified during one statewide and 7 regional water resources problems-research needs workshop conferences were segregated under 18 broad topic headings and listed on a needed water resources research priority ranking questionnaire together with research need topics mentioned in the available literature. The titles of the broad topic headings were: water quality, water supply, water-oriented recreation, wetlands and drainage, soil and water, flood damage reduction, water-borne transportation, mining and water resources, groundwater, lakes and streams, conserving water, urban runoff, water laws, planning, water information, multi-state aspects, economic aspects, and social aspects. A total of 227 water resources research need topics were listed on the questionnaire.

The questionnaire was sent to 1,200 people distributed uniformly throughout the State in December 1973 to survey the current state of public opinion concerning water resources research needs. All conference participants (386) and 814 people with an active interest in water resources and affiliated with the University of Minnesota, State and Private Colleges, State agencies, Federal agencies, local agencies, Interest Groups, industries, and consulting firms received questionnaires. Questionnaire recipients were requested to rank, in the spaces provided, research need topics according to their priority preferences keeping in mind that limited funds are available to support research and only a limited number of research projects can be started each year by assigning a number to the following priority scale: (3) high priority, (2) medium priority, and (1) low priority. Spaces were provided at the end of the questionnaire

for people to add and rank additional research topics known to them but not mentioned in the list. Questionnaire recipients were requested to give name, affiliation and address in the spaces provided at the end of the questionnaire.

A total of 191 questionnaires or about 16 percent of the questionnaires distributed were completed and returned. Judging from the results of the conferences and the small number of returned questionnaires, more people are willing to report on research needs than are willing to assign priorities.

A regional OWRT matching grant research project proposal has been generated and funded as a result of a meeting held on May 2, 1974, attended by Upper Mississippi River Basin Commission (UMRBC) personnel, the Directors of the Water Resources Research Institutes in the States (Minnesota, Wisconsin, Iowa, Illinois, and Missouri) within the basin, and the Regional Representative of OWRT. The purpose of that meeting was to explore possibilities of improving communication between the UMRBC and the Water Resources Research Institutes in the states within the basin, and to explore research opportunities associated with the activities of UMRBC. During that meeting, it was announced that UMRBC is presently in the process of considering planning goals and objectives and identifying water and related land resources problems in its basin. The task is scheduled for completion during the next 7 to 12 months. It was emphasized that applied research is needed on methodology for identifying and ranking problems to support UMRBC activities. Both UMRBC and OWRT urged the immediate formulation of a multi-state, multi-University, multi-disciplinary regional research project proposal for submission to OWRT. Potential principal investigators were quickly identified and met with the UMRBC Chairman and staff members on May 23 for the purpose of developing a proposal relevant both to current UMRBC needs and to ongoing water resources research interests. The proposal was refined in further work sessions of the co-principal investigators on May 24, and during the week of May 27-31, 1974 and submitted to OWRT for its consideration.

The title of the research project is: "Methodology for Identifying and Ranking Water and Related Land Resources Problems in the Upper Mississippi River Basin." The project duration is: July 1, 1975 through June 30, 1976. Principal Co-Investigators are: T.A. Austin, Dept. of Civil Engineering, 487 Town Engr., Iowa State University, Ames, Iowa 50010; L.F. Blair, Dept. of Urban and Regional Planning, University of Illinois, 909 West Nevada, Urbana, Ill. 61801; Herman Felstehausen, Land Tenure Center, University of Wisconsin, 310 King Hall, Madison, Wis. 53706; J.J. Waelti (Coordinator) Dept. of Agricultural & Applied Economics, 231-d COR, University of Minnesota, St. Paul, Minn. 55108.

The proposed research project will develop methodology which can be used by the Upper Mississippi River Basin Commission to identify and rank water and related land resources problems in the area of its responsibility. The project duration fiscal year 1975, was selected in light of the Commission's agenda. The project will assist the Commission in setting in motion some of the steps necessary to implement its statement of goals and objectives. The proposed research project is primarily an office study

which involves: review and evaluation of current techniques for problem identification, identification and development of taxonomy for major factors involved in problems, identification of market failure, technological forecasting, a pilot study, and evaluation and a final report. The project is regional, multi-University, multi-State, and multi-disciplinary in nature; four principal investigators from Iowa State University, University of Illinois, University of Wisconsin, and University of Minnesota will participate in the research. The total cost of the project is about \$77,000.

A group of Water Resources Research Center Directors from the following states are working together to promote regional OWRT research projects: Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, West Virginia, and Wisconsin. The Illinois Center Director chairs the Committee. Liaison between the group and the Upper Mississippi River Basin Commission, Great Lakes Basin Commission, and Ohio River Basin Commission is maintained through Center Directors in Minnesota, Michigan, and Indiana, respectively. The group was created because OWRT is emphasizing the need for regional matching grant research projects.

INFORMATION DISSEMINATION

On December 2, 1971, the President approved P.L. 92-175 which amended certain sections of P.L. 88-379, the Water Resources Research Act of 1964. Among the amendatory provisions of Section 100(b) is the new requirements that "it shall be the duty of each such institute to plan and conduct and/or arrange for a component or components of the college or university with which it is affiliated to conduct competent research, investigations, and experiments of either a basic or practical nature, or both, in relation to water resources and to provide for the training of scientists through such investigations, and experiments. Such research, investigations, experiments and training may include without being limited to, ... scientific information dissemination activities, including identifying, assembling, and interpreting the results of scientific and engineering research deemed potentially significant for solution of water resource problems, providing means for improved communication regarding such research results, including prototype operations, ascertaining the existing and potential effectiveness of such for aiding in the solution of practical problems, and for training qualified persons in the performance of such scientific information dissemination.

Increased attention is being given to making available to the public, governmental agencies and the research community the information produced by the Center's programs. During the period 1965 through June 30, 1975, 190 reports, 26 theses and 156 Information circulars related to the programs of the Water Resources Research Center have been published. The Center has published and distributed to 700 people throughout the State 40 quarterly Newsletters. Upon request, the Center has distributed about 140 copies of its publications per month to people throughout the State and Nation. The Center has widely distributed 54,000 copies of 80 Bulletins describing the results of research projects.

The Center has increased its information dissemination activities, initiating a new Public Report Series designed to make information available to the public on an "easy to understand" basis. The first two reports were primers on lakes and general Minnesota water resources. These reports are designed to be a useful point of departure both for citizen, and for governmental personnel wishing to upgrade their knowledge for their role in legislation and administration of water resource related programs.

To provide an opportunity for professional people and students working in the field of water resources to meet and to exchange information, the Center has sponsored 31 interdisciplinary Seminars since 1964. Attendance at the Seminars has averaged 50 people.

Information concerning scientific information dissemination activities during fiscal year 1975 of all personnel (Director, P.L.'s, other researchers, graduate assistants, etc.) associated with the Center's public service program is summarized below.

Item	Number of Events	Size
		Average Audience
Technical Publications Issued	22	700
Popular Articles Published	25	1,000
News Letters	4	700

Arrangements have been made for the Environmental Conservation Library (ECOL) Minneapolis Public Library to serve as the depository for publications received by the Center. ECOL is also assisting the Center in disseminating information on water resources. The 1971 Minnesota Legislature designated ECOL as the State center for environmental information.

During FY 1975, the Center distributed to about 700 people in Minnesota mimeographed Information Circulars covering the following subjects:

<u>Information Circular No.</u>	<u>Title</u>
149	Digest of Information Concerning the Energy Shortage in Minnesota
150	Agenda for Developing a Statewide Water Information System
151	Research Needs Associated With Land Wastewater Treatment Systems
152	Electric Power Generation and Waste Heat Utilization - A Review of Water Resources Research Needs
153	Standards Development-- A Governmental View
154	Water Quality--Is It Getting Better or Worse?
155	Federal Water Information Systems
156	Legislative Response to Some Key Minnesota Water Resource-Related Policy Issues

The Center has initiated a new publication series, labeled the "Public Report Series." The objective of this series is to present information of a less technical, more readable nature. These reports are intended to serve as a base of information for students, interested citizens, and governmental personnel who wish to become better informed on various aspects of public policy.

Two manuscripts are being processed for publication. These are:

A Primer on Limnology, by John B. Lundquist

Minnesota Water Resources: A Primer, by William C. Walton

A third manuscript is being written, tentatively entitled "Water Research in Minnesota: A Decade Under the Water Resources Research Act."

The Center receives many requests for copies of its Bulletins, Newsletters and Information Circulars. A few excerpts from letters addressed to the Center Director expressing appreciation for the Center's publications are given below:

This Center is interested in obtaining a copy of the publication,
"Role of the Scientist Technician in Water Policy Decisions at the Commu-
nity Level: A Study in Purposive Communication."

Your attention to this request will be greatly appreciated, since we
are currently conducting a water resources research project in which it appears
to be pertinent and therefore will be of assistance.

Sincerely yours,

Ruth Krenlick
Director
Technical Guidance Center
317 Hills North
University of Massachusetts
Amherst, Massachusetts 01002

Water Resources Research Center Conference

A conference was held in December, 1974 on "Trends in Water Management."
Representatives of various Federal and Minnesota State agencies having
responsibilities regarding water management outlined their programs and
discussed trends in public water policies. The Conference was attended by
50 people. There was ample opportunity for questions and discussion be-
tween the audience and the speakers.

INFORMATION CONCERNING RESEARCH PROJECT
PROPOSALS SUBMITTED TO OWRT BY CENTER, FY 1976

Lists of FY 1976 Annual Allotment, Matching Grant and Title II research project proposals submitted to OWRT by the Center are given below. A table summarizing the number of Center proposals funded or rejected by OWRT FY 1965-75 is also provided.

About 25 percent of Matching grant proposals have been funded and 100 percent of Annual Allotment proposals have been funded. One Title II proposal has been funded.

No Annual Allotment Research Project Proposals were submitted to OWRT by the Center for Fiscal Year 1976.

List of Matching Grant Research Proposals Submitted to OWRT by Center, Fiscal Year 1976:

*(Proposals Funded)

Factors Controlling the Carbon-Nitrogen Ratio in Lake Sediments

Methodology to Promote and Facilitate the Development of Detailed Buried Bedrock-Valley Aquifer Maps for Minnesota

Baseline Study of Heavy Metals in Waters and Lake Sediments in North-eastern Minnesota Prior to Development of Copper-Nickel Deposits

Development of a Small Stream Watershed Model for Water Resources Management Integrating Aquatic, Terrestrial, and Sociological Studies

* Effects of Silt and Turbidity from Agricultural Drainage on Benthic Invertebrates in Streams in Western Minnesota

Use of Mathematical Models for Flood Forecast Research in the Upper Midwest

* Effects of Drainage Projects on Surface Runoff from Wetland Topography of the North Central Region

Chemical Composition of Atmospheric Precipitation in Minnesota, in Relation to the Influence of Geography, Geology, Climate and Human Activities

Key Social Factors Affecting Copper-Nickel Mining and Water Resources Policy Decisions in Minnesota

List of Title II Research Proposals Submitted to OWRT by Center, Fiscal Year 1976:

New Methods for Determining Floods and Low Flows in Ungaged Streams Using Drainage Basin Characteristics.

<u>Fiscal Year</u>	<u>Annual Allotment</u>			<u>Matching Grant</u>		
	<u>Funded</u>	<u>Rejected</u>	<u>Total</u>	<u>Funded</u>	<u>Rejected</u>	<u>Total</u>
1965	7	0	7	0	0	0
1966	2	0	2	5	2	7
1967	1	0	1	0	3	3
1968	4	0	4	2	1	3
1969	2	0	2	3	2	5
1970	2	0	2	3	15	18
1971	3	0	3	4	15	19
1972	2	0	2	4	8	12
1973	1	0	1	3	11	14
1974	2	0	2	4	16	20
1975	3	0	3	1	15	16
1976	0	0	0	2	7	9
Total	29	0	29	31	95	126

Title II

<u>Fiscal Year</u>	<u>Funded</u>	<u>Rejected</u>	<u>Total</u>
1968	0	2	2
1969	0	6	6
1970	0	9	9
1971	0	2	2
1972	0	1	1
1973	0	1	1
1974	1	2	3
1975	0	2	2
1976	0	1	1
Total	1	26	27

FISCAL YEAR 1975 OWRT BUDGET

Annual Allotment Program

<u>Project Title, Principal Investigator and OWRT Project No.</u>	<u>Federal Funds \$</u>
Center Director's Office	40,000
Water Quality Status and Trends in Minnesota - Indices for Water Supply and Groundwater Pollution - Conrad R. Straub, School of Public Health (A-029-Minn)	13,500
Analysis of Organic Carbon as a Pollution Index - Walter Maier, Department of Civil and Mineral Engineering (A-030-Minn)	14,000
Developing a Statewide Water Information System for Minnesota, John J. Waelti, Department of Agricultural and Applied Economics (A-031-Minn)	15,000
Water Quality Status and Trends in Minnesota - Social Dimensions, Roy E. Rickson, Department of Rural Sociology (A-032-Minn)	13,500
Assessment of Water Quality Status and Trends in Minnesota by Remote Sensing Techniques, A.C. Mace, School of Forestry (A-033-Minn)	<u>14,000</u>
TOTAL	110,000
Annual Allotment Non-Federal Contribution	45,478

Matching Grant Program

	<u>Federal Funds \$</u>	<u>Non-Fed. Funds \$</u>	<u>Total Funds \$</u>
A Hydronomic Analysis of Forest Manage- ment Alternatives for Environmental Quality - A.C. Mace and J.M. Hughes, School of Forestry (B-053-Minn)	8,800	13,080	21,880
Spatial and Temporal Variation of Precipitation of a Concentrated Network in Both Urban and Rural Environments - Donald G. Baker, Depart- ment of Soil Science (B-068-Minn)	14,664	12,409	27,073
The Geochemical and Biostratigraphic Record of Natural and Pollutional Eutrophication of Minnesota Lakes - Eville Gorham and H.F. Wright, Botany Department and Limnological Research Center (B-081-Minn)	28,817	24,069	52,886

Bio-manipulation of Lakes for Elimination of Blue-green Algae - J. Shapiro, Limnological Research Center (B-087-Minn)	23,400	22,483	45,883
Thermal Pollution and Second Trophic Level Fauna in Lake Superior - Wayland R. Swain and Robert S. Posoz, University of Minnesota, School of Medicine, Duluth, Minnesota(B-097-Minn)	20,681	20,816	41,497
Feasibility of Using Iron-Ore Overburden Mat- erials as a Media for Disposal of Secondary Sewage Effluent in Northeastern Minnesota, A.C. Mace, School of Forestry (B-102-Minn)	22,920	23,189	46,109
TOTAL	119,282	116,046	235,328

ANNUAL ALLOTMENT PROGRAM

NARRATIVE PROGRESS REPORTS

Form OW-1 (1972)

OWRT Project No.: A-029-Minn

Annual Allotment Agreement No.: 14-31-0001-5023

Project Title: Water Quality Status and Trends in Minnesota - Indices for Water Supply and Groundwater Pollution

FCST-COWRR Research Category: 05-C

Name and Location of University Where Project is Being Carried Out.
University of Minnesota, Minneapolis, Minnesota 55455

Project Began: July 1, 1973 Scheduled Completion: June 30, 1976

Principal Investigator: Conrad P. Straub Degree: Ph.D.

Discipline: Public Health

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
Milton W. Anderson	B.A.	Biology & Chemistry
Alain DuChene	B.A.	Mathematics
Jung Ahn	M.S.	Environmental Health

Narrative Statements

(A) Research Project Accomplishments:

Data from the Division of Environmental Health, Minnesota Department of Health published in 1971¹ have been used to assess the quality of public water supplies in Minnesota. Utilizing these data, a report has been prepared² indicating the degree of compliance of the following water quality characteristics to existing U.S. Public Health Service Drinking Water Standards³ and the American Water Works Association goals: hardness as CaCO₃, iron, manganese, chlorides, sulfates, nitrates, sodium, and filterable residue. These parameters, identified in four groupings of quality, were plotted on maps and illustrate water quality for each of the ground and surface public supplies in the State. A second report⁴ lists the number of municipalities supplying and populations served waters of the various quality criteria indicated.

Progress relating to transfer of data to computers - Alain DuChene

For the present, we have limited ourselves to the transfer to data contained in "State of Minnesota Public Water Supply Data, 1971, Revised 1972,"⁵

Data have been separated into supply data and quality data and a minimum of recoding has been used to facilitate key punching from the data book.

Programs are being written for each set of data to edit for correctness and completeness; to recode certain data fields and revise the data records to facilitate retrieval; and to store the revised records on a computer file which can be accessed by subprograms developed to analyze the data.

Preliminary formats and numerical codes for "super" supply and quality records have been developed which will include data in addition to that presently collected. Some of the suggested inclusions are supply latitude and longitude, sanitation safety rating, method of disposal of water treatment wastes, well elevation, and other water analyses such as coliform counts, taste, odor, color and turbidity measurements, and measurements of organics, radioactivity, pesticides, and other important metals and compounds.

Special Studies, Surface and Ground Waters - Velta Goppers

Considerable effort was devoted to the development of methods applicable to the microanalytical techniques used in thin layer and gas chromatography and infrared spectroscopy. The methods that were developed are described elsewhere⁶ and were used in identifying the presence of specific compounds and groups of compounds in the variety of water samples collected for analysis. Preliminary results obtained in the application of these microanalytical techniques are given by the examples cited below.

Water Treatment Plant A.

Check on Polyelectrolyte movement through water treatment plant. Polyelectrolytes or polymers are compounds of high molecular weight whose structure can be considered as being made up of many smaller molecules -- monomers. These compounds contain large numbers of functional groups with reactive double bonds and for that reason they are used as coagulants or coagulant aids in water treatment. Some polyelectrolytes are used in water clarification processes as coagulant and filter aids and others are being considered as possible primary coagulants to replace inorganic coagulants such as alum and iron. They have several advantages including formations of tougher, compact flocs which settle more rapidly and do not penetrate as deeply^{7,8} in rapid sand filters. Since polyelectrolytes are toxic substances,⁹ one primary concern was whether the polyelectrolyte used was present in the finished water entering the distribution system.

To answer this question, microchemical studies utilizing thin-layer chromatography were employed because of their high specific sensitivity and because the technique could be used in conjunction with other instrumentation, e.g., densitometer, gas chromatograph, and infrared spectrometer, for compound identification. Samples were taken at each processing step and of the commercial polyelectrolyte used -- Nalcolyte 9113. The

samples were processed by passage through activated U.S.P. powdered carbon (Mallinckrodt Cat. No. 4394) contained in a Gelman magnetic filter (1 part activated carbon to 1000 parts of sample), extracted with spectro grade chloroform (Eastman Organic Cat. No. 13056) in a Soxhlet extraction unit, concentrated to small volume in a rotating evaporator, and then transferred to a 3 ml volumetric flask (1:1000 concentration). The concentrated chloroform extracts were chromatographed on specially prepared thin-layer chromatoplates and processed. Chromatograms prepared for the raw and finished waters showed presence of additional compounds in the finished water identical to those in the Nalcolyte standard chromatogram. The three monomers present were identified in accordance with their R_f values as methyl methacrylate, butyl-methacrylate, and acrylonitrile. These qualitative results indicate that the polyelectrolyte used--Nalcolyte 8113--was present in the finished water. Further quantitative studies would be desirable to identify the actual concentrations present. Although of academic interest, the results are not as directly pertinent now, since the use of the polyelectrolyte has been discontinued.

Gas chromatographic scans of these samples revealed the presence of additional compounds in the finished water as compared to the raw water and supported the preliminary thin-layer chromatographic results.

In summary, the thin-layer chromatograms demonstrated that: a) polyelectrolyte is present in the finished water, b) the polyelectrolyte was present as a polymer and at least three monomers, and 3) the polyelectrolyte or other chemicals added (e.g., chlorine and ammonia) have reacted with organic substances present in the raw water to form new compounds in the finished waters prior to discharge to the distribution system.

Qualitative Indication of Organics in public water supplies. Plants A and B.

Surface water supply sources can be contaminated by a wide variety of organic chemicals associated with the release of industrial wastes, domestic sewages, agricultural runoff, degradation products from natural sources, and pollutants introduced with precipitation and runoff. Two surface water supplies were selected for preliminary examination. One supply (B) takes raw water directly from a river and the other from a stored-lake supply (A). The primary purpose of the study was to note the effects of the treatment process on the composition of organics initially present and to identify, if possible, the changes induced by storage of the raw water supply.

Samples were collected of the raw water, process waters following treatment steps, and finished water. The purpose of collecting process water samples was to note changes induced by the addition of halogens used in disinfection.

Thin-layer chromatography was used to identify those organic compounds in each of the samples. The method included removal of organics by adsorption on activated carbon and extraction with chloroform or hexane. The concentrated extracts were separated on thin-layer chromatoplates and com-

pared with reference compounds. The separated pure substances were then eluted and examined further on the gas chromatograph and infrared spectrophotometer. A reverse procedure was also used in which the chemical compounds present in a suitable solvent were separated in a gas chromatograph equipped with a sample fraction collector. In this case, half of the sample from each separated peak can be collected outside the gas chromatograph on a moving thin-layer chromatoplate for further separation and/or examination in the infrared spectrometer. Samples were prepared as described previously.

Specific organic chemical compound groups were separated by thin-layer chromatography. The selected groups were: chlorinated hydrocarbons, insecticides-pesticides, plant phenols and their derivatives, and polymers used as coagulant aids. Details used in separating the various groups have been reported. The results indicated the possible presence of aldrin, parathion or diazinon, tricresyl phosphate, alkylbenzenesulfonic acid, detergents, and plant phenolics. Samples showing plant phenols and other compounds were analysed by gas chromatography (3% SA 30 column) and showed 19 peaks. Although the results are qualitative they do indicate the presence of phenolic compounds in both the raw and finished waters.

Water Treatment Plant C.

This was a ground water supply collected from a well 92.4 meters deep. Analyses by thin-layer chromatography showed the presence of ortho- and para cresols.

Organic constituents in spring runoff waters

Foam resulting from the aeration of runoff waters (spring floods) was collected and analyzed following concentration on activated carbon and extraction with chloroform, ethanol, or petroleum ether. The extractant was analyzed by thin-layer chromatography and gas chromatography as described. These studies indicated the presence of hydrocarboxylic acids, gallo tannins and some percentage of phenyl hydrocarboxylic acids (thin-layer chromatography) and partially separated hydrocarboxylic acids and humic derivatives (gas chromatograph on 5% Carbowax column).

Contacts with Other Agencies - Conrad P. Straub

Minnesota State Department of Health. A copy of the first report² was made available to the Minnesota State Department of Health in time for their budget hearings and was incorporated in their legislative presentations. The State Department of Health made additional data to that published^{1,6} to provide a historical record of analyses and to assist in indicating changes in water quality as a function of time.

Minnesota Geological Survey. The study underway was discussed with representatives of the Minnesota Geological Survey particularly to identify directions of ground water movement in the various aquifers used as sources of water supply. Such information would be helpful in indicating changes of water quality as a function of residence time. Cooperation of the Survey was indicated.

U.S. Geological Survey. Similar discussions were held with representatives of the U.S. Geological Survey and they provided maps and results of studies of ground water flow systems in the state. Again, they assured us of their cooperation.

(B) Publications

The following publications have been prepared or are in preparation:

Straub, C.P. Quality of Water Supplies in Minnesota - I. Submitted to the Water Resources Research Center, University of Minnesota. 22 pages. (September 23, 1974).

Straub, C.P. Quality of Water Supplies in Minnesota - II. Number of Plants Supplying and Populations Consuming Waters of Given Quality Characteristics. (In preparation)

Coppers, V. and Straub, C.P. Studies on Organic Constituents in Public Water Supplies. (In preparation)

(C) Project Status

The project is to continue for an additional year.

(D) Application of Research Results

Safe Drinking Water Act, Public Law 93-523.

The study provides relevant material on public water supply quality which will be helpful in assessing the extent of effort required to bring public water supplies to accepted water quality standards. Similarly, the data are useful in determining adherence to the proposed interim EPA Primary Drinking Water Standards. Only two -- fluorides and nitrates -- of the several parameters routinely reported in Minnesota have had primary standards established.

Agency Use of Material.

As indicated earlier, the first report,² generated by the project, was used by the Minnesota State Planning Agency in water quality information to permit more effective planning of growth areas within the State. Certainly, public water supply quality would be one factor of primary concern.

Class use of data and project equipment.

The data obtained were used in class room discussions on water quality and the environmental health implications of such water quality.

Water sampling and analysis, based upon the studies indicated under section 1.3, were incorporated into the curriculum in a course in analytical methods utilizing advanced microanalytical techniques.

Use of data upon completion of study.

Upon completion, the study will provide the following kinds of information:

1. Identify number of supplies that are exceeding currently recognized water quality recommendations or goals.
2. Identify number of persons consuming waters exceeding currently recognized water quality recommendations or goals.
3. Identify treatment needs to meet minimal water quality requirements.
4. Provide cost estimates for improving water quality to minimal requirements.
5. Provide basis for recommending regionalization of water supplies in State for more adequate treatment, etc.
6. Identify areas of impaired water quality for planning purposes (growth areas in State).

(E) Work Remaining, and Progress Contemplated Next Year:

The following activities are indicated for the remaining year of the project:

Completion of transfer of data to key punch cards for retrieval of data by computer.

Development of sub-programs to retrieve specific kinds of information.

Populations consuming waters of specific quality.

Number of plants providing water of specific quality.

Development of a water quality index.

Indication of water quality changes as a function of chronological time.

Relationship between water quality and specific aquifer use.

Development of sample collection and analysis schedule to meet requirements of Safe Drinking Water Act.

Cost estimates.

Circumscribed evaluation of regional approach to water quality improvement.

Circumscribed evaluation of costs to improve water quality to meet recommended levels or goals.

Evaluation of other methods for indicating quality changes in ground waters.

Preliminary evaluation of surface water quality trends.

References:

1. Division of Environmental Health, Public Water Supply Data. 1971. State of Minnesota. Minnesota Department of Health, Minneapolis, MN.
2. Straub, C.P. Quality of Water Supplies in Minnesota-I. Submitted to Water Resources, Research Center, Univ. of Minnesota. 22 pages (Sept. 23, 1974).
3. U.S. Department of Health, Education, and Welfare. Public Health Service. Public Health Service Drinking Water Standards. Revised 1962. Washington, D.C. (1962).
4. Bean, E.L., Chairman. Quality Goals for Potable Water--Statement of Policy. American Water Works Association. Task Group 2640P. Water Quality Goals. Jour., Am. Water Works Assn., 60(12):1317-1322 (1968).
5. Straub, C.P. Quality of Water Supplies in Minnesota-II. Number of Plants Supplying and Populations Consuming Waters of Given Quality Characteristics. (In Preparation).
6. Division of Environmental Health, Public Water Supply Data-1971, Revised 1972. State of Minnesota, Minnesota Department of Health, Minneapolis, Minnesota.
7. Report on Coagulant Aids for Water Treatment, Water Supply Division, Office of Air and Water Programs, U.S. Environmental Protection Agency, Cincinnati, Ohio. October 1974 and January 1975.
8. Health Aspects Relating to the Use of Polyelectrolytes in Water Treatment for Community Water Supply. A Report of a Consultant Group, Technical Paper No. 5. International Reference Center for Community Water Supply, World Health Organization, The Hague, The Netherlands. (July 1972).
9. Goppers, V. and Straub, C.P. Methods Developed and Methodology Used in the Identification of Organic Constituents in Public Water Supplies. (In preparation).

OWRT Project No.: A-030-Minn

Annual Allotment Agreement No.: 14-31-0001-5023

Project Title: Analysis of Organic Carbon as a Pollution Index

FCST-COWRR Research Category: 05-C

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

Project Began: July 1, 1973 Scheduled Completion: June 30, 1976

Principal Investigator: W.J. Maier Degree: Ph.D.

Discipline: Sanitary Engineering

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
Claude Anderson	Undergrad	Civil Engineering
Elizabeth Sullivan	Undergrad	Chemistry
Mike Porter	Undergrad	Chemistry

Narrative Statements

(A) Research Project Accomplishments:

The monitoring program to measure organic and inorganic carbon concentrations in surface and groundwaters is continuing.

The presence of organic matter in natural waters is an important measure of water quality from several viewpoints:

a) oxygen budgets, and dissolved oxygen concentration in particular, are strongly influenced by the presence of organics; high concentrations are likely to result in oxygen depletion and anaerobic conditions.

b) organic materials serve as food for a host of micro-organisms and thus provide a critical link in aquatic life cycles; organic carbon concentrations are one of the controlling factors in biological population densities.

c) organics have been implicated as chelating agents or adsorbants for trace elements such as heavy metal ions; this has implications in terms of the availability of trace elements in naturally occurring geo-biochemical conversions; chelation and adsorption may also act as a concentrating mechanism of trace elements.

d) the toxic or pathogenic nature of some organic constituents of natural origin (toxins, virus, bacteria) and a variety of manmade materials (pesticides, chlorinated hydrocarbon) constitute a danger to man and other life forms; the biologically refractory man-made materials are of particular concern because of possible long-range effects.

e) recently publicized information about the presence of chlorinated hydrocarbons in drinking water supplies that have been chlorinated may be another potential health hazard.

A modification of the commercially available Beckman Carbaneous Analyzer is being used for the determination of both inorganic and total carbon at the 1 to 100 mg/l level. This test is nonspecific and does not distinguish between naturally occurring and anthropogenic sources or between toxic-pathogenic and innocuous materials. Nevertheless, it is a useful analytical tool for monitoring and assessing water quality and for detecting trends. Monthly samples from more than 100 sampling stations representing the major Minnesota surface waters have been tested and analyzed. Organic carbon concentrations range from 0 to 35 mg/l; concentrations vary seasonally due to weather changes and geographically due to geo-hydrologic differences; long-term (year-to-year) changes have also been discerned and are believed to reflect long-term weather and hydrologic phenomena. Seasonal patterns reflect the effects of snow melt runoff (lower organic concentration), the effects of low winter temperature and hence reduced rates of biological activity (lower organic concentration), the effects of higher summer temperatures and attendant increase in biological and photosynthetic activity (higher organic concentration) and, the effects of dry periods which result in decreased surface runoff and higher proportions of ground-water seepage (lower organic concentrations). The St. Louis River data show a substantial increase in organic carbon in the downstream direction. It appears likely that at least part of the increase is due to industrial-municipal waste discharges. By contrast, the Minnesota River has essentially the same concentration throughout its whole length. The Mississippi shows a slight increase in the upper reaches but no change in the lower reaches that drain the more populated areas. Concentrations of organic carbon in the Mississippi are relatively low, 6.9 mg/l average for all stations; the range is 1. to 15. mg/l in 1974-75; concentrations in 1968-69 were substantially higher. Very low organic carbon concentrations have been measured in the Southeastern tributaries namely the Kumbro, Whitewater and Root Rivers; low concentrations are the result of groundwater seepage which generally contains very little organics. Agricultural drainage by subsurface tiles or ditches appears to be a significant factor in regulating the organic carbon concentrations in the Minnesota River; drainage has low concentrations of organics. Lake Superior data for 1968-69 and 1973-75 indicate that organic carbon concentrations have decreased markedly. The data probably reflect near shore water quality variations and mirror trends observed in the tributaries along the North Shore.

Organic carbon determinations provide a sensitive tool for measuring and monitoring water quality and should be obtained on a routine basis. Additional data are needed to develop predictive correlations for use in water resources planning. Such correlations are needed in order to assess the possible effects of alternative water uses and water resource allocations which have generally concentrated on the hydrological aspects and neglected water quality effects.

(B) Publications

Seven publications, presentations and reports have been prepared in connection with this study.

Maier, W.J., McConnell, H.M., "Carbon Measurements in Water Quality Monitoring", J. Water Pollution Control Fed., Vol. 46, 4, 623-633.

Maier, W.J., McConnell, H.M., Conroy, L.E., "A Survey of Organic Carbon Constituents in Natural Fresh Waters", Proceedings of the First World Congress on Water Resources, Water for the Human Environment, Sept. 24-28, 1973, Vol. IV, Special Sessions, p. 500.

Maier, W.J., Conroy, L.E., and Anderson, C.T., Survey of Organic Concentrations in Minnesota Surface Waters, Central States Water Pollution Control Conference, Madison, Wis., May 22, 1975.

Anderson, C.T., Maier, W.J., Organic Carbon Contents of Water Supplies, Presented at 95th American Water Works Association Meeting, Minneapolis, Minn., June 8-13, 1975. To be published in proceedings.

Maier, W.J., Gast, P.G., Anderson, C.T., Nelson, W.W., "Carbon Contents of Surface and Underground Waters in South Central Minnesota", Scientific Journal Series, Minnesota Agricultural Experiment Station, University of Minnesota, St. Paul. Submitted for publication.

Maier, W.J., Conroy, L.E., and Anderson, C.T. "The Occurrence of Organic Carbon in Surface Waters," to be presented at International Symposium on the Geochemistry of Natural Waters, Burlington, Ontario, Canada, August 18, 1975.

"Written Comments and Recommendations for Interim Primary Drinking Water Standards", Water Supply Division WH-450, U.S. Environmental Protection Agency, Washington, D.C. 20460.

(C) Project Status

The project will continue during the 1974-75 academic year at essentially the same scale. Research findings to date suggest the need for expanded effort and a request for additional support is in preparation. Program plans are described in Section E.

(D) Application of Results

The results of this test program have been of direct practical value to state agencies and have potential significance in drinking water standards being set by E.P.A.

The Minnesota Pollution Control Agency and Health Department have decided to obtain organic carbon analysis on a routine basis on all water samples. This decision to incorporate this test is at least partly based on the results from this program. The State Laboratory of Hygiene at Madison, Wisconsin is also adopting the organic carbon tests as a water quality parameter (letter from Dr. Delfino to Maier, June 11, 1975).

One practical outgrowth of this project is that municipal water supply systems for St. Paul, Minneapolis and St. Cloud were monitored to determine the fate of the organic matter as it passes through the treatment works. The results show that all treated waters tested contained substantial concentrations of organic carbon. Values range from 0.5 - 6.0 mg/l and account for 20-60% of the organic carbon in the raw water. This shows that a large fraction of the organic carbon present in surface waters can pass through conventional treatment processes which are known to produce aesthetically acceptable water. Although the composition of these organics is unknown and their sources have still to be elucidated it appears likely that most of the organics are of natural origin. There is no evidence of any detrimental effects of these materials to water consumers. However, the presence of 0.5 to 6.0 mg/l of unknown organic carbon materials in our water supply systems is at best a disquieting situation that deserves further investigation and reinforces the importance of identifying organics found in natural and treated waters. Further work is in progress.

As a follow up on this work a letter was sent to the Water Supply Division of E.P.A. recommending routine measurement of organic carbon in municipal water supply systems. This recommendation was submitted to E.P.A. (letter May 14, 1975) in connection with their recent review of Interim Primary Drinking Water Standards.

(E) Work Remaining and Progress Contemplated During Next Year

The objectives of the program for the coming year are an extension and expansion of previous work and include:

- 1) monitoring of organic carbon in surface and groundwaters,
- 2) characterization of organic materials found in natural waters,
- 3) description of the fate of organic constituents both in the natural environment and in water supply treatment systems.

Monitoring of routine surface water samples will continue only as long as necessary to ensure that testing by the State Health Department Laboratory give equivalent results. However, some monitoring of subsurface waters will be carried out to define the range of organic carbon concentration in major aquifers.

Some testing of agricultural and forest land drainage will be done to help establish the major sources of organics. This work is a joint undertaking with the North Central Soil Conservation Research Center and the Agricultural Experiment Station. A continuing effort to measure the concentration of carbon in tile line drainage is planned to establish the organic carbon contribution of artificial drainage systems.

Investigations of the physical-chemical-biological characteristics of organic constituents are being expanded. Additional information about the size distribution of organic constituents will be obtained using the millipore molecular filter sieves on samples from different geographical

locations and at different times of the year; tests will be made to see if there are significant differences between surface drainage, subsurface drainage and groundwater.

Ion exchange media and high surface area adsorbents such as activated carbon will be used to obtain a measure of the ionic character of organic constituents.

Studies of the rate of biodegradation of organics found in surface and subsurface waters is of interest in terms of modeling the behavior of these materials in the environment. Oxygen uptake data obtained earlier indicate that the rates of oxidation are low and essentially independent of concentration of organics. However, the material balance data from this test were inconclusive. Rate information will give insight on residence time (age) of these materials and could give clues on sources and methods of control. A series of oxygen consumption tests on Mississippi River water spiked with concentrates is planned. If the tests develop useful information similar measurements on water samples from different locations and at different times of the year will be carried out.

There is considerable interest in the removal of organics by conventional water treatment (or new treatment processes) and on the long term fate of the organics in the environment.

Data on carbon concentrations at various stages of treatment in local water treatment plants (see section D) are very interesting and have been publicized. Additional samples will be tested periodically to see whether there are any seasonal trends. We may approach one or more water treatment plants to see if a more extensive test of the anthracite filters is of interest; a study of frequency of backwashing with anthracite filters might also be interesting to follow up on the observation that more carbon passes through these filters.

The biological degradation tests described above will be correlated with field studies of oxygen demand and BOD data to provide more complete descriptions of the ultimate fate of organics in surface waters.

(C) Project Status

The project will continue in progress in fiscal year 1976.

(D) Application of Research Results

The previously mentioned watershed maps were used by the Minnesota Department of Natural Resources and the Minnesota State Planning Agency in their Coastal Zone Management Study. Copies of these maps were also requested for planning use by the Minnesota Arrowhead Regional Development Commission.

The goal of the experimental small watershed study is to demonstrate the utility of a complete water resources information data base in governmental decision making, private decision making, and university research. It is hoped that this study will lay the groundwork for future statewide water resources information system investigations and also provide recommendations concerning information needs, duplications, and analysis routines.

(E) Work Remaining and Progress Contemplated Next Year

For the next fiscal year the project will deal with the analysis of previously mentioned water resources information and investigation into the deficiencies and needs for improved decision making.

OWRT Project No.: A-031-Minn

Annual Allotment Agreement No.: 14-31-0001-5023

Project Title: Developing a Statewide Water Information System for Minnesota

ECCT-COWRR Research Category: 07-A, B, C

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

Project Began: July 1, 1974 Scheduled Completion: June 30, 1977

Principal Investigator: J.J. Waelti Degree: Ph.D.

Discipline: Agricultural Economics

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
Bryan Higgins	B.A.	Geography
Gregory Buckle	Undergrad	Ecology

Narrative Statements(A) Research Project Accomplishments:

In conjunction with the Minnesota Land Management Information System the watersheds of the Arrowhead region were mapped. Included in this process was the write up of a methodology to perform future watershed mappings. In addition a scheme to systematically number the watersheds of any region was devised and documented for future use.

Research investigations into statewide water information and policy was made with thought toward a future publication. Overall water information was systematically charted and existing water policies were shown in relation to this framework. Also, the Swan River watershed was chosen to focus an experimental study which would display the (1) potential of comprehensive water resources computer data base and (2) the decision making assistance possible with a combined land and water information system. Existing water resources information was gathered and coded for this watershed in the first step of this pilot study.

(B) Publications

Deick, Barbara, Higgins, Bryan, and Nessa, Scott, "Watershed Mapping in Minnesota. 50 p., 10 diagrams, 6 maps. (In preparation).

(D) Application of Research Results

The research results will be communicated to the general public and to other professionals concerned with policy formation in the area of environmental quality. The data will supply knowledge of public reaction to environmental problems and how their reaction agrees or is congruent with the reaction of leaders, scientists, and professionals working in the area of environmental quality.

(E) Work Remaining and Progress Contemplated Next Year

The bulk of the research work will be undertaken in the following year. This includes hiring and training interviewers and working with undergraduate and graduate research assistants.

OWRT Project No.: A-032-Minn

Annual Allotment Agreement No.: 14-31-0001-5023

Project Title: Water Quality Status and Trends in Minnesota - Social Dimensions

FCST-COWRR Research Category: 05-C

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

Project Began: July 1, 1974 Scheduled Completion: June 30, 1977

Principal Investigators: R.E. Rickson Degree: Ph.D. Discipline: Sociology
G.A. Donohue Ph.D. Sociology
P.J. Tichenor Ph.D. Mass Communication Research

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
Charles Ruffenach	Undergrad	Social Sciences
Marjorie Gardeen	Undergrad	Sociology and Nutrition
Hong Ik Chung	M.A.	Sociology
Peter Nowak	B.A.	Sociology

Narrative Statements(A) Research Project Accomplishments:

During the last year, data was analyzed from interviews with university scientists, industrial managers, and members of the general public. The analysis of the data is not sufficient that conclusions can be drawn but will be so shortly so that papers will be distributed concerning the results. Interview data was also collected, three hundred interviews, concerning public response to water quality problems.

(B) Publications

Rickson, Roy E., and Donohue, G.A. "Industry-Community Relationships and Pollution Abatement Change by Industry". This paper will be submitted to a professional journal and published as a Water Resources Research Center Bulletin.

Rickson, R.E., G.A. Donohue, P.J. Tichenor and C. Olien. "Role of the Scientist-Technician in Water Policy Decisions at the Community Level: A Study of Purposive Communication," WRRR Bulletin 79.

(C) Project Status

The project will continue for the next two years.

OWRT Project No.: A-033-Minn

Annual Allotment Agreement No.: 14-31-0001-5023

Project Title: Assessment of Water Quality Status and Trends in Minnesota
by Remote Sensing Techniques

FCST-COWRR Research Category: 05-C

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

Project Began: July 1, 1974 Scheduled Completion: June 30, 1977

Principal Investigator: Arnett C. Mace Degree: Ph.D.

Discipline: Forestry

Student Assistants	Degree Held	Discipline or Academic Background
Bonnie Dovenmuehle	B.S.	Biology
Jan Seewald	B.S.	Biology
Marty Christensen	B.S.	Biology
Robert Schierel	B.S.	Forestry

Narrative Statements(A) Research Project Accomplishments

Remote sensing data was acquired by three overflights of Lake Minnetonka on July 30, September 16, and October 17, 1974 at scales of 1:6,000 and 1:3,000 using 35 and 70 mm photography. The following film/filter combinations were used at both scales:

35 mm	Aerchrome Infrared/Wratten 15
35 mm	Kodacolor-X/No Filter
70 mm	2402 Plus-X Aerographic/Wratten 25A
70 mm	2402 Plus-X Aerographic/Wratten 58

The 70 mm film was shot in a quadri-camera mount using four Hasselblad cameras while the 35 mm film was shot using a Minolta motor-drive camera on a side mount.

Film density readings obtained by a VP-8 Image Analyzer were used to correlate with groundtruth data collected simultaneously with the overflight. White buoy markers and three foot diameter white secchi disks were used for sample location identification.

Water quality parameters correlated with film density readings of the four film/filter combinations included color, turbidity, sediment, phytoplankton, chlorophyll and secchi disk depth. Prediction equations have

been developed where significant relationships (0.05 and 0.01) existed between film density and measured or predicted (chlorophyll) water quality parameters. Significant correlations between density and water quality parameters for three overflights, film/filter combinations and scales are shown in Table 1. These data indicate:

- (1) 35 mm color infrared and normal color provide the greatest significant correlation between film density readings at both scales and water quality parameters monitored. 70 mm 2402 Plus-X Aerographic/Wratten 25A film/filter combination is the least effective combination for predicting these water quality parameters.
- (2) Color, turbidity, sediment, secchi disk and predicted chlorophyll were significantly correlated with film density at both scales. The larger scale (1:3,000) provides more significant correlations when 2402 Plus-X Aerographic/Wratten 58 film/filter combination is used.

Significant correlation between color and film density did not exist during the October 17th overflight. Also, correlation coefficients were lower during this overflight indicating that the potential of remote sensing techniques for evaluation of water quality parameters decreases as variability decreases.

(B) Publications

None.

(C) Project Status

This project will continue during the next fiscal year.

(D) Application of Research Results

Information obtained from this research effort will provide a significant tool for agencies responsible for monitoring water quality status and trends. Results and techniques obtained in this study will be used by the U.S. Forest Service during the next fiscal year to evaluate changes in lake and/or pond productivity resulting from the 1964 earthquake on the Copper River Delta of Alaska.

(E) Work Remaining and Progress Contemplated During Next Year

Four overflights during the forthcoming year will be expanded to include lakes other than Lake Minnetonka to evaluate a greater range of productivity and other water quality parameters. Additional analysis of the present data will be initiated in an attempt to reduce some of the confounding effects such as color, turbidity and phytoplankton.

In addition, other film/filter combinations will be used in an attempt to improve the present correlations. Wratten filters 48 and 61 will be used as well as new water penetrating film for evaluation of mean lake depth.

Table 1 - Significant correlations (0.05 level between film density and water quality parameter for three overflights of Lake Minnetonka by film/filter combination and scale.

Water Quality Parameter	Scale							
	1:6,000				1:3,000			
	IR/15	Color	2402/25A	2402/58	IR/15	Color	2402/25A	2402/58
Color	*	*			*	*		*
Turbidity	*		*	*	*	*	*	*
Sediment	*	*		*	*			*
Phytoplankton	*		*					*
Secchi dish	*	*			*	*		*
Chlorophyll	*	*			*	*		

MATCHING GRANT PROGRAM

NARRATIVE PROGRESS REPORTS

Form OW-1 (1972)

OWRT Project No.: B-053-Minn

Matching Grant Agreement No.: 14-31-0001-3600

Project Title: A Hydronomic Analysis of Forest Management Alternatives for Environmental Quality: A Case Study of Itasca County

FCST-COWRR Research Category: 06-G

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

Project Began: July 1, 1971 Scheduled Completion: June 30, 1975

Principal Investigator: A.C. Mace Degree: Ph.D.

Discipline: Forestry

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
J. Fychaner	M.S.	Hydrology
M. Majeski	M.S.	Hydrology
A. O'Hayre	M.S.	Hydrology
J. Halverson	Undergrad	Hydrology

Narrative Statements

(A) Research Project Accomplishments:

Input-output models have proved to be a valuable tool for regional planning. Extension to the methodology for estimating environmental as well as economic consequences of management alternatives has not been received as well outside the academic setting. It seems likely that this failure may stem partly from not providing information that is useful to the decision maker. A lumped estimate of residuals discharge has little value for actual decision making unless it can be related to some parameter of environmental quality.

In this study, an attempt was made to extend the input-output methodology to determine the effects of management alternatives and economic activity on stream water quality lake water quality in the region. The portion of total lake area in various trophic classes or the risk of exceeding minimum dissolved oxygen criteria may or may not be appropriate decision criteria for water quality in the region. If lake value is approximately a linear function of lake surface area and not highly dependent on location, the TSI criterion probably has merit. If location is important for a limited number of cases, a separate analysis could be made of these lakes. The DO risk criterion is a standard criterion for water quality planning. But the DO criterion alone presents a restrictive view of water quality. At the same time the water quality model under development has the capability of examining other water quality parameters including aquatic plant productivity and nutrient levels.

The specific modeling techniques employed to relate management alternatives and economic activity to lake water quality were selected because of the characteristics of the region such as the large number of lakes with poorly defined watershed boundaries. The Monte Carlo simulation used to assess regional lake water quality requires substantial amounts of computer time. This limits the number of alternatives that can be examined using the methodology.

For other regions the basic methodology should be applicable but the modeling techniques used for environmental assessment may vary somewhat. For some regions it may be desirable to identify the trophic properties of only the lakes having primary importance in terms of environmental quality for the region. Groundwater may be a critical resources in other regions in the region. In any event, it should be possible to develop the spatial models of economic and environmental relationships for specific regions. The critical points, however, are the infeasibility of developing the spatial models without computerized data systems and the worth of the information provided in terms of decision making.

(B) Publications

None.

(C) Project Status

The project has been completed.

(D) Application of Research Results

With the original input-output model, Hughes (1970) used three examples to illustrate the results of:

1. A change in the sales level of a given sector.
2. A structural change: i.e. a change in the number of establishments by size, class and/or kind within a sector.
3. The addition of an entirely new kind of business to the economy.

These examples are just some of the possible alternatives that could be examined using the proposed methodology for regional analysis of economic and water quality impacts of management alternatives.

To illustrate the procedures in applying the methodology, the example of a change in timber stumpage sales discussed by Hughes (1970) is used. He assumed that an additional 50,000 cords of pulpwood could readily be harvested each year from Itasca County forests. The stumpage value of the additional cut was \$75,500 for an increased harvest composed of the following volumes of different species at the indicated prices:

Aspen	30,000 cords @ \$1.00
Jack Pine	5,000 cords @ \$2.00
White & Red Pine	5,000 cords @ \$1.60
Spruce	5,000 cords @ \$1.00
Mixed Hdws.	5,000 cords @ \$1.00

Using the input-output model, the direct plus indirect economic impact of this hypothetical increase was determined for each sector.

To apply the methodology developed for both economic and water quality analysis to this example, it is necessary to compare the impacts for two different situations:

1. The original levels of timber harvest and the original level of final demand for output from each sector
2. The expanded levels of timber harvest but the original levels of final demand for output from all other sectors

The input-output approach is used to determine the direct plus indirect economic impact and the direct plus indirect point source discharge of nutrients at various locations. For each timber harvest alternative, the areas harvested from each timber type for the county are determined using forest inventory information for Itasca County and information on the species composition involved in achieving the given level of final demand from the timber production sector.

Monte Carlo simulation is used to simulate regional lake water quality for each proposed timber harvest alternative. Quadrate samples are drawn from the square grid land use data base (MMIS). Non-point source nutrient loadings are determined using Monte Carlo simulations as previously discussed. Point source nutrient contributions determined from the results of the economic and environmental linkages model are combined with non-point source loadings at the appropriate locations in the quadrat samples. Repeated sampling of quadrates is used to establish the distribution of trophic state indices in the region for a particular management alternative. The approach is repeated for each management alternative considered.

The nutrient loading distribution--lake TSI distribution model was calibrated using specific townships in Itasca County. Monte Carlo simulation of the TSI distribution for Itasca County for the suggested forest management alternative is currently underway.

Data for the Mississippi River was used in developing the river water quality simulation model for the stretch of the river below Grand Rapids. Field data on water quality parameters were collected during the low flow period in hopes of determining the fitted parameters for the model. Unfortunately, the systems identification problem could not be solved for the model with the standard quasilinearization procedure. Attempts are being made to modify the model to make it more amenable to mathematical optimization. At the same time work is being done on modifying the quasilinearization routine to allow it to handle systems identification for complex river water quality models.

(E) Work Remaining and Progress Contemplated During Next Year

None.

OWRI Project No.: B-068-Minn

Form OW-1 (1972)

Matching Grant Agreement No.: 14-31-0001-3901

Project Title: Spatial and Temporal Variation of Precipitation of a Concentrated Network in Both Urban and Rural Environments

RCST-COWRR Research Category: 02-B

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

Project Began: July 1, 1972 Scheduled Completion: June 30, 1975

Principal Investigator: Donald G. Baker Degree: Ph.D.

Discipline: Soil Science

Student Assistants	Degree Held	Discipline or Academic Background
John C. Klink	Ph.D.	Geography/Soil Science
John W. Enz	M.S.	Soil Science

Narrative Statements

(A) Research Project Accomplishments:

A relatively dense network of precipitation gages has been established across the state. The network now totals more than 2000 stations. This is equivalent to one station per 40 square miles, but of course, the stations are not uniformly distributed. A number of different groups are cooperating including the following: 1) the regular National Weather Service observers; 2) Future Farmers of America; 3) Forestry Service, State of Minnesota; 4) "Backyarders" (Twin City metropolitan area resident volunteers).

A special precipitation form was developed for ready determination of each station location to the nearest township, range and section. A unique computer program was developed which will summarize the great amount of data to manageable terms. The program flags individual storms of certain selected amounts, totals the monthly precipitation at each station, and calculates the mean precipitation in each township and in each county. In the near future, we hope to have a program that will plot the data on maps and draw the isohyets.

Analysis of a data from a dense network in the Twin City metropolitan area indicates that relatively minor topographic features can have important effects upon the precipitation under certain wind conditions. Because the conditions bringing these effects about do not always occur, this kind of influence can be easily overlooked. In some cases, such results may be attributed incorrectly to such things as an urban influence. Without the rain gage density available in this study, results from one

study in this project were tentatively, but incorrectly, described as due to an urban influence.

The areal distribution study indicated that a precipitation gage density of about one per 57 square miles for a "true" sample is required under Twin Cities type of summer weather conditions. The "true sample" is the minimum number of gages required to detect 0.01 inch or more within the region.

(B) Publications

Baker, D.G. and E.L. Kuehnast. 1973. Climate of Minnesota. Part VII. Areal distribution and probabilities of precipitation in the Minneapolis-St. Paul metropolitan area. Minn. Agric. Expt. Sta. Tech. Bull. 293, 19 pp.

Kuehnast, E.L., D.G. Baker, and J.W. Enz. 1975. Climate of Minnesota, Part VIII. Precipitation patterns in the Minneapolis-St. Paul metropolitan area and surrounding counties. (Minn. Agric. Expt. Sta. Tech. Bull. - in press).

(C) Project Status

The project is terminated as a Water Resources Research Center project as of June 30, 1975.

The precipitation gage network will be continued and the data used for similar purposes and studies in the future. This is too valuable a network not to continue it as a superior data source.

(D) Application of Research Results

Data from the precipitation network and publication have been used by a number of State and Federal agencies and others.

1. Soil Conservation Service, U.S. Dept. of Agriculture.
2. National Weather Service, N.O.A.A., U.S. Dept. of Commerce.
3. Department of Natural Resources, State of Minnesota.
4. Office of Emergency Services, State of Minnesota.
5. Department of Agriculture, State of Minnesota.
6. Various consulting meteorologists, hydrologists and engineers.

The data have shown the location and areal extent of severe storms, and they have given a new picture as to the frequency that storms may be expected. Thus, the results are extremely useful in the planning of various designs and structures that are used to carry or direct the flow of water.

(E) Work Remaining and Progress Contemplated Next Year

This project is terminated.

Matching Grant Agreement No.: 14-31-0001-4095

Project Title: The Geochemical and Biostratigraphic Record of Natural and Pollution Eutrophication of Minnesota Lakes

FCST-COWRR Research Category: 05-C

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

Project Began: July 1, 1973 Scheduled Completion: June 30, 1975

Principal Investigators: Eville Gorham Degree: Ph.D. Discipline: Botany
H.E. Wright Ph.D. Geology

Student Assistants	Degree Held	Discipline or Academic Background
John R. Underwood	M.S.	Botany
Denise Tilton	Undergrad	Botany
Donald Wilton	B.S.	Botany
Nancy Eyster	B.S.	Biology
Sheryl Perley	Undergrad	Pharmacy

Narrative Statements(A) Research Project Accomplishments:

Work this year has concentrated on:

Investigation of fossil chlorophyll derivatives, epiphytic and hypophytic carotenoids as stratigraphic sedimentary indices to the cultural eutrophication of Shagawa Lake in Northeastern Minnesota. A paper on this work will be presented at the June, 1975, meeting of the American Society of Limnology and Oceanography.

Analysis in the same Shagawa sediment core of the specific pigments beta-carotene and lutein, which are ubiquitous in green plants, and myxoxanthin, which is specific to blue-green algae. During the past year the techniques have been improved considerably by the use of a streaker to load the thin-layer chromatograms on which the pigments are separated. Analyses are now complete and a paper by J.E. Sanger and E. Gorham will be prepared during the coming year. The work has been coordinated with similar analyses in surface sediments from a wide range of productive and unproductive Minnesota lakes.

Investigation of the mineralogy and elementary chemistry of a sediment core from Kirchner Marsh in which fossil pigments have already been measured (Sanger, J.E. and E. Gorham, 1973 Limnology and Oceanography 17:840-854). This work is now almost complete, and a paper by W.E. Dean, Jr., and E. Gorham will be presented at the June 1975 meeting of the American Society of Limnology

and Oceanography. A similar study has been made of a core from Elk Lake in Northeastern Minnesota, where considerable paleoecological has already been done.

Work has been nearly completed on fossil pigments in a sediment core from Cedar Bog Lake, where paleoecological studies have been made by Dr. E.J. Cushing. Work has also begun on Iron Lake in Northeastern Minnesota, where blue-green algal blooms are frequently encountered in a dilute tea-colored lake where they are quite unusual and not (as far as we know) ascribable to cultural eutrophication.

Diatom analysis of short cores of lake sediments previously completed were correlated with pollen and chemical profiles. The pollen stratigraphy provides a time marker in the sedimentary sequence because of the abrupt increase in ragweed and other plants resulting from agricultural land clearance. Methods of phosphorus analysis of sediments were perfected to give consistent results. An analytical method was developed for opaline silica, as an independent indicator of the abundance of silicious diatom tests in the sediments. Changes in the profiles at the several sites were correlated with known historic events of disturbance in the lake or watershed, such as waste disposal, logging, or agricultural activities.

The sensitivity of diatoms to water quality makes it important to include stratigraphic studies on lakes that have been only slightly disturbed within historic time, to see if any changes at all have occurred. Accordingly, a lake on the fringe of a wilderness area (Boundary Waters Canoe Area) in northern Minnesota was studied, in connection with a project concerned with the effects of forest fire on lakes. Apparently a very slight amount of logging in the watershed, along with the immigration of dust from disturbed areas, changed the ionic content of the water sufficiently to have a significant effect on the diatom populations as well as on the mineral sediment.

(B) Publications

Gorham, E. and J.E. Sanger. "Fossil pigments as stratigraphic indicators of cultural eutrophication in Shagawa Lake, Northeastern Minnesota", submitted for publication.

Bradbury, J.P., S.J. Tarapchak, J.C.B. Waddington, and R.W. Wright. The impact of a forest fire on a wilderness lake in northeastern Minnesota: Internatl. Limnol. Assoc., 19th Congress (Winnipeg 1974), proc. in press.

(C) Project Status

Although funding will cease on June 30, 1975, work on the project by E. Gorham, J.E. Sanger, and W.E. Dean will continue, albeit at a much reduced level of effort.

(D) Application of Research Results

The paper presented in 1974 at the International Limnological Congress in Winnipeg was well received and several requests for preprints have been

met. We believe that the techniques of pigment analysis applied to Shagawa Lake should provide a useful and relatively simple tool for those studying the origins of natural and cultural eutrophication.

(E) Work Remaining, and Progress Contemplated During Next Year

The studies of fossil pigments in surface sediments should be further correlated with studies of standing crops of pigments in Minnesota Lakes.

The analysis of the Iron Lake sediment core requires a good deal of further work.

Studies of pigments in detrital material caught by sediment traps could not be accomplished, but are perhaps the most important desideratum in our work on fossil pigments to date. They will, however, require substantial funding.

Various minor aspects (fossil pigments in the sediments of meromictic lakes, pigments diversity and plant phylogeny) require only a little further effort, and can readily be completed without further funding.

OWRT Project No.: B-087-Minn

Matching Grant Agreement No.: 14-31-0001-1096

Project Title: Bio-manipulation of Lakes for Elimination of Blue-green Algae

FCST-COWRR Research Category: 05-G

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

Project Began: July 1, 1973 Scheduled Completion: June 30, 1976

Principal Investigator: J. Shapiro Degree: Ph.D.

Discipline: Limnology

<u>Student Assistants</u>	<u>Degree</u>	<u>Discipline or Academic Background</u>
Michael Lynch	M.S.	Ecology (Limnology)
Vincent Lamarra	M.S.	Ecology (Limnology)
Sheryl Perley	B.A.	Pharmacology
Leland Comb	B.A.	Ecology
Gunilla Lindmark	M.S.	Ecology (Limnology)

Narrative Statements

(A) Research Project Accomplishments:

As noted in the last progress report, during the early spring of 1974 a series of rafts capable of supporting one-meter polyethylene bags was constructed. Nine such rafts were placed in Lake Emily, a small eutrophic lake near St. Paul, Minnesota. Six pH stats were arranged along with appropriate electrodes, solenoids, air compressors, etc. to control pH in certain of the bags using either CO₂ or HCl. During the summer of 1974 a number of experiments were done in which various treatments were tested for their ability to cause a shift from blue-green algae to green algae. In all, fifty-eight separate manipulations were performed. Analyses done on the experiments included pH measurements, transparency measurements, total PO₄-P, NH₃-N, NO₃-N, chlorophyll, phaeophytin. In addition samples of the algae were taken at frequent intervals, preserved and photographed to help in the analysis. Although analysis is not yet complete, a number of findings can be defined.

1. pH adjusted to 5.5 with either CO₂ or HCl usually results in a shift to green algae.
2. Preventing the pH from rising above 8.5 may result in a shift from blue-greens to greens.

3. Inoculation with green algae increases the rate of shift of the population from blue-greens to greens.
4. Reversal, i.e. greens to blue-greens will not occur unless the systems are reinoculated with blue-greens and the pH is allowed to rise.
5. The shift from blue-greens to greens under the influence of CO₂ is either delayed or prevented by the presence of arsenate.
6. The shift from blue-greens to greens can occur at pH values above 9.5 under the influence of added chlorine.
7. All of these observations can be explained on the basis of lysis of the blue-greens followed by release of their nutrients, including phosphorus, and the uptake of the phosphorus by any green algae present followed by subsequent growth of the greens. The release of phosphate has been demonstrated. As arsenate interferes with phosphate uptake by green algae its effect is in accord. Furthermore the effect of chlorine in suppressing phosphate uptake more for blue-greens than for green algae has been demonstrated so its effect in inhibiting the blue-green to green shift is understandable.
8. Previous speculation has been that the algal shift is brought about by a change in the direction of competition for nutrients such as CO₂ and PO₄. However we have found that the effect of CO₂ treatment is a rapid decrease in blue-greens, followed by the release of phosphate, followed by the growth of greens. Because of the rapidity of the happening a new hypothesis has been developed. This is that the effect of the CO₂ or the low pH or the chlorine treatment is to stress the blue-green algae so that the algal viruses normally present in natural waters attack the blue-greens and lyse them. Following this the green algae grow rapidly because of the increased nutrient supply and the lack of competition. To test this idea we obtained an algal virus and a blue-green alga, *Plectonema*, susceptible to it, and performed various experiments. In one of the experiments the alga was subjected to a variety of pH levels in the presence and absence of the virus. In the absence of the virus the alga grew well or moderately well at all pH levels. In the presence of the virus the alga grew well at high pH levels but lysed at the lower levels. These results make the virus hypothesis look plausible and the work is being continued.
9. Most of the early work was done on Lake Emily. Therefore in order to determine if the phenomenon was more universal we performed experiments on four other lakes using both the CO₂ and chlorine treatments. In general the results agreed with those on Lake Emily.
10. During the spring of 1975 we began a series of experiments designed to test the feasibility of large scale treatment of ponds and lakes. After obtaining permission to use several ponds and a quarry for our experiment we began a sampling program to determine baseline conditions. Also we have started experiments aimed at defining the extent and duration

of treatment necessary to work on a large scale. For example in our 1974 experiments certain data suggested that continued alteration of conditions is unnecessary i.e. that a short term treatment might be sufficient. This, in addition to being in accord with the virus hypothesis, would of course be economical. Unfortunately it has been an exceedingly dull and wet spring so that the blue-green populations normally present appear to be delayed. These experiments therefore will be continued this summer. In addition we expect to do a highly detailed experiment on Lake Emily in which all of our hypotheses will be tested simultaneously and in which many parameters will be measured to help determine the mechanisms of the algal shift. We also intend to do experiments in which zooplankters are added to populations with and without treatment to determine the edibility of the algae by the zooplankters. Our preliminary experiments show that the green algae resulting from treatment are grazed but the work should be repeated on a large scale. Finally we expect to do large scale treatments on ponds with either CO₂ or chlorine. One such experiment with CO₂ has already been attempted but the weather failed to cooperate.

(B) Publications

J. Shapiro, V. Lamarra, M. Lynch, "Biomaniipulation--an ecosystem approach to lake restoration. Presented at: Conference on Lake Protection and Management, Madison Wisconsin, 1974; Conference on Biological Control, Gainesville, Florida, 1975; Submitted to SCIENCE as a lead article.

(C) Project Status

The project will be continued in FY 1976.

(D) Application of Research Results

A great deal of interest has been exhibited and numerous reprint requests have been received. Reprints of the Madison conference have been mailed by the organizers of that meeting and the proceedings of the Conference on Biological Control are in the process of being published. The results thus far seem to provide a possible explanation for the effects of artificial circulation on lakes--both beneficial and undesirable--and suggest ways to circulate lakes to achieve desirable results.

(E) Work Remaining, and Progress Contemplated Next Year

The work to be done this year is detailed under (A). Most of the work next year will involve data analysis and attempt to use the results for large scale studies.

OWRT Project No.: B-097-Minn

Matching Grant Agreement No.: 14-31-0001-4097

Project Title: Thermal Pollution and Second Trophic Level Fauna in
Lake Superior

FCST-COWRR Research Category: 05-C

Name and Location of University Where Project is Being Carried Out:
University of Minnesota, Duluth, Minnesota 55812

Project Began: July 1, 1973 Scheduled Completion: June 30, 1975

Principal Investigator: Wayland R. Swain Degree: Ph.D.

Discipline: Environmental Biology-Environmental Health

Student Assistants	Degree Held	Discipline or Academic Background
R. Peter Neri	M.S.	Biology (aquatic biology)
G.S. Porter	undergrad	Biology (aquatic biology)

Narrative Statements(A) Research Project Accomplishments:

In order to access effectively alterations in behavior, physiology, locomotor activity, reproductive potential and the like as a consequence of thermal additions, it is necessary to first understand the behavior, physiology, etc. of these organisms in their natural state. One of two single major problems has been the necessity for seriously altering the natural environment in question in order to be able to observe changes in organism activity. Quite frequently, the alteration has materially effected the longevity of the organism, hence rendering the technique subject to question. In other cases, in order to avoid organism mortality, studies have been conducted which were dependent for observations on the chief parameters of concern.

Thus, non-invasive remote monitoring of physiologic and locomotor activity has been a long sought research goal to eliminate the necessity of surgical implantation, restrictive weight or the generation of unnatural activity. In the conduct of this study, methodology has been developed which overcomes the problems noted above by means of remote sensing using impedance conversion.

Initial studies in mammals utilized impedance conversion techniques to monitor the movements of erythrocytes within blood vessels. Based on knowledge of these observations, it was reasoned that the use of impedance conversion might hold particular promise for remote non-invasive monitoring of the behavior of freshwater invertebrate populations.

By definition, impedance is the resistance to the flow of alternating current and may be more specifically defined as the apparent total opposition to current flow in an alternating current circuit corresponding to the true resistance in a direct current. Impedance is equal to the ratio of the root mean square (rms) electromotive force in the circuit to the root mean square (rms) current produced by it, and is usually expressed by the notation:

$$Z = \sqrt{R^2 + iX^2}$$

where A = Impedance,

R = Ohmic resistance, and

iX = Reactance

Reactance is further defined as the opposition to the flow of an alternating electric current caused by the inductance and capacitance in the circuit. Reactance, therefore, may be defined by the equation:

$$iX = \frac{1}{2 \pi f c}$$

where f = Frequency, and

c = Capacitance

Thus, any change occurring in either the ohmic resistance (R) or reactance (iX) would of necessity induce changes in impedance (Z).

Since small aquatic invertebrates moving in such a field would oppose the flow of alternating current, it was reasoned that change in the impedance of the system would be induced. Further, if the system was sufficiently sensitive, it would be possible to observe zooplankters resting at a plane between electrode grids from the changes in impedance caused by the movement of various appendages of the organisms.

The system developed for this study consisted of a rectangular column constructed of plexiglass. A bi-polar arrangement of stainless steel grid electrodes (20 mesh/inch; 0.023 Gauge wire, type 304) were cemented on opposing walls in series 10 cm. apart. These electrodes were then connected by shielded cable to a Brush Impedance Coupler (model 11-4307-06) which utilized an excitation frequency of 50 KHz and maximum excitation current of 1.5 milli-amperes. The signal output from the impedance converter was then amplified and monitored on Brush 440 multi-channel recorders, a cathode ray oscilloscope and a 3 watt audio monitoring system.

Systems ranging from four to eight of these electrode pairs have been utilized. There appears to be no limit to the number of grids that may be used in sequence.

The present study reports the use of a system consisting of electrode pairs horizontally situated 3 and 5 cm. apart depending upon the size of the

test organism. Alternative arrangements of electrode pairs, variations in materials and styles of electrodes have been tried, but the present arrangement appears to yield maximum sensitivity and minimizes interference from extraneous radio frequencies and the effects of adjacent grids.

It was learned that maximum signals could be consistently achieved if the distance between electrode pairs exceeded the overall body length of the test organism by approximately 1.5 - 1.75 times. These values would tend to place the organism closer to one electrode grid than the other, maximizing the signal transmitted to the impedance unit. With this arrangement of electrode grid pairs, it was possible to detect the test organism as much as 1 cm. above and below the level of the electrodes.

It will be noted that the experimental chamber consisted of a square plexiglass column with stainless steel bi-polar grid pairs placed uniformly throughout its length. Two grid pairs are used to indicate their relationship to a nichrome-loop heating element which was used to alter the thermal regime above the element to provide a comparison of behavior in heated water. With this device, an artificial thermocline could be created at either of two points in the column where nichrome elements were located.

In order to simulate varying levels of light intensity found in lakes, a high intensity illuminator was situated above the water column in a light-baffled shroud. This source of illumination was equipped with a focusing element and an iris diaphragm to accurately control the amount of light allowed into the water column. To permit access to the column, the mount for the illuminator was hinged. Accurate levels of light at very low intensity were maintained by use of neutral density filters. In addition, narrow band-pass filters for the production of near monochromatic light were used. The filters utilized varied between 20 and 70 milli microns in total wave length spread.

A variety of aquatic organisms have been tried with this experimental system ranging in size from the opossum shrimp Mysis relicta var. oculata (Loven) of 1-2 cm. in length through Daphnia magna of 1-2 mm. in length to Limnocalanus macrurus (Sars) some 600 microns in average body length. Figure 1 shows a downward vertical movement of Daphnia magna in a 3 cm. by 3 cm. column over a total vertical distance of 36 cm. in 4.25 seconds. It is clear from this recording that signal to noise ratios are quite acceptable.

The movements of four dark-adapted mysids are shown in Figure 2. These organisms were placed in a 5 cm. by 5 cm. column 78 cm. in height. The column was situated in a light-tight environmental chamber in which the thermal regime was maintained at $8.5^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$. Thermistor probes were sequentially inserted throughout the length of the chamber to monitor temperature and a heating unit was located in the top of the column between the first and second electrode pairs. This unit created an artificial thermocline 24 cm. from the top of the column with a sharp gradient between the 8.5°C . "hypolimnion" and the 14.0°C . "epilimnion". It is evident that although Mysis did not preferentially select the colder environment, the activity of this organism in warmer water appears to be reduced both in frequency and amplitude of movements.

Figure 3 is a reproduction of a recording of a single mysid migrating from one depth to another. Visual observation of organism activity initially correlated with impedance tracings indicate that as this organism maintained a spatial position within the field of the top electrode pair, tail movements and swimming motions of the organism's exopods are evident as smaller oscillations superimposed on the larger curve.

The system described has been used to monitor individual species for as long as twenty days at a time with excellent results. By use of impedance conversion, the organisms can be monitored remotely and the influence of environmental parameters can be carefully controlled. Thus, a lake segment can be modelled in isothermal or stratified state, to which an artificially induced heated water stratum can be applied. In studies with Mysis relicta, preliminary results yielded data of an unexpected sort. In some fifteen trials, mysids showed a tolerance for temperature levels varying between one and thirteen degrees Centigrade in long term contact; and indicated a short range temperature tolerance up to seventeen degrees Centigrade. Existing literature indicates light to be a major cause of diurnal vertical migration in mysid population. Studies with mysids in the system described above indicate successful adaptation of this species to all levels of light utilized, up to the equivalent of full sunlight. It was noted, however, that as light intensity increased, acclimatization time increased proportionately to a maximum of approximately five minutes. Available literature indicates that these data may correlate well with rhodopsin conversion time in the eyes of mysids.

Concurrent studies with temperature effects on Daphnia magna indicate that if mysids are taken to be a stenothermal population that D. magna populations are far more eurythermal in nature. Tolerance ranges for this organism have been observed to span nearly thirty degrees Centigrade, from approximately one degree Centigrade to thirty-one degrees Centigrade. While specific data will be described elsewhere, predictive behavioral response of these organisms has been observed just prior to heat shock, which apparently precedes thermal death by approximately five degrees Centigrade. Just prior to thermal shock, gravid Daphnia undergo a vertical tumbling activity accompanied by release of immature young. These young, though premature, appear to be far more tolerant in short term tests to increased levels of heat than their parents. Acclimatization temperatures of both adult and premature young forms are currently being studied and data will be available shortly.

The long term effects of caelefaction on reproductive potentials of Daphnia magna have also been examined. It is apparent that an upper threshold for reproduction does exist, and this level is well below the temperatures at which Daphnia is killed or stupified by the heated water. This study was designed to assess fertility, fecundity and reproductive potential throughout a series of temperature ranges spanning the total tolerance level for Daphnia magna. Some evidence exists at the present time to support the contention that the effects of caelefaction may not be manifest on the original population but may, in fact, reduce or eliminate reproductive potentials in the progeny or the organism stressed by temperatures.

Preliminary data has been acquired from the utilization of a new variety of aquatic sampling designed to assess preferential light selection among a variety of aquatic organisms indigenous to Lake Superior. Preliminary data indicates that differentiation of light regimes selected by the test organisms correlate well with the light levels at which the organisms were acclimatized. Thus, these field data tend to confirm and corroborate the laboratory studies undertaken in the remote sensing column. A master's thesis was developed on this premise and reports these data.

Light levels have been monitored within this new sampling system and in the laboratory vertical column by means of a prototype electronic device which utilizes a photo-receptive transistor to convert changes in light levels to electronic resistivity, and thus to DC milliamperes. This final output is easily calibrated by means of a Tektronics commercial light meter to be read in either foot-candles or micro-watts per centimeter squared. This device is also described in the master's thesis developed under sponsorship of this project.

Since the culture of many of these organisms is required in order to maintain a stable test population, a great deal of additional information in long term culture of crustaceans has been acquired. Of particular interest is the culture of *Mysis relicta*, apparently never before tried. These organisms were found to be extremely sensitive to very low levels of neoprene or synthetic rubber based compounds. It is estimated that this sensitivity is in terms of parts per trillion.

(B) Publications

- W.R. Swain, R.M. Wilson, and R.P. Neri. 1973. Vertical migration of crustacean zooplankton in Lake Superior. Proceedings of the 10th Annual Lake Superior Biological Conference.
- W.R. Swain. 1975. Cold tolerance in relation to starvation in *Rhyzopertha dominica*. Manuscript in press, The Canadian Entomologist to appear circa November, 1975.
- W.R. Swain, R.S. Pozos, R.M. Wilson and R.P. Neri. 1974. A new technique for remote monitoring of freshwater invertebrate populations (Abstract). Proceedings of the 37th Annual Meeting of the American Society of Limnology and Oceanography.
- W.R. Swain, R.S. Pozos, R.M. Wilson and R.P. Neri. 1974. Impedance Conversion: A new technique for non-invasive remote monitoring of freshwater aquatic invertebrates. (Abstract). Proceedings of the Annual Meeting of the Entomological Society of Canada.
- Neri, R.P. 1975. A study of vertical migration of selected zooplankton of Lake Superior as affected by light regimes. Master's degree thesis - University of Wisconsin, Superior.
- W.R. Swain, R.M. Wilson, R.P. Neri and G.S. Porter. 1975. A new technique for remote monitoring of freshwater invertebrate populations with special reference to oxygen consumption by naids of *Anax sp.* and *Somatochlora sp.* (Odonata). Manuscript submitted for publication in The Canadian Entomologist.

- W.R. Swain, R.M. Wilson, R.P. Neri and G.S. Porter. 1975. An inexpensive sampler for studies of threshold levels of tract metals and persistent organic compounds in surface waters. Manuscript in preparation for submission to Journal of the Fisheries Research Board of Canada.
- W.R. Swain, R.M. Wilson, R.P. Neri and G.S. Porter. 1975. Selected effects of thermal additions on cold water fauna. Manuscript in preparation for submission to Water Resources Research Center for publication as a WRRC Bulletin.

(C) Project Status:

Project's support will terminate on June 30, 1975. Project will be continued by investigative team as unsponsored research (see item F below).

(D) Application of Research Results

Wide interest has been generated by this project including personnel from the National Water Quality Laboratory, University of Wisconsin System, regional and national consulting groups as well as members of the scientific community.

Information on this system and its application to other aquatic studies have been submitted by Doctor Fry of the University of Toronto Institute for Environmental Studies. Further, a student from the University of Washington, Seattle (and co-worker in Doctor Edmonston's laboratory), Mr. Robert Pastorak, worked in the Duluth laboratory on the basis of the ASLO presentation. It is planned that he will return in September of 1975 to utilize the system to monitor prey location and attack adaptation of Chaoborus larvae.

(E) Work Remaining and Progress Contemplated During Next Year

The support of this project by the Water Resources Research Center terminates on June 30, 1975. However, it is planned that work will continue on this project into the coming year. The remainder of the study will obviously be on an unfunded and unsupported basis.

During this period, however, it is anticipated that linkage with the School of Medicine's new analog computer can be established to enable effective handling of the massive amounts of data being accumulated. Once the linkage is established, other indigenous Lake Superior species and their response to stress, e.g., thermal additives, oxygen deprivation, and the like can be easily studied.

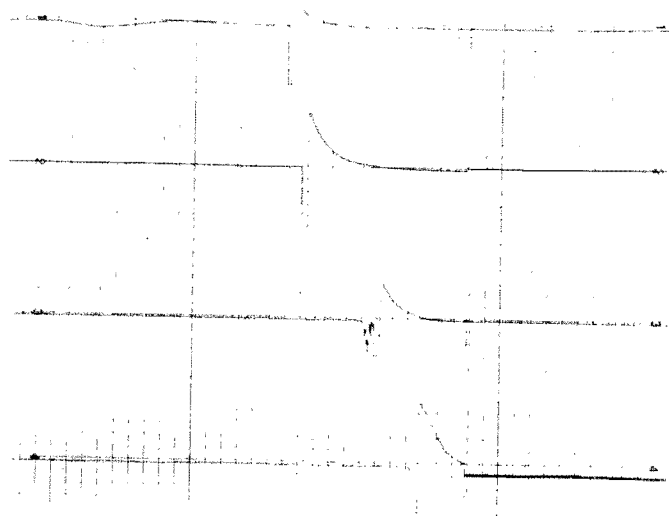


Figure 1. Recording of the downward vertical movement of the Daphnia magna in a 3 cm. by 3 cm. column over a total vertical distance of 36 cm. Instrument sensitivity, 0.005 scale units; chart speed, 1 mm/sec.

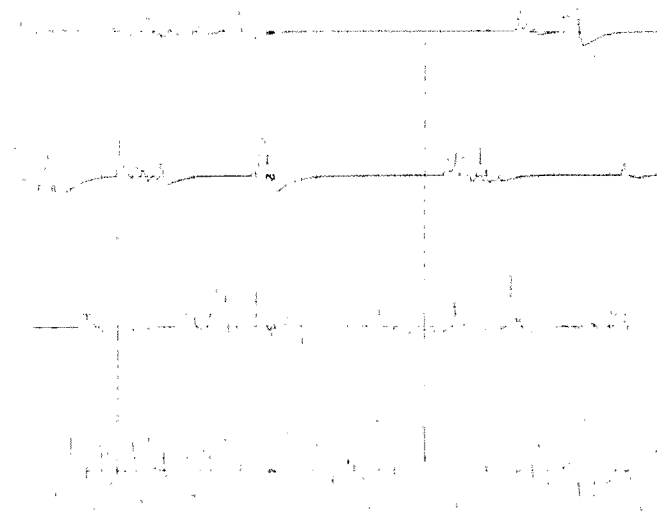


Figure 2. Recording of the movements of four dark-adapted mysids in a column 5 X 5 X 78 cm. The top tracing records activity of the organisms at a temperature of 14.0° C., while the bottom three records indicate activity at 8.5° C. Instrument sensitivity, 0.01 scale units; chart speed, 1 mm/sec.

OWRT Project No.: B-102-Minn

Matching Grant Agreement No.: 14-31-0001-5127

Project Title: Feasibility of Using Iron-Ore Overburden Material as a Media for Disposal of Secondary Sewage Effluent in North-eastern Minnesota

PCST-COWRR Research Category: 05-E

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

Project Began: July 1, 1974 Scheduled Completion: June 30, 1976

Principal Investigator: A.C. Mace Degree: Ph.D.

Discipline: Forestry

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline or Academic Background</u>
John Borovsky	B.S.	Forestry
David Holschlag	B.S.	Forestry

Narrative Statements(A) Research Project Accomplishments:

Sixteen plots (70' x 70') were established on overburden materials of the mine site of Erie Mining Company at Hoyt Lake, Minnesota. Four plots serve as a control, while the remaining plots will be sprinkler irrigated at rates of 1.0, 2.0 and 4.0-inches per week. Irrigation will be at a rate of 0.5 inches per hour for the period of June through October.

Eight forest species have been planted on the treatment and control plots. Irrigation has begun and will continue throughout this growing season. Pretreatment soil samples have been taken and the soil description completed.

Soil water samplers are installed at depths of 24 and 48-inches for collection of leachate to evaluate nutrient input and output. Samplers will be installed at 12-inches during the next month.

(B) Publications

None.

(C) Project Status

The proposed completion date is June 30, 1976. However, due to the late initiation of this project field analysis will be conducted during the 1976 growing season. No additional funds will be required for this research effort.

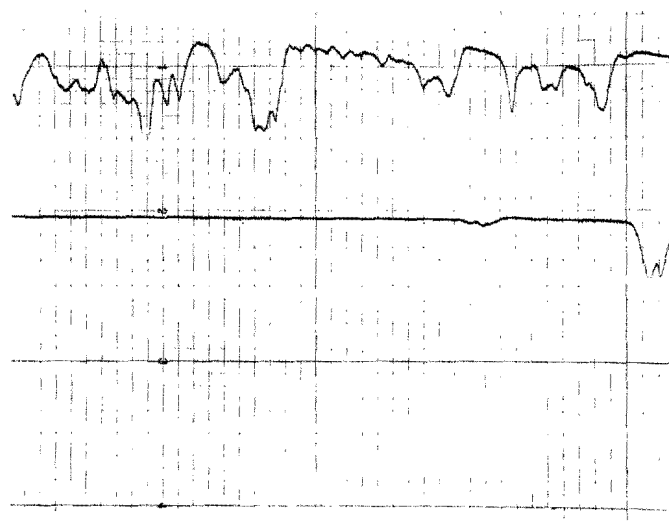


Figure 3. Recording of the activity of single mysid migrating from the top electrode pair to the second. Larger oscillations represent gross body movements, while the smaller oscillations superimposed on the curve represent the movements of swimming appendages. Instrument sensitivity, 0.01 scale units; chart speed, 5 mm/sec.

(D) Application of Research Results

Results from this on-going research will be useful for numerous mining companies for amelioration of unproductive overburden sites. The Minnesota Pollution Control Agency and Department of Natural Resources have expressed interest in this research effort as a method of increasing production and renovation of secondary effluent. This may be the only feasible and economical technique for disposal of secondary effluent for the many small communities in Minnesota.

(E) Work Remaining, and Progress Contemplated During Next Year

The major work remaining and contemplated next year entails weekly application of the secondary effluent, collection of soil water leachate, chemical analysis of soil-water leachate and groundwater and evaluation vegetation establishment and growth on each treatment site. Irrigation of 1.0, 2.0 and 4.0-inches will be applied at rates of 0.5-inches per hour each week with a portable irrigation system. Groundwater samples will be analyzed bi-monthly and soil water percolate weekly for pH, nitrate nitrogen, organic nitrogen, phosphorus, calcium, sodium, chlorine, magnesium, manganese, boron, and alkyl benzene sulfonates. Vegetation establishment and growth rates of each species will be evaluated periodically.

Soil physical characteristics such as soil temperature and moisture will be evaluated on a periodic basis to provide additional information for interpretation of plant establishment and growth.

TITLE II GRANT PROGRAM

NARRATIVE PROGRESS REPORT

OWRT Form OW-1 (1972)

OWRT Project No.: C-5111-Minn

Title II Agreement No.: 14-31-0001-4227

Project Title: Computer Programs and Simulation Models in Water Resources:
Scope and Availability

FCST-COWRR Research Category: 02-E

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

Project Began: July 1, 1973 Scheduled Completion: June 30, 1976

Principal Investigator: C.E. Bowers Degree: M.S.

Discipline: Hydrology

<u>Student Assistants</u>	<u>Degree Held</u>	<u>Discipline</u>
C.S. Chu	M.S.	Civil Engineering

Narrative Statements

(A) Research Accomplishments:

The primary objective of this study is the compilation and dissemination of 1) information on computer programs in water resources and 2) urban runoff data. Accomplishments to date include:

1. Letters have been mailed to individuals and organizations to obtain general information, documentation and source programs. Responses have been received from various organizations. These include 1) Battelle, 2) EPA, National Environmental Research Center, 3) HEC, Davis, CA, 4) ARS, 5) National Weather Service, 6) Federal Highway Administration, 7) Soil Conservation Service, and 8) numerous firms and individuals. A literature survey for computer programs related to the water resource field has been made through professional journals.

All together about 450 computer programs have been selected with short abstracts. These include hydrology, urban hydrology, statistical analysis of data, water surface profiles, peak flow rates, optimization, sewage and waste water treatment, municipal and industrial water supply, reservoirs and dams, groundwater, flow routing, water quality, water resources systems, and others.

2) So far ten programs have been selected and summarized for inclusion in the final report. These represent programs of special interest and merit a fairly detailed description. The remainder of the programs will be described in an annotated bibliography.

3. The RUNOFF and TRANSPORT BLOCKS of the EPA Storm Water Management Model (SWMM) have been converted to an OVERLAY structure to reduce the required core memory. This modified version has been tested for 1) Bloody Run Watershed, Cincinnati, Ohio, 2) Oakdale (12.9 acres), Chicago, Illinois, 3) 10 Acre Tract, Chicago, and 4) Northwood, Baltimore, Md.

4. The University of Cincinnati Urban Runoff (UCUR) model has been obtained, compiled, and run with 1) Chicago 10 Acre Tract test data, and 2) Oakdale (12.9 acre), Chicago, Illinois data. Also, modifications have been made to the pipe routing procedure so that the program can accept more complex pipe networks.

5. Data on four urban catchments have been collected and tested with the EPA SWMM and UCUR model. These four catchments are 1) Bloody Run Watershed, Cincinnati, Ohio, 2) Oakdale (12.9 acres), Chicago, Illinois, 3) 10 Acre Tract, Chicago, Illinois, and 4) Northwood, Baltimore, Md. For the Bloody Run Watershed, a complete data set is ready for EPA SWMM model. This includes a subcatchment map, sub-area map, sewer map, and all corresponding data.

For both Oakdale and the 10-Acre Tract Watershed, input data for both SWMM and UCUR are available. The subwatershed map and sewer map will soon be ready.

For Northwood, the data deck for the EPA SWMM for the RUNOFF BLOCK is complete.

6. Data have been obtained on several Australian urban catchments for possible inclusion in the report.

(B) Publications

None.

(C) Work Remaining and Progress Contemplated During Next Year

1. Select additional programs for detailed review.
2. Complete annotated bibliography.
3. Work with EPA SWMM to include the STORAGE and RECEIVING WATER BLOCK in the OVERLAY structure.
Run HEC-STORM model.
4. Prepare and distribute final report.

PROGRAM UNDER P.L. 88-379

Courses Developed

Agricultural Economics 5-650: Economics of Natural Resource Policy,
K.W. Easter and J.J. Waelti

This course reviews the role of the market in resource decisions, sources of market failure, project analysis, resource scarcity, and economic aspects of environmental quality.

Additional Water Resources Related Staff Members Added

Robert M. Wilson,	Junior Scientist	M.S.	Limnology (Interdisciplinary)
R. Peter Neri,	Junior Scientist	M.S.	Freshwater Biology
G.S. Porter,	Senior Lab. Tech.		Freshwater Biology

Staff Members Employed to Replace Those Who Retired, Died, or Moved

None.

New Research and Training Facilities Other Than Research Equipment Items

As a result of project B-097-Minn. and others, the Lakeside Laboratory, formerly a function of the School of Public Health, Minneapolis, will be developed as a full-time limnological facility in Duluth. Because of this project and similar studies, a program called the Lake Superior Basin Studies Center was established on the Duluth Campus of the University of Minnesota by the Minnesota State Legislature. Thus, a major new program and the renovation of a new facility was accomplished as a result of the support of this project and other similar programs.

NUMBER OF STUDENTS RECEIVING EMPLOYMENT AS RESEARCH PROJECT OR PROGRAM ASSISTANTS THROUGH THE P.L. 88-379 PROGRAM

Category of Students	No. by Scientific Discipline or Major Field of Study (Engineering, Biology, Economics, etc) ^{2/}	
	Scientific Discipline of Student	Number
(1) <u>Undergraduates</u>	Biology	1
	Botany	1
	Chemistry	2
	Civil Engineering	1
	Ecology	1
	Hydrology	1
	Social Science	1
	Sociology	1
(2) <u>Master's Students</u>	Biology	5
	Botany	2
	Ecology	1
	Forestry	3
	Geography	1
	Mathematics	1
	Pharmacology	1
	Sociology	1
	Pharmacy	1
	(3) <u>Doctoral Students</u>	Biology
Ecology		3
Environmental Health		1
Botany		1
Hydrology		3
Sociology		1
Soil Science		1
(4) <u>Post Doctoral Students</u>		Geography

^{2/} This refers to educational background prior to employment as research assistant on P.L. 88-379 projects - not to departments in which projects are being conducted.

EMPLOYMENT STATUS OF MAJORS IN WATER RELATED FIELDS WHO GRADUATED DURING THE SCHOOL YEAR ENDING ABOUT JUNE AND WHO RECEIVE P.L. 88-379 SUPPORT

EMPLOYMENT STATUS	Category of School Year Graduate By Degree Obtained			
	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
1. No. employed in water-related positions in:				
Total - - -	6	6	1	13
Federal Agencies - - - - -	1	2	0	3
State and Local Agencies - - -	1	2	0	3
University or College - - - -	0	0	0	0
Other - Including private enterprise - - - - -	4	2	1	7
2. No. graduates returning to school for advanced degree - -	5	3	0	8
3. No. going into military service - - - - -	0	0	0	0
4. No. unemployed or working in other fields - - - - -	0	1	0	1
5. No. status unknown - - - - -	8	3	1	12
6. Totals - - - - -	19	13	2	34

The number of M.S. and Ph.D. majors in water-related fields who graduated and received support during the period 1965-75 varied as follows: 1965-0; 1966-1; 1967-3; 1968-3; 1969-4; 1970-5; 1971-5; 1972-9; 1973-7; 1974-11; and 1975-15.

TYPE OF EMPLOYMENT OF THOSE SCHOOL YEAR GRADUATES WHO RECEIVED P.L. 88-379 SUPPORT AND WHO ARE KNOWN TO HAVE GONE INTO WATER-RELATED POSITIONS

Category of School Year Graduate
by Degree Obtained

Number of Graduates Engaged in Water-Related Work In:	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
1A. <u>Federal Agencies:</u>				
a. Primarily Research	1	0	0	1
b. Primarily Planning	0	0	0	0
c. Primarily Development	0	0	0	0
d. Primarily Operations	0	0	0	0
e. Primarily Management	0	0	0	0
f. Other or not known	0	0	0	0
1B. <u>State and Local Agencies:</u>				
a. Primarily Research	1	1	0	2
b. Primarily Planning	0	0	0	0
c. Primarily Development	0	0	0	0
d. Primarily Operations	0	0	0	0
e. Primarily Management	0	1	0	1
f. Other or not known	0	0	0	0
1C. <u>University or College:</u>				
a. Primarily Teaching	0	0	0	0
b. Primarily Research	0	0	0	0
c. Primarily Research & Teaching	0	0	0	0
d. Other or not known	0	0	0	0
1D. <u>Other - Including Private Enterprise:</u>				
a. Primarily Research	4	1	0	5
b. Primarily Planning	1	0	0	1
c. Primarily Development	1	1	0	2
d. Primarily Operations	0	0	0	0
e. Primarily Management	0	0	0	0
f. Other or not known	2	0	0	2
Totals	6	2	0	8

Selected summary of above data -- from the "Total" column:

Research (1Aa, 1Ba, 1Cb, 1Cc & 1Da)	3
Planning (1Ab, 1Bb & 1Db)	2
Development (1Ac, 1Bc & 1Dc)	0
Operations (1Ad, 1Bd & 1Dd)	0
Management (1Ae, 1Be, & 1De)	1

PROJECT-RELATED REPORTS AND THESES
PUBLISHED DURING 1975

- Anon. 1975. Environmental Assessment and Design, Proceedings of a Seminar. Water Resources Research Center, Univ. of Minn. Bulletin 78.
- Anon. 1975. Proceedings of Conference on "Trends in Water Management." Water Resources Research Center, Univ. of Minn. Bulletin 80.
- Anon. 1975. Tenth Annual Report, Water Resources Research Center. Water Resources Research Center, Univ. of Minn. Bulletin 71.
- Anon. 1975. "Written Comments and Recommendations for Interim Primary Drinking Water Standards", Water Supply Division WH-450, U.S. Environmental Protection Agency, Washington, D.C. 20460.
- Anderson, C.T., Maier, W.J. 1975. Organic Carbon Contents of Water Supplies, Presented at 95th American Water Works Association Meeting, Minneapolis, Minn., June 8-13, 1975.
- Baker, D.G. and E.L. Kuehnast. 1975. Climate of Minnesota, Part VIII. Precipitation patterns in the Minneapolis-St. Paul Metropolitan area and surrounding counties. Minn. Agric. Exp. Sta. Tech. Bull.
- Bradbury, J.P., S.J. Tarapchak, J.C.B. Waddington, and R.F. Wright. The impact of a forest fire on a wilderness lake in northeastern Minnesota: Internatl. Limnol. Assoc., 19th Congress (Winnipeg 1974), proce. (In Press).
- Christianson, R.W. 1974. Commercial Navigation on the Upper Mississippi River: An Economic Review of its Development and Public Policy Issues Affecting Minnesota. Water Resources Research Center, Univ. of Minn. Bulletin 75.
- Drown, D.B., T.A. Olson, T.O. Odlaug. 1974. The Response of Nearshore Periphyton in Western Lake Superior to Thermal Additions. Water Resources Research Center, Univ. of Minn. Bulletin 77.
- Gorham, E. and J.E. Sanger. "Fossil pigments as stratigraphic indicators of cultural eutrophication in Shagawa Lake, Northeastern Minnesota", submitted for publication.
- Hopwood, A.J. 1974. Thermal Effects of a Nuclear Power Plant on the Mississippi River at Monticello, Minn. Water Resources Research Center, Univ. of Minn. Bulletin 69.
- Linn, J.G., R.D. Goodrich, and E.J. Staba. 1974. Aquatic Plants from Minnesota, Part 5 - Digestibility and Fermentation of Aquatic Plants. Water Resources Research Center, Univ. of Minn. Bulletin 70.
- Lundquist, J. 1975. A Primer on Limnology, Public Report Series No. 1. Water Resources Research Center, Univ. of Minn.

- Maier, W.J., McConnell, H.M., Conroy, L.E. 1973. "A Survey of Organic Carbon Constituents in Natural Fresh Waters", Proceedings of the First World Congress on Water Resources, Water for the Human Environment, Sept. 24-28, 1973, Vol. IV, Special Sessions, p. 500.
- Maier, W.J., Conroy, L.E., and Anderson, C.T. Survey of Organic Concentrations in Minnesota Surface Waters, Central States Water Pollution Control Conference, Madison, Wisc., May 22, 1975.
- Rickson, K.E., P.J. Tichenor, G.A. Donohue, C.E. Olien. 1975. Role of the Scientist Technician in Water Policy Decisions at the Community Level: A Study in Purposive Communications. Water Resources Research Center, Univ. of Minn. Bulletin 79.
- Shapiro, J., V. Lamarra, M. Lynch, "Biomanipulation--an ecosystem approach to lake restoration. Presented at: Conference on Lake Protection and Management, Madison, Wisconsin, 1974; Conference on Biological Control, Gainesville, Florida, 1975.
- Swain, W.R., R.S. Pozos, R.M. Wilson and R.P. Neri. 1974. Impedance Conversion: A new technique for non-invasive remote monitoring of freshwater aquatic invertebrates. (Abstract). Proceedings of the Annual Meeting of the Entomological Society of Canada.
- Swain, W.R., R.S. Pozos, R.M. Wilson and R.P. Neri. 1974. A new technique for remote monitoring of freshwater invertebrate populations (Abstract). Proceedings of the 37th Annual Meeting of the American Society of Limnology and Oceanography.
- Waelti, J.J. 1974. Minnesota Water and Related Land Resource Policies with Emphasis on the 68th Legislative Session. Water Resources Research Center, Univ. of Minn. Bulletin 76.
- Waelti, J.J. 1975. Surface Water Quality in Minnesota: The Translation of Goals and Policies into Results. Water Resources Research Center, Univ. of Minn. Bulletin 72.
- Walton, W.C. 1974. Understanding the Water Resources Research Center, Graduate School, University of Minnesota. Water Resources Research Center, Univ. of Minn. Bulletin 73.
- Walton, W.C. 1974. Digest of Energy Facts for Water Resources Studies in Minnesota. Water Resources Research Center, Univ. of Minn. Bulletin 74.
- Walton, W.C. 1975. Minnesota's Water Resources: A Primer. Public Report Series No. 2, Water Resources Research Center, Univ. of Minn.

THESES

- Neri, R.P. 1975. A study of vertical migration of selected zooplankton of Lake Superior as affected by light regimes. Master's degree thesis - University of Wisconsin, Superior.