Twelfth 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, 1976

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 1976

Minneapolis, Minnesota

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

CONTENTS

PREFACE

This is the Twelfth 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, 1975, and ending June 30, 1976, 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 1976 program and to OWRT Annual Allotment Agreement No.: 14-34-0001-6024.

FCST-COWRR Research Category: 09-D

Publication Abstract:

The fiscal year 1976 budget of the Center was $271,079. The Center supported 9 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; bio-manipulation of Minnesota lakes for elimination of blue-green algae; social trends of water quality status and trends in Minnesota; assessment of water quality status and trends in Minnesota by remote sensing techniques; feasibility of using iron-ore overburden material as a media for disposal of secondary sewage effluent in northeastern Minnesota; effects of silt and turbidity from agricultural drainage on benthic invertebrates in streams in western Minnesota; and effects of drainage projects on surface runoff from wetland topography of the North Central Region. About 30 students received employment through the Center's program. During fiscal year 1976, there were 18 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 (OWRT)
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 foundations, business and industry, contributed very substantially to a major redefinition of the role of research in the university. The

1/ Ikenberry, S.O. and R. C. Friedman. 1972. Beyond Academic Departments. Jassey-Bass Inc., Publishers. San Francisco, Washington and London

emergence of research centers reflects, in part, attempts of universities to accomodate 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, 1976 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 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 inter-disciplinary 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 years 1975 and 1976.

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 inter-disciplinary 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, 1976 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 (OWRT), 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 universitites. 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 1976 are shown in the table below. The sources of funds are also indicated.

Source of Funds

Fiscal Year	Center's Budget $	Fed.(OWRT)$	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	91,944	0	3,867	500
1970	328,160	180,930	123,055	20,795	0	3,200
1971	338,872	192,846	109,022	29,493	4,011	3,500
1972	432,777	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	378,584	229,636	145,448	0	0	3,500
1976	271,079	163,159	107,920	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 9 in fiscal year 1976, 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
1976	9

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 (FCST) 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
I. Nature of Water	0	0	0	0	0	0	0	0	0	0
II. Water Cycle	2	3	3	4	6	5	4	4	4	3
III. Water Supply Augmentation and Conservation	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
V. Water Quality Management and Control	3	5	5	5	6	4	3	3	2	6
VI. Water Resources Planning	0	0	0	1	2	5	10	11	9	6
VII. Resources Data	0	0	0	0	0	0	0	1	1	0
VIII. Engineering Works	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
X. Scientific and Technical Information	0	0	0	0	0	0	0	0	0	0

FCST Category	1975	1976
I. Nature of Water	0	0
II. Water Cycle	2	1
III. Water Supply Augmentation and conservation	0	0
IV. Water Quantity Management and Control	0	0
V. Water Quality Management and Control	8	6
VI. Water Resources Planning	1	1
VII. Resources Data	1	1
VIII. Engineering Works	0	0
IX. Manpower, Grants and Facilities	0	0
X. Scientific and Technical Information	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 here has been no research in the following 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
Physical Sciences	4	11	10	8	7	5	7	8	6	7
Biological Sciences	3	3	3	4	4	5	4	5	4	5
Social Sciences	0	0	0	2	3	4	6	7	7	4

Broad Aspects	1975	1976
Physical Sciences	3	3
Biological Sciences	6	5
Social Sciences	3	1

Some 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: Professional	Students	Clerks, etc.	Total
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
1976	3.65	6.23	1.55	10.43

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
1976	59,900	35,500	23,400	1,000

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 1976 for non-expendable equipment items associated with the Center's research programs total $148,586. 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.

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.

University or College and Unit Performing Research	Cumulative Funds Associated with Center's Research Program Through Fiscal Year 1976 $
University of Minnesota	2,697,251
Institute of Agriculture	1,016,568
Department of Agricultural Engineering	297,310
Department of Entomology, Fisheries & Wildlife	11,608
School of Forestry	167,574
Department of Soil Science	290,597
Department of Agricultural & Applied Economics	167,699
Department of Horticultural Science	81,782
Institute of Technology	625,862
St. Anthony Falls Hydraulic Laboratory	259,522
Limnological Research Center	291,416
Geological Survey	9,523
Department of Geology & Geophysics	54,596
Department of Civil & Mineral Engineering	48,205
Health Sciences	379,620
School of Public Health	311,511
Department of Pharmacognosy	68,109
College of Liberal Arts	273,253
Department of Anthropology	71,494
Department of Sociology	201,759
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 500 people throughout the State 44 quarterly Newsletters and 157 Information Circulars in an effort to disseminate information concerning water resources. Research projects supported by the Center have generated 18 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 57,500 copies of 87 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. Seventy-five 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.

DIRECTOR'S SUMMARY STATEMENT 1976

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 suddeness. 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 1976 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); Bio-manipulation of lakes for elimination of blue-green algae (B-087-Minn); Feasibility of using iron-ore overburden material as a media for disposal of secondary sewage effluent in northeastern Minnesota (B-102-Minn); Effects of silt and tur-

bidity from Agricultural drainage on benthic invertebrates in streams in western Minnesota (B-120-Minn); Effects of drainage projects on surface runoff from wetland topography of the North Central Region (B-122-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. A rational objective of research is to generate information and concepts such that more rational decisions regarding the use of scarce resources can be made. Most water problems involve conflict of use and/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 1976 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 eduction 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 43 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.

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

First Example

OWRT Project No.: B-077-Minn. started July 1, 1972, completed June 30, 1974.

Of all water-related problems, flooding is probably the quickest to destroy and kill. Within a few hours, it forces people from their homes - 23,000 in the Minnesota River Basin in 1969 - destroys their farms, crops, and homes - $147 million worth in that flood including losses of wages and profits, and causes deaths - 11 that time. Even that was a relatively mild flood when compared to 1965, with the highest water levels ever recorded in parts of Minnesota. Water covered an area one mile wide, forty miles long, costing the inhabitants over $153 million. The Red River of the North, caused extensive damage in Minnesota and North Dakota as it overran its banks in 1975.

Although much of the flood damage often includes crops, it is not limited to farms. Cities, originally located on rivers because of access to transportation, suffer extensive flood damages. Planners and developers often either ignore water-flow experts (hydrologists) or are unable to get enough information with which to plan, because the experts do not have it. Farmland, which is enriched by the river, is also vulnerable to its floods.

Floods are facts of life. The problem, however, is to limit the extent of damages caused by floods. In order to limit damages, control and prediction are vital. Prediction, enabling communities to plan against disaster, is the focus for C.E. Bowers, Professor of Hydrology at the St. Anthony Falls Hydraulics Laboratory, University of Minnesota.

Sometimes hydrologists are able to help prevent extensive damage. For instance, in 1969 they helped cut the estimated $280 million loss to $147 million, almost halving it. Bowers affirms that computers and simulation models have been the basis for the most important advances in hydrology, including flood prediction, in the last 50 years.

Much of Bowers work is on the Minnesota River Basin (which brought the 1965 and 1969 floods), containing the Minnesota River and 14 of its tributaries. Starting in South Dakota, the Minnesota flows southeast to Mankato, where it turns northeast to join the Mississippi at the Twin Cities. Important due to the severe floods it repeatedly brings, it contains 17 observation posts to keep track of them - hopefully warning of potential disasters - maintained by the Minnesota Department of Natural Resources and the U.S. Geological Survey. They provide information, which the researchers use in developing models and computer systems on amounts of flow, peaks, and times. Information for 1963 through 1971 is on tape, making it useful for computer analysis.

Weather information is the other necessary component for flood forecasting. To supply this, the National Weather Service maintains and reports from 45 stations in or near the 15 watersheds in the Basin, covering a 16,200 square mile area. What is reported includes temperature, precipitation, solar radiation (the percentage of the sun's rays hitting the earth), and dewpoint temperature. At two points, one near Watson and the other near St. James, the soil's temperature is reported. If frozen, it will not soak up any of the snow's moisture. The 1965 flood, for instance, is said to have been at least aggravated, if not caused, by a layer of ice and a deep frost beneath the snow. Again, the information should be on tape if computers are to use it. Tapes were available only for 1963 through 1971 from the National Oceanographic and Space Administration (NOAA). Although Bowers has obtained these tapes, he would like to keep the information up to date, something which NOAA is not doing. Going back in time, manual records (which have to be put on tape if computers are to use them) are available as far back as the last 71 years from one station near Mankato.

Using both pieces of information - water flow and weather conditions - computer programs (instructions for the computer) help to predict water flow conditions. Type of information, its usefulness for Minnesota conditions, and its accuracy, all depend on the program. Other agencies create their own programs, a few of which Bowers has tested. One, the "Streamflow Synthesis and Reservoir Regulation Model", came out very well after a few changes to suit it to local conditions. The National Weather Service and the U.S. Army Corps of Engineers developed it in Portland, Oregon, a quite different area from Minnesota. Portland is mountainous, rainy (rain has more moisture than snow), and warm in winter compared to Minnesota (30's and 40's compared to 10's and 20's), and is in a completely different weather system from the midwest. However, the relationships in the program were similar enough to Minnesota to forecast well, once some adaptations were done. Another model, HEC-1, developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers was also moderately successful, since it could work on only one rainfall at a time and did not account for soil moisture depletion between rains. As long as these are found separately, it forecasts well. An added bonus: it is easy to adapt to local conditions. Some of the first tests for a new National Weather Service program, the "National Weather Service River Forecast System" (NWSRFS), were performed in this lab. It did very well although requiring more than the usual amount of knowledge to run it. Usually the tests include more than one year's data (the researchers would like to find a minimum necessary for testing a program) for comparing the computer results to what actually happened.

The work is not limited to testing other models. To make their own models and programs, they either use raw data from the tapes, observation posts, and weather stations or they build an artificial channel system, which Bowers describes as a "branching network of channels of all sizes...all of which combine into larger channels...until all the flow is diverted through the main channel to the watershed outlet." The flow is not constant: a rain may swell a stream for a while, a dry day slow it down. In building the channel they keep some criteria in mind, that it can be applied anywhere in the network, has a continuous flow, comes up with the same results as those using raw data, includes what is happening throughout the system and

the channel itself, and will not require extra computer time beyond that needed for determining the flow itself.

One factor, of primary interest to Bowers is snow melt. It seems to be a major factor in spring flooding in Minnesota. At this time, predictions are difficult since no one knows all of the correlations between it and other known factors, such as soil temperature. If more could be known, predictions would be much more accurate, better warnings could be given, and better preparations made for flooding. Bowers has been able to do some work on this, mainly in evaluating programs for possible use in Minnesota. The Army Corps of Engineers and NOAA have been very much interested in the results. However, he would like to continue this and to determine variables that related to snow melt floods.

Flood forecasting, then, seems to be a promising method in reducing property damage and loss of life from flooding. Bowers work in adapting existing models and in formulating new models is a significant step in enabling future reduction of flood damages.

Second Example

OWRT Project No. A-025-Minn. started July 1, 1970, completed June 30, 1973.

Water weeds that grow so abundantly along shorelines, are the source of several problems. They destroy fisheries, interfere with irrigation and hydroelectric plants, impair navigation, and at times obstruct water flow.

In addition, they provide a breeding ground for mosquitoes. Some weeds even produce their own toxins; two types of blue-green algae carry poisons strong enough to kill a variety of animals within a few hours or even minutes.

Reasons for the growth of these weeds include farming virgin land, changing the water courses, establishing communities on the water's edge, navigation, and hydroelectric power development. In some cases, people have directly aggravated the problem by cultivating weeds in the public waters. As some species such as water lillies are very attractive, they are imported from areas that have biological controls (such as natural enemies) on them, grown in public waters, and encouraged to grow as weeds here.

One possible solution to this problem is to harvest the weeds, using them for some commercial purpose. Plants of all types, including weeds, have contributed some very important drugs to the fight against disease. With this in mind, Professor E. John Staba, Department of Pharmacognosy began researching some of Minnesota's water weeds. Pharmacognosy is the field concerned with discovering new drugs.

Some new drugs that have come from plants have included anti-cancer and anti-tumor agents, drugs that work against microorganisms, and substances that work on the central nervous system (such as caffeine). In testing the plants in Minnesota for any such possibilities, the first step was to see whether

any of them were toxic; toxicity, since it is a strong drug reaction, indicates that there are drugs in the plant. All of the Minnesota aquatic plants tested were quite low in toxicity. Staba next looked for anti-cancer properties. One plant Nuphar variegatum (a yellow flowered water lilly with heart shaped leaves) showed possibilities in this direction. Anti-coagulation effects were relatively strong in Nuphar variegatum, Carex lacustria (a purplish, densely flowered plant that grows in lake margins), Myriphyllum aelbescens (water mifoil), and Nymphaea tuberosa (white water lilly).

Antimicrobial properties seem important to at least some plants; these plants, such as some algae and the tomato plant, produce their own antimicrobial substances against natural enemies. So with the possibility that the same thing might be true in the plants that Staba was studying, he subjected the plants to a series of bacteria. The results, although relatively positive, were disappointing, at least as far as eventually using the plants for antibiotics against human diseases goes. One plant, Mymphaea tuberosa, was active against Mycobacterium smegmatis (an organism belonging to the same group responsible for tuberculosis). Staba was able to purify the chemicals that were active against the mycobacterium.

The most promising aspect of the study was in animal nutrition. The plants are rich in nutrients, serving as the main food source for many animals. Many animals graze on plants growing in the water; moose, muskrat, beaver, and waterfowl all like water plants.

The main plant ingredients are: carbohydrates (combinations of carbon, hydrogen, and oxygen), crude protein (including amino acids, some nitrogen, and related products), fats, and minerals. The last component, minerals, is especially important, since most forage lacks phosphorous, a mineral. Since most animals need phosphorous, cereal grains containing it are usually added to the forage. It might be that aquatic plants, less expensive than cereal grains, could substitute for them.

Aquatic plants have already been used for feeding farm animals, especially in Europe; farmers in Holland, Germany, and Yugoslavia have routinely fed their animals water plants. Researchers investigating the nutritional contents of the food, have found good amounts of proteins and minerals. In the water plants, Staba found that one of the main problems was the high amount of water; 10 pounds of wet plants ended up as only about a pound of dry material. How much dry plant he would get varied a great deal; so did the crude protein amounts of ash, and the crude fiber (all usually lower than alfalfa's). The amount of fat was about the same as for alfalfa. Particularly good, though, were the minerals. Calcium, potassium, magnesium, and sodium, as well as the trace minerals (such as iron) were all very high.

After looking at the nutritional values, it appeared that water weeds might have value in animal nutrition. The crucial question is whether the animals will eat them. Although the livestock ate them, conventional forage was preferred. The plants were not very digestable. Crude fiber was the only part that really digested well at all. The best mixture, in any case, seemed to be a 50/50 mix with other forage.

Storage was a problem, as the plants did not ensile well. Ensiling is a process in which food is treated in order to stop complete chemical breakdown.

The most promising aspects seem to be in the area of animal nutrition. Problems yet to be worked out are the harvesting (slow, inefficient, and costly) and how to get the animals to eat them. The University of Wisconsin is currently working on both problems, encouraged by Staba's original work and that done at this University.

Third Example

Minnesota's second nuclear-powered electric generating plant, located on the Mississippi River three miles northwest of Monticello, began feeding energy to about a sixth of Northern States Power's customers in 1971. Licensing had taken almost ten years to acquire. Part of that whole acquisition process had included preparation of an Environmental Impact Statement, a statement of, among other things, the effects of the thermal effluent on the ecology within the immediate area of the plant. In addition, monitors had to be established, in order to keep a check on what happened after the plant's opening.

In 1968 A.J. Hopwood, Department of Biology, St. Cloud State College, with the assistance of OWRT Project B-032-Minn. started research in this area. Little was known about the animals and plants living in the area when the studies began. Some information on the water quality itself, however, was known from Minnesota Pollution Control Agency (MPCA) records, which contained information on chemical and physical properties which existed between 1953 and 1965. The first studies on macroinvertebrates (insects) were done in 1969 on information on ecology near the power plant. Prior to that, about the only animals that had really been investigated were amphibians and fish. As far as understanding the ecology near the power plant went, amphibians, reptiles, and birds remained to be studied. For one thing, a complete up-to-date census was necessary.

Once the census had been completed, it was important to find out how all of the organisms related to each other; that is, it became important to examine the food web. A food web is a pattern in which some organisms receive certain types of energy, such as sunlight, making that energy useful for other organisms which eat the original organisms. In this way, the sunlight energy, for instance, becomes a useful form of energy for organisms that cannot directly use it. There is almost always a crucial organism in the food web. When that organism is affected, the others will likewise be affected. It was important to discover, then, which organisms might be most influenced by the power plant.

It was also necessary to determine what amounts of heat were discharged into the river, for how great an area, and how the heat affected the plants and animals in that zone.

Dr. Hopwood was able to finish a census of the fish and macroinvertebrates, as well as an analysis of the turtle population near the plant. He also observed the birds. For the first time, a census was complete for the area near the power plant.

On analyzing the census, it became apparent that the insects were crucial organisms in the food web; plants, on the other hand, were quite unimportant. The ecosystem itself is based on the combined energy from land vegetation, nutrients from runoff and waste water, sunlight, and algae. All of these combine into food for the bottom-living organisms and insects, which in turn become food for fish; finally, birds eat the fish and the whole cycle repeats itself. Thus, it becomes important, when looking for effects on the ecosystem, to look at the insects and the bottom-living organisms.

The next step was to see just how much heat was involved (usually less than a 5° rise) and what effects it had on the organisms. By tagging the fish, counts were made of the populations. Hopwood found that the extra heat had almost no influence on the populations. If anything, they were growing at a more rapid rate than was to be expected; this seemed to be because the insect population, one of the major food sources, was growing quite rapidly, as a result of the heat.

One of the major reasons for the lack of ill effects is that the water is clean to begin with; in dirty waters, where there is already an oversupply of some organisms, the consequences can be disasterous. The only significant danger in this study was the possibility of "cold shock." That is, if for some reason, the heat were to be rapidly lost, the fish unable to react quickly to a fast change in temperature, might die.

This is not to say that the river does not change often on its own. For instance, the currents change throughout the day; those changes determine where at least some of the animals will be. Minnows like certain velocities at certain times of day. They also like heat, so they come into the heated zones quite often. To the minnows, current and temperature are the important things in life; food is everywhere, so that doesn't really count.

Besides the ecosystem analyses, a few more contributions came out of the research. First, it is possible that at least some of the parameters are common to other places. One such site is Becker, where a new power plant, this time using coal, is planned. It is only a few miles from the Monticello plant, so much of the same data is applicable to it.

All things, however, can change. The ecology in the Monticello area is no exception. To help in watching for possible changes, Hopwood has initiated some monitoring guidelines. They, hopefully, will help stop trouble before it becomes a real problem.

Finally, public information and service have grown out of this program. Training has ranged all the way from several graduate students to concerned citizens' groups. Several of Hopwood's graduate students are now working in the field. The concerned citizens' groups, who frequently ask Hopwood to speak, are learning more about water, water problems, and how it all relates to them.

Fourth Example

Minnesota's lakes are its most notable natural resource. However, Minnesota's lakes have been undergoing varying rates of biological change resulting partly from natural sources, but mostly as a result of human activity. A major objective of concerned citizens is to prevent further deterioration and to improve lakewater quality where possible.

Research is needed to understand the ecology of lakes, if public policy is going to be directed toward preserving and improving the quality of Minnesota's lakes.

A fast relatively inexpensive method for studying lake ecology and condition has been devised by Eville Gorham, Professor of Ecology, and Herbert Wright, Director of the Limnological Research Center at the University of Minnesota under OWRT Project B-081-Minn.

They take a square sample about 10 inches on a side, as deep as they like (one inch equals about ten years of sedimentation), from the lake bottom. The pigments found in the sample tells what lives in the lake and what it used to be like, going back as far as 10,000 years (when the glaciers formed the lakes), depending on how deep a sample is taken. Since the sedimentation evens out the seasonal changes, one sample is generally enough to get some general picture of what has been happening to the lake. Generally, the contents have come mainly from the lake; only in very nonproductive lakes is the land input important, and it is clear from the sediment when that is the case.

In the traditional method, researchers sample water several times a year for several years (usually at least two or three times), analyze it, and average out the data, since seasonal changes and short-term events will throw it off somewhat. Although it gives more chemical information than does the new method, it tells nothing of the history. Since restoring a lake means restoring it to what it was in the natural state, it is vital to know what that was. Furthermore, analyzing the changes it has undergone helps in identifying the factors which affect it for better or worse, possibly leading to clues of what affects similar lakes.

Since the sedimentation methods involves only one sampling, it needs less money and time, as well as fewer personnel, then does the water-sampling method. This makes it ideal for a lakes survey, complemented by what is already known from water sampling. An extensive survey would facilitate classifying lakes according to their problems, needs, and factors that affect them for good or bad. Restoration and preservation could then be attempted, using this classification.

Eutrophication is a major problem; because little oxygen is available, most animals cannot live in such lakes. It shows up in the organic part of the sample (the other part being silt, sand, and clay), in the pigment, the sediment will be rich in nutrients but poor in oxygen, sodium, potassium, and magnesium. To study other oxygen-poor, but not eutrophic lakes, they

chose a few that do not have complete circulation in the fall when most lakes "turn over" due to temperature changes. These were in the Itasca Park region of northwestern Minnesota. Tests showed highly organic muds (high in carbon, representative of living organisms), abundant in chlorophylls (green pigments needed for photosynthesis, found in blue-green algae, plants, and some bacteria), and carotenoids (yellow, orange, or red fat-soluble pigments found in algae and plants, associated with chlorophyll). Compared to completely circulating, but eutrophic, lakes, the chlorophyll was three times that usually present. The carotenoids, in the highest concentration ever found in this laboratory, were four times the usual concentrations.

Although chemical analysis is possible with this method, water sampling gives more information. The real value of the sedimentation methods is in providing a history of the lake: what problems it has had and what factors have affected it. This is important in preserving and restoring the lake's health in much the same way as a medical history is important to a doctor in a medical examination.

One important factor seems to be settlement, which disturbs the watershed, the land shedding water into the lake. When the researchers examined samples of about a hundred years ago they saw a distinct growth in algae that occurred at about that time. Settlement, evident from a great increase in ragweed pollen, was associated with the growth. Another lake, Shagawa, in northeastern Minnesota, showed the same type of change; sewage runs into it, aggravating the eutrophication. Cedar Bog Lake, in Central Minnesota, was chosen for historical study because it has been extensively studied by other investigators. Iron Lake was also chosen, because of its mysterious blooms (sudden increases in algae populations).

Evolution was a final area of interest. To study this, they applied a concentration of plant pigment to paper after which they applied a solvent to the sample "streaking" it down the paper. Depending on relative weights of sample to solvent, spots appeared out of the concentration. As pigment diversity declined, so did the number of spots. They discovered that algae, with the greatest number of spots, have the greatest pigment diversity, the diversity increasing as the plants evolved.

One final step remains: seasonal analysis of the sediments to determine whether or not the sediments average out all of the lakes' events or just the major ones; whether the method is really valid for seeing all that is occurring in the lake.

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, and Winona State College. Plans have been made for the Center to co-sponsor Conferences. The 1976 roster of the Center is as follows:

John J. Waelti, Acting Director
Elizabeth Hermansen, Secretary

Advisory Committee

University of Minnesota

C.E. Bowers	St. Anthony Falls Hydraulic Laboratory
K.N. Brooks	College of Forestry
D.G. Brown	Deparrment of Geography
R.G. Bond	School of Public Health
K.W. Easter	Agricultural and Applied Economics
L.D. Hanson	Department of Soil Science
K. Huston	Agricultural Experiment Station
W. Ibele	Graduate School
C.L. Larson	Dept. of Agricultural Engineering
W.J. Maier	Dept. of Civil & Mineral Engineering
W.P. Martin	Department of Soil Science
G.D. Rose	Institute of Agriculture
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
C.H. Fuchsman	Center for Env. Studies, Bemidji State College
A.J. Hopwood	Dept. of Biology, St. Cloud State College
J. Jack	Dept. of Geography, Mankato State College
R.T. Moline	Dept. of Geography, Gustavus Adolphus College

State, Local and Federal Agencies

C. Oster	Environmental Protection Agency
M. Dorton	Metropolitan Council
R.M. Dennistoun	Minn. Dept. of Agriculture
F.H. Geisenhoff	Minn. Dept. of Economic Development
G. Hollenstein	Minn. Dept. of Natural Resources
C.A. Johannes	Minn. Pollution Control Agency
E.H. Ross	Minn. Dept. of Health
J.E. 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
E.S. Verry	U.S. Forest Service

Interest Groups and Private Concerns

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
E. Parham	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 Evnironmental Quality at the University of Minnesota.

A research project (OWRT 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 COB, 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, 1976, reports, theses and 157 Information circulars related to the programs of the Water Resources Research Center have been published. The Center has published and distributed to 500 people throughout the State 44 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 58,500 copies of 87 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 1976 of all personnel (Director, P.I.'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	18	500
Popular Articles Published	25	1,000
News Letters	4	500

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 1976, the Center distributed to about 500 people in Minnesota the following technical Bulletins:

Bulletin No.	Title
81	Study of Criteria & Models Establishing Optimum Level of Hydrogeologic Information for Groundwater Basin Management.
82	Eleventh Annual Report, Water Resources Research Center.
83	A Hydronomic Analysis of Forest Management Alternatives for Environmental Quality: A Cast Study of Itasca County.
84	Studies on the Effects of Thermal Additions on Selected Zooplankton Populations.
85	Proceedings of Conference on "Perspectives on Formulating State Water Policy."
86	The Contribution of a Water Information System for Environmental Planning In Minnesota.
87	Proceedings: 8th Annual Water Resources Seminar.

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.

In preparation is the 3rd publication of the Public Report Series, tentatively entitled "Water Research in Minnesota: A Decade Under the Water Resources Research Act."

Also in preparation is a bulletin reviewing all graduate water-related programs of Minnesota educational institutions. An earlier technical bulletin on Minnesota Water Law is being updated and will be published in Fy 1977.

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:

I have just been alerted to material contained in the report cited below, a contribution from your Center, which will continue to have, for me, great value as a reference bearing on pollution assessment/abatement programs with which I am associated.

Swain, Wayland R., et al. 1975. Studies on the effects of thermal additions on selected zooplankton populations. Minnesota Water Resources Center. Bulletin # 84.

I would, therefore, greatly appreciate receiving a copy of this highly useful study if such copies are available for general distribution without further cost to the Federal service.

Sincerely yours,

Henry C. Fichhorn, Chief
Biology Branch
Water Quality Engineering Division
U.S. Army Environmental Hygiene Agency
Aberdeen Proving Ground, Maryland 21010

I would like to thank you for the letter (December 31) and the package of publications that you sent us. This material will be very helpful to us in our future water resource planning efforts.

On January 7 I visited your office and obtained a list of bulletins published by your office. I have studied the list and if possible would like to request the following bulletins:

No. 53, Proceedings of Conference on Inland Lake Renewal and Shoreland Management; No. 57, Mobilization and Participation of Citizens Groups in Improving Quality of Water Resources Environment ; No. 68, Water Resources Problems and Research Needs in Minnesota; No. 72, Surface Water Quality in Minnesota; No. 74, Digest of Energy Facts for Water Resources Studies in Minnesota; No. 76, Minnesota Water and Related Land Resource Policies with Emphasis on 68th Legislative Session; and No. 80, Proceedings of Conference on "Trends in Water Management".

If there are any costs involved in sending these to us, please bill us. Thank you again for your assistance.

Sincerely,

Dick Carlstrom, Regional Planner
Six East Regional Development Commission
31 West 6th Street
Willmar, Minnesota 56201

I have recently received a copy of John B. Lundquist's A Primer on Limnology, WRRC, U of M, Public Report Series Number 1. After looking it over I believe that I would like to distribute a copy to each of my students in my Introductory Limnology Course. Would it be possible for you to send 40 copies for this purpose?

I especially liked the Minnesota orientation of this work and am sure that my students will put it to good use.

Thanking you for your trouble taken to answer this request, I remain

Sincerely,

Charles S. Holt, Ph.D.
Associate Professor of Biology
Bemidji State College
Bemidji, Minnesota 56601

I am a biology instructor at Swanville High School in central Minnesota. I am currently teaching a class in environmental studies for which I am accumulating materials pertaining to limnology. Recently, I was informed that your group has published two booklets: "A Primer on Limnology", by John B. Lundquist and "Minnesota's Water Resources: A Primer", by William C. Walton. Both of these booklets have been highly recommended to me and I am sure that they would present useful background material for our outdoor studies. A copy of each would be greatly appreciated. I would also be greatful for any other material on Minnesota lakes that you feel might have direct applications to our studies.

Thank you very much for your help in enriching our high school environmental program.

Sincerely yours,

Michael R. Kaus, Biology Instructor
Swanville High School
Swanville, Minnesota 56382

Received the two publications on water and limnology and they look very interesting. I would like to request 25 copies of each one if I'm allowed to get this many.

Distribution will be made to 5 high schools, 3 local public libraries, the County Planning Commission members and the County Board.

Sincerely,

Harley S. Shurson, Extension Agent
East Polk County Extension Office
Municipal Building
McIntosh, Minnesota 56556

I have had occasion to refer to publications of your Centre which I believe are #46, 47 and 48 dealing with aquatic plants. Unfortunately, these are not easily available and I would very much appreciate one copy of each if they could be provided. Perhaps there have been other publications dealing with aquatic plants or algae and their use. If so, I would be most grateful to receive copies.

We have worked on a harvesting and research project for the Ontario Ministry of the Environment over the past two years and the information coming from this work will be compiled during the coming summer. At this time our interests have been in silage for cattle feed and we have successfully fed animals this winter on rations based on Milfoil silage. We have also experimented with composts and evaluated their use in greenhouse studies.

If your group has continued with similar work, I would be very pleased to receive the names of persons with shom we might exchange information.

Thanking you in advance for any publications or information you may be able to supply, I remain,

Yours very truly,

John H. Neil, President
Limnos Ltd.
22 Roe Ave.
Toronto, Ontario, Canada

Thanks very much for your letter enclosing information on the University's Water Resources Research Center activities.

I am pleased to have information on the new projects and, of course, am especially interested in the research proposal entitled "Ground Water Quality in Southeastern Minnesota."

With kindest regards, I am

Sincerely,

Albert H. Quie, Member of Congress
2182 Rayburn House Office Bldg.
Washington, D.C. 20515

Water Resources Research Center Conference

A Conference was held in November, 1975 on formulating State water policy in Minnesota. Representatives of the executive, legislative, and judicial branches of state government gave their views on the role of their respective branches of government in formulating state water policy, and reviewed necessary actions by each branch of government to deal with current problems and issues.

INFORMATION CONCERNING RESEARCH PROJECT PROPOSALS SUBMITTED TO OWRT BY CENTER, FY 1977

Lists of FY 1977 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 1965-76 is also provided.

List of Annual Allotment Research Project Proposals submitted to OWRT by the Center for Fiscal Year 1977:

(* Proposals Funded)

* Water Quality of Aquifers as Affected by Movement of Fertilizer Nutrients Under Irrigation.

* Ground Water Quality in Southeastern Minnesota.

* A Study of the Effect of Land Spread Septage on Water Quality in Minnesota.

List of Matching Grant Research Proposals Submitted to OWRT by Center, Fiscal Year 1977:

Computer Identification of Insect Water Quality Indicators in the North Central United States.

Thermal Effluent Dispersion and Ice Growth in the Duluth-Superior Harbor.

Eutrophication of Western Lake Superior with Special Reference to Energy Production.

* A Trophic Classification of Minnesota Lakes Based on Lake Sediments.

Hydrocarbon, Trace Metal, and Organo-Metallic Geochemistry of Minnesota Lakes and Streams.

Development of Methodology for Quantitative Descriptions of Chemical Composition and Flow Dynamics of River Waters.

* Key Social Factors Affecting Water Related Resource Development Decisions in Minnesota.

Application of Mathematical Simulation Models to Flood Forecasting and Low Flow Analysis in the Upper Midwest.

Investigation of Atmospheric Inputs of Selected Trace Elements and Chlorinated Hydrocarbons to Minnesota Lakes and Surface Accumulatory Mechanisms.

Water Quality Status and Trends in Minnesota--Indices for Water Supply and Ground Water Pollution.

Aqueous Ozonation Studies of Organic Pollutants.

Predicting Groundwater Pollution by Oil Spills Through Experimental and Numerical Investigations of Spreading Mechanisms.

Dynamics of Interacting Microbial Populations.

The Measurement of Inadvertant Weather Modification Influence on the Hydrologic Cycle.

List of Title II Research Proposals Submitted to OWRT by Center, Fiscal Year 1977:

Analytical Methodology for Detection and Characterization of Aquatic Organics.

	Annual Allotment			Matching Grant		
Fiscal Year	Funded	Rejected	Total	Funded	Rejected	Total
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
1977	3	0	3	2	12	14
Total	32	0	32	33	107	140

Title II

Fiscal Year	Funded	Rejected	Total
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
1977	0	1	1
Total	1	27	28

FISCAL YEAR 1976 OWRT BUDGET

Annual Allotment Program

Project Title, Principal Investigator and OWRT Project No.	Federal Funds $
Center Director's Office	40,700
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)	15,300
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)	13,000
TOTAL	110,000
Annual Allotment Non-Federal Contribution	50,958

Matching Grant Program

	Federal Funds $	Non-Fed. Funds $	Total Funds $
Bio-manipulation of Lakes for Elimination of Blue-green Algae - J. Shapiro, Limnological Research Center (B-087-Minn)	8,400	12,414	20,814
Feasibility of Using Iron-Ore Overburden Materials as a Media for Disposal of Secondary Sewage Effluent in Northeastern Minnesota, A.C. Mace, School of Forestry (B-102-Minn)	22,953	22,577	45,530
Effects of Silt and Turbidity from Agricultural Drainage on Benthic Invertebrates in Streams in Western Minnesota, T.F. Waters, Department of Entomology, Fisheries, and Wildlife (B-120-Minn)	11,608	11,577	23,185
Effects of Drainage Projects on Surface runoff From Wetland Topography of the North Central Region, C.L. Larson, Department of Agricultural Engineering (B-122-Minn)	34,784	34,784	69,568
TOTAL	77,745	81,352	

ANNUAL ALLOTMENT PROGRAM

NARRATIVE PROGRESS REPORTS

Form OW-1 (1972)

OWRT Project No.: A-029-Minn

Annual Allotment Agreement No.: 14-34-0001-6024

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

Student Assistants	Degree Held	Discipline or Academic Background
Milton W. Anderson	B.A.	Biology and Chemistry
Alan DuChene	B. Math	Mathematics
Jung Ahn	M.S.	Environmental Health
Harold Lenhart	B.S.	Biological Sciences
Charlene Kannianen	B.S.	Chemistry
Winthrop Watts	M.S.	Public Health
Carleen Stoskopf	B.S.	Biology, Philosophy

Narrative Statements

(A) Research Project Accomplishments

Using data available on water quality in public water supplies a study was initiated to indicate the degree of compliance of the following water quality characteristics to existing U.S. Public Health Service Drinking Water Standards and the American Water Works Association goals: hardness as $CaCO_3$, 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 supplies in the State. A report was prepared of this study. A second report extended the data reported to include information on the number of supplies which provided or used as a source of water, waters which exceeded the limits for the particular parameters identified above and the number of persons consuming such waters.

To rank the various water supplies on the basis of their chemical characteristics a simple attempt was made to determine the water quality index for all well supplies, for which data on the parameters of interest were indicated, in those counties located south of the Minnesota River. These counties were selected for the initial evaluation, because, in general, their characteristics deviated more from the recommended limits indicated earlier.

Two series of values were obtained: the first, a quality index based on meeting the water quality recommendations of the DWS, and second, a water quality index based upon the goals suggested by the AWWA.

The equation used in arriving at an index value was of the form

$$\frac{C_1}{P_1} + \frac{C_2}{P_2} + \frac{C_3}{P_3} + \ldots + \frac{C_n}{P_n} = \text{Water Quality Index}$$

where

$C_1, C_2, C_3, \ldots C_n$ are the reported concentrations of the specific parameters measured, and

$P_1, P_2, P_3, \ldots P_n$ are the recommended permissible concentrations of the specific parameters measured.

In this expression, C_1 represents the reported hardness concentration, C_2 the iron concentration, C_3 the manganese concentration, C_4 the nitrate concentration, C_5 the chloride concentration, C_6 the sulfate concentration, C_7 the sodium concentration, and C_8 the total solids or filtrable residue concentrations. Similarly, P_1, P_2, P_3, ... P_8 represent the permissible concentrations recommended by the DWS and the AWWA, respectively, for hardness, iron, manganese, chloride, sulfate, nitrate, sodium, and total solids or filtrable residue.

The methodology can be used to get a rough indication of quality. It would be more desirable to apply a weighting factor to each of the parameters identified to assess the true significance in terms of quality but this can be considered for the future. The difficulty is in an indication of the true weighting factor. Attempts at developing such a weighting factor in calculating a water quality index in water pollution control have been reported. The methodology offers another advantage in that the magnitude of each fraction represents the general significance of each term studies.

The data show that there are variations in quality for different wells in a community serving as sources of supply and they also show for one of the examples indicated that surface water quality (Budd Lake) has a lower water quality index than did any of the ground water supplies except for the sample of spring water. The data for raw and treated water show an improvement in quality resulting from the treatment provided.

In general, it will be seen that these index values are lower than those reported for ground water supplies. The major factors accounting for these differences would be the hardness of the water, the iron and manganese levels, and the total solids content. These data also show that the treatment processes used were effective in reducing the levels of the specific parameters used in the evaluation.

As ground waters move through the ground specific cations may be removed and replaced by other cations as a result of ion exchange. Since anionic constituents are not so affected as the water moves through the soil, use was made of the sulfate to chloride ratio (SO_4:Cl) to identify specific aquifers with a view to perhaps indicating their movement and to hopefully use this characteristic to develop a better approach to sample collection and analysis on a time sequence basis to better measure changes of water quality with time. The use of such ratios have been identified in the past. One of the earlier attempts was that by Kobayashi who reported that apoplexy death rates in Japan were associated with acidic waters. He used a CO_3:SO_4 ratio. Since data were available on only the sulfate, chloride, and nitrate levels, use was made of the SO_4:Cl ratio to identify similar ground water supplies. Initially, the values were computed manually, but subsequently a computer sub-Program was developed to calculate this ratio for the various ground water supplies.

Highest sulfate concentrations were apparent in supplies serving the southwestern portion of Minnesota. Highest chloride concentrations, on the other hand, were associated with water supplies located in northwestern Minnesota.

More study invilving a better knowledge of the hydrogeology of the area South of the Minnesota River will be necessary to help in the evaluation and indication of the significance of the SO_4Cl ratio.

For the present, we have limited our activities to a transfer of the data contained in "State of Minnesota Public Water Supply Data, 1971, revised 1972" onto computer cards. Transcribing the data onto coding sheets was rejected because of the time required and the possibility of transcription errors. The layout of the "Yellow Book" made direct keypunching feasible with a minimum of precoding of data. Since the data were listed in alphabetical order by supply name, supply numbers were assigned in numeric order. County code and health and economic district codes were added, and ownership and source codes were changed from alphabetical to numeric. Data comment codes were assigned to each sample, and decimal points were added to certain numeric fields to avoid having to add leading zeros. Pump type and capacity data and treatment data were not coded but were keyed as alphabetical fields which would acquire special computer routines to translate the alphabetical information into numeric codes. Data pertaining to the supply were keyed on two supply data cards and data pertaining to each well in the supply community are keyed on two well data cards.

Two programs were written to edit the data cards. Program EDIT12 edits the two supply data cards and creates a 136 character per record master supply data file, and program EDIT34 edits the two well data cards and creates a 120 character per record master data file. The files were created so that they could be accessed interactively by teletype or CRT (Cathrode ray tube) to manually correct errors found by the edit programs. The programs check for missing data, check the type, size and range of each of the data items and recode certain fields. The most complex part of the programs are the two subroutines (CKTRT in program EDIT12 and CKPUMP in program EDIT34) which check the alphabetical treatment codes and pump type and capacity codes and recode the data into numeric codes.

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 developed and used have been reported elsewhere, and were used in identifying the presence of specific compounds and groups of compounds in the water samples collected for analysis. Results obtained in the application of these microanalytical techniques are given in the examples cited below.

Laboratory investigation revealed that a particular polyelectrolyte added to raw water as a coagulant and filter aid was present in the finished (treated) water. Studies showed that the polyelectrolyte in the finished water appeared as the polymer and as monomers. The polyelectrolyte or other added chemicals reacted with the organic compounds in raw water forming new substances that were transferred through the various stages of water treatment to the finished water prior to discharge to the distribution system.

The thin layer chromatograms demonstrated that (1) the polyelectrolyte was present in the finished waters, (2) the polyelectrolyte in finished waters appeared as the polymer and as monomers, and (s) the polyelectrolyte or other added chemicals (e.g., chlorine) reacted with the organic compounds in raw water forming new substances that were transferred through the various stages of water treatment to the finished water prior to discharge to a distribution system for human consumption.

Since polyelectrolytes are toxic substances their presence in raw waste waters or their addition during treatment, without subsequent removal, could be of public health concern.

Public water supplies contain a variety of chemical contaminants of natural, municipal, agricultural, or industrial origin. Some of these compounds are believed to be toxic, carcinogenic, mutagenic, and/or teratogenic, and thus, may be potentially hazardous to health. Organic chemicals as a group are of most concern. They are found in public water supplies in a wide range of concentrations, but most often in minute quantities. Existing analytical methods, which require extensive concentrations of dissolved substances in water before analyses can be made, are not feasible for the direct identification of the organic substances encountered.

Accurate, high precision, rapid, and economical methods for determining organic compounds in water are needed to separate the complex materials present into specific groups initially, and subsequently, into single entities within the groups. Thin-layer chromatography provides the techniques needed to separate these substances with excellent resolution, high sensitivity, great speed, and economy. For analysis, microgram quantities of material are required. In contrast to existing methods, which require concentration of up to several thousand gallons of water, the thin-layer chromatographic procedures described herein called for concentration of only three liters of sample.

Concentration techniques used, whether for large volume samples or three-liter volumes used, must be quantitative and nondestructive with regard to the physical properties and the chemical structure of the compounds. The conventional scheme of concentrating organic compounds on activated carbon with recovery by solvent extraction was used. Recognizing the inadequacies in the use of activated carbon as a sorbent and the solvents used for extraction -- variable solubilities and possible interaction of solvents -- the results of our studies were reported on a qualitative basis. This was the first of a series of studies on the identification of compounds found in raw and treated waters in Minnesota.

Raw and finished water samples were collected from three municipal systems using surface waters as their source of supply. All three plants included coagulation and settling, lime softening, recarbonation, rapid sand filtration, and chlorine-ammonia disinfection, but neither the order of treatment nor the chemicals used were identical. The procedures used have been identified and will not be repeated here. The groups selectively separated by the methods used were: chlorinated hydrocarbons, phosphoric acid esters, plant (vegetative) phenols and their derivatives, and detergents.

A ground water supply was collected from Water Treatment Plant D, a well 92.4 meters deep. Analyses by thin-layer chromatography showed the presence of ortho-and para cresols.

Foam resulting from the aeration of runoff waters (spring floods 1975) 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).

Lime sludges and waste backwash water samples were collected from Water Treatment Plant C and analyzed for trace inorganic heavy metals by thin-layer chromatography. The qualitative findings indicated the presence of the following cations in the sludge:

Major components: Al^{3+}, Fe^{3+}, and Ca^{2+}

Trace quantities: Ni^{2+}, Cr^{3+}, Mn^{2+}, Zn^{2+}, Mg^{2+}, Pb^{2+}, and Cd^{2+}

Minute quantities: Ra^{2+} and Ag^{+}

The backwash water contained:

Major components: Al^{3+}, Fe^{3+}, and Ca^{2+}

Trace quantities: Ni^{2+}, $Cr^{\#+}$, Mn^{2+}, and Mg^{2+}

The raw water was analyzed for cadmium but none was found.

It would be of interest to identify the source of the substances found--raw water or treatment chemicals used.

Discussions have been held with representatives of the Minnesota Geological Survey and the U.S. Geological Survey relative to the movement of groundwaters particularly in the southwestern portions of the State where waters of lesser quality are generally found. The intent of these discussions was to obtain information on aquifer levels, on additional water quality data pertaining to these aquifers, and some indication of flow directions of these aquifers.

These studies are continuing, and information developed to date does not permit any conclusions in these particular areas. As indicated earlier, sulfate:chloride ratios are being used, and it is hoped they may shed some light on these complex problems.

An examination of the literature is being completed related to the presence or absence of particular chemical agents in water and their role in relation to disease. Areas studies include the relationship between mineral substances in water and cardiovascular disease mortality; the effect of nitrates on incidence of methemoglobinemia in infants (there were five public water supplies in Minnesota in 1971 that exceed the permissible NO_3-N level in drinking water); and the effect of high sulfates on animal and human health.

The literature is being searched to obtain information on treatment methods that may be used to improve ground water quality, particularly for the removal of nitrates and sulfates.

Similarly, information is being sought to identify areas where water supplies have been regionalized.

(B) Publications

Straub, C.P., Quality of Water Supplies in Minnesota - II - Number of Plants and Populations Served Waters Meeting Specific Quality Requirements. Submitted to Water Resources Research Center, University of Minnesota. 32 pp. and 8 pp. Appendices (Aug. 15, 1975).

Goppers, V. and Straub, C.P., Polyelectrolyte Persistence in a Municipal Water Supply. Jour. Am. Water Works Assn., 68(6): 319-321 (1976).

Goppers, V.M. and Straub, C.P., Application of Thin-Layer Chromatography of the Determination of Organic Contaminants in Public Water Supplies. Jour. Am. Water Works Assn. In Press.

(C) Project Status

The project terminates on June 30, 1976.

(D) Application of Research Results

Safe Drinking Water Act, Public Law 93-523.

The study summarizes chemical data on public water supplies in Minnesota, and provides a basis, at least for two of the parameters reported -- nitrates and fluorides -- for judging compliance with the National Interim Primary Drinking Water Regulations. The recommended limits are unchanged from those recommended by the U.S. Public Health Service namely, nitrate (as N) 10 mg/liter (or approximately 45 mg/l as NO_3); and fluorides ranging from 1.4 to 2.4 mg/l as a function of temperature, ranges 32.5 to 12.0°C, respectively.

Agency Use of Material

The first report generated by the project was used by the Minnesota State Department of Health as supplemental material in their biennial budget presentation 1976-1977.

Interest on the part of the State Planning Agency was also expressed in water quality information to permit more effective planning of growth areas within the State. Copies of the first report were made available to the State Planning Agency for their use.

There were several requests for copies of the report by individuals and their agencies in the State.

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 were incorporated into the curriculum in a course in analytical methods utilizing advanced microanalytical techniques.

Use of Data Upon Completion of the Study

The information developed will be or can be used as follows:

1. The study identified the number of supplies and the number of persons consuming such supplies that exceed chemical constituents currently included in the National Interim Primary Drinking Water Regulations (nitrates in particular), the levels recommended by the U.S. Public Health Service Drinking Water Standards applicable to interstate carrier water supplies and the levels recommended as goals by the American Water Works Association.

2. Attempts at providing a basis for numerical representation of quality parameters, although very simplistic in their initial approach, assisted in ranking supplies and indicating those having the greatest deficiencies in meeting quality requirements.

3. Identification of water supplies of impaired quality will assist in defining treatment requirements for improving water quality to meet desired or recommended limits and goals.

4. The information indicated in the above items will help in determining the costs of improving those supplies to meet the defined or recommended limits and goals.

5. Where individual costs of improving specific water supplies may be excessive, consideration can and should be given to the possibility of recommending regionalization of specific supplies to obtain more adequate treatment at lower costs and with better operational controls.

6. The information available identifies areas of the state where water quality is impaired and will have a bearing on the potential planned growth of these areas unless water quality is improved.

7. An approach has been suggested through the use of ratios of anions (specifically sulfate to chloride ratios - the major anions reported) for identifying specific aquifers serving as sources of ground water supply. This information could be helpful in indicating flow patterns in these aquifers and could be useful in developing a more meaningful sampling program to provide chronological information on changes in water quality.

8. The data available on water supplies in Minnesota have been put on computer tape and will facilitate retrieval of information, will permit investigation of particular relationships (as in the case of sulfate to chloride rations), and will help evaluate other parameters through the appropriate application of computer subroutines.

(E) Work Remaining to be Completed.

The study identified the following as areas worthy of additional investigation.

1. The application of the simplistic water quality index indicated that, in general, surface waters are of better chemical quality than are ground waters. A more sophisticated approach may provide more meaningful information to rank the various raw water supply sources and the finished waters to indicate those requiring improvement.

Such studies indicate the need for developing standards of water quality for ground water supplies. Because of increased potential for mineralization, these sources may have permissible concentrations of these substances that are greater than those permitted in surface waters.

These studies also indicated that, in general, some treated water supplies, on the basis of the quality parameters used, were of lower quality, i.e., a higher water quality index, than were the raw waters used as sources of supply. This lesser quality resulted primarily from the addition of sodium to the water during the treatment process. There is considerable concern about sodium levels in water and its relation to disease.

2. The study indicated the need for identifying the specific aquifers used as sources of supply. This kind of information would be valuable for several reasons: a) it would be possible to establish a more meaningful sampling and monitoring program to provide information on quality changes related to season of the year, direction of flow, etc.; b) changes in the ratios of specific anions in the aquifer would indicate additions to the ground water flow from surface or other sources, and would assist in identifying possible pollutional inputs; and c) such information might be helpful in developing regional water supply systems.

3. Because the chemical parameters available for this study were so few in number, particularly as they relate to public health effects, there is a need to modify the analytical program to provide such information, and at the same time to meet the new National Interim Primary Drinking Water Standards. Of the standards currently identified, only two are routinely analyzed in the State -- nitrates and fluorides -- and the latter is a chemical added to the water to control the incidence of dental caries.

Laboratory studies were initiated to develop a simpler approach to the identification of potentially carcinogenic and other organic chemicals found in both surface and ground water supplies. The approach studies to measure and identify the microgram or submicrogram quantities of these contaminants involved the application of thin layer chromatography complemented by gas chromotography and infrared spectroscopy.

OWRT Project No.: A-030-Minn

Annual Allotment Agreement No.: 14-34-0001-6024

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

Student Assistants	Degree Held	Discipline or Academic Background
Claude Anderson	B.S.	Civil Engineering
Richard Pokorny	Undergrad	Chemistry
Hee Bong Kim	B.S.	Civil Engineering

Narrative Statements

(A) Research Project Accomplishments:

The first phase of this project consisted of an extensive monitoring program to determine the occurrence and concentration of organic and inorganic carbon in surface and ground waters. The objective was to evaluate carbon measurements as an analytical tool for monitoring water quality for pollution control and water quality improvement studies.

Carbon measurements were made with a modified Beckman carbonaceous analyzer; total carbon is measured by injecting a 20 microliter water sample into a 900°C combustion zone in the presence of air which converts all organic and inorganics to carbon dioxide; carbon dioxide is measured with a nondispersive infrared analyzer. Inorganic carbon is measured in a similar manner but uses a 150°C reaction zone in the presence of nitrogen gas and a phosphoric acid catalyst to liberate CO_2. Organic carbon is calcualted by substraction. The whole testing procedure requires a few minutes and measurements are reported to the nearest milligram per liter. The test is nonspecific and does not distinguish between naturally occurring and anthropogenic sources or between toxic-pathogenic and innocuous materials. Nevertheless, it is a very useful analytical tool for monitoring and assessing water quality and for detecting trends because it is much more rapid - 2 minutes per sample compared to 5 days for BOD measurements and 0.5 to 4 hours for COD measurements; (BOD and COD are the conventional analytical tools used to monitor the presence of organics in natural waters.

Monthly samples from more than 100 sampling stations representing the major Minnesota surface waters have been tested and analyzed for a period of 3 years. 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 longterm 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 which contains lower carbon contents.

Data for the major river basins in Minnesota have been published in the literature. Comparison of the carbon data with conventional measurements of BOD and COD to determine the extent of organic pollution indicate that organic carbon measurements are sensitive and probably more reliable as indicators of the presence of organic matter. It is gratifying to note that several state agencies, Minnesota Pollution Control Agency is one of the first, are now using this test on a routine basis to monitor surface and ground water quality.

The second phase of this project was aimed at evaluating other analytical techniques for detecting, measuring and identifying organic materials in natural waters. A variety of techniques for concentrating and fractionating organics were evaluated.

Preliminary results have been published. Anion exchange resins are the most effective solid adsorbent for removing the bulk (upward of 90%) of the naturally occurring trace organics from water. Activated carbon and XAD resins are effective for removing weak and nonionic constituents. Concentrates have been prepared for chemical analysis and for biochemical degradation studies. The results of this work have been used to formulate systematic schemes for use in research programs aimed at elucidating the concentration, composition and sources of the organic constituents in surface waters. Negotiations are underway with federal agencies to sponsor this program.

Chemical characterization of the organic constituents has not progressed as rapidly as planned. Spectroscopic analysis have been obtained on prefractionated and concentrated samples. The results show that aquatic organics resemble "humic" matter from soils. However, further work is planned to describe elemental composition, structure, conformation and to describe the interactions with metal ions. Some progress has been made using a combination pyrolsis-gas chromatograph to measure groups of organic constituents, specifically to detect organics originating from recent anthropogenic sources. However, this technique requires further refinement and calibration.

The third phase of this project was focused on obtaining insight on the residence time of organics in the aquatic environment. It is obvious that organics undergo biological-chemical-physical transformations in the aquatic environment. However, there is almost no information about rates

of transformation and their ultimate fates. The objectives of this phase were a) to determine the rates of biochemical degradation of aquatic organics and b) to establish the physical size distribution of the organic matter and to see whether the particle-colloid-molecular size distribution changes with time and location because this could have a major effect on sedimentation. The results obtained to date show that biochemical degradation is very slow. Less than 50% of the organic carbon is oxidized in the first 100 days. Rate coefficients have been determined and will be published in the near future. As regards size distribution, the results obtained to date show that flocculation to form layer aggregations of organics is dependent on water chemistry; the presence of divalent cations (such as calcium) has an important bearing on size distribution. However, further work is needed to elucidate the effects of cation interactions and time.

(B) Publications

No additional publications have been issued in FY 1976. Three papers are in preparation.

(C) Project Status

Work is continuing on the second and third phases; one graduate student has chosen to do his M.S. thesis on phase two and the biochemical degradation work is the focus for a Ph.D. thesis. Research findings to date suggest the need for expanded effort and a request for additional support has been submitted to two federal agencies.

(D) Application of Research Results

The results of this test program have been of direct practical value to state agencies and have potential significance in the formulation of drinking water standards 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 drinking waters contain 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 showing that a large fraction of the organic carbon present in surface waters passes through conventional treatment processes which otherwise produce acceptable water. Although the exact composition of aquatic organics is not known, 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. These findings have been communicated 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 will focus on:

1. characterization of organic materials found in natural waters
2. description of the residence time and fate of organic constituents both in the natural environment and in water supply treatment systems
3. determination of major sources of organics

Assuming that funding will be made available, the investigations of the physical-chemical-biological characteristics of organic constituents will be expanded. A detailed program plan involving staff and students from the Departments of Civil and Mineral Engineering and Chemistry has been submitted.

OWRT Project No.: A-031-Minn

Annual Allotment Agreement No.: 14-34-0001-6024

Project Title: Developing a Statewide Water Information System for Minnesota

FCST-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

Student Assistants	Degree Held	Discipline or Academic Background
Bryan Higgins	B.S.	Biology
Scott Nessa	B.A.	Geography

Narrative Statements

(A) Research Project Accomplishments:

This project has produced or been involved with the following research efforts:

Assistance in writing, editing and disseminating the Water Information Systems Catalog with the Minnesota Water Resources Council.

Publication of the Contribution of a Water Information System for Environmental Planning in Minnesota.

In conjunction with the Minnesota Land Management Information System a map of the watersheds for the Arrowhead Region of Minnesota was drawn. The Lake County portion of this map appears in the Lake County Atlas being produced jointly by the Minnesota Land Management Information System and the Arrowhead Regional Development Commission. The portion of this map contiguous to Lake Superior is being used by the Coastal Zone Study being done by the Minnesota State Planning Agency. Finally, this map was also used in the Copper-Nickel Mining Study by the Minnesota State Planning Agency.

(B) Publications:

Water Information Systems Catalog, Minnesota Water Resources Council. MWRC-1, April, 1975. 197 p.

The Contribution of a Water Information System for Environmental Planning in Minnesota, Bryan R. Higgins. WRRC, Univ. of Minn. March 1976. Bulletin 86. 70 p.

(C) Project Status

The project will continue in progress in fiscal year 1977.

(D) Application of Research Results

Standardized data formats for different forms of water information were discussed with the Minnesota Water Resources Council's Water and Land Resources Information Systems Subcommittee.

(E) Work Remaining and Progress Contemplated Next Year

In the next fiscal year in conjunction with Minnesota Land Management Information System this project will investigate the water aspects of agricultural suitability in Roseau County. Also, working with Minnesota Development Region 6E Commission, a computer analysis of water use will be undertaken. Finally, research concerning the "People's Guide to Environmental Regulation in Minnesota" will provide general information on institutional involvement for individual use or public concern with water in Minnesota. In addition, a survey of water and sewer rate structures will be made for municipal water systems in Minnesota.

OWRT Project No.: A-032-Minn

Annual Allotment Agreement No.: 14-34-0001-6024

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

Student Assistants	Degree Held	Discipline or Academic Background
Peter J. Nowak	B.A.	Sociology
Majorie Gardeen	Undergrad.	Sociology
David Miller	Undergrad.	Sociology

Narrative Statements

(A) Research Project Accomplishments

Research data were collected in five different communities throughout the state. Eleven hundred households were selected for the interviews. Interviewers were instructed as to the person to be interviewed in each household. Some of the interviewing remains in two of the communities. Approximately 90% of the respondents contacted agreed to be interviewed and successfully completed the interview. The content of the interview was directed toward determining public definitions of environmental quality, particularly, water quality, and how the public thinks problems such as these should be resolved. An important aspect of the interview content had to do with the position of water quality or environmental quality in the overall assessment by people of the quality of life in their community.

(B) Publications

Rickson, Roy E. Knowledge Management in Industrial Society and Environmental Quality, Human Organization. 1976. (in press).

Rickson, Roy E. and Charles E. Ramsey. Industrial Change and Environmental Quality, submitted for publication to Human Organization. 1976.

Rickson, Roy E. Dimensions of Environmental Management: Legitimation of Government Regulation by Industrial Managers, Environment and Behavior. 1976. (in press).

Rickson, Roy E. and Peter J. Nowak. Trends in Minnesota Public Opinion about Environmental Quality and Management, 1970 through 1976. 1976.

(C) Project Status

The project will continue through the next fiscal year.

(D) Application of Research Results

Public attitudes about the environment and the importance of environmental quality for community satisfaction are basic to the development and application of policy for any matter that has some consequences for environmental quality. For example, our research results, so far, suggest that the public continues to place considerable value on water and air quality as aspects of the overall quality of life in their communities. Economic development problems will have to take these values into account if economic and quality goals are to be balanced.

(E) Work Remaining and Progress Contemplated During Next Year

Two more communities will be added to the study. One is an urban area with a very large concentration of lakes. Deterioration of the lakes has been marked during the past ten years and there is a great deal of public concern about the issue. Another community in a non metropolitan area will also be added in order to balance our sampling of communities as to urban and rural location. In general, the data will be analyzed during the next fiscal year. A segment of the data will be used as a dissertation topic for one of our graduate students. Papers and the final report of the research will be completed by late Spring.

OWRT Project No.: A-033-Minn

Annual Allotment Agreement No.: 14-34-0001-6024

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
Marty Christensen	B.S.	Biology
Jeanette Stiegler	B.S.	Geology

Narrative Statements

(A) Research Project Accomplishments:

Prior to the 1975 field season, aerial photographs were taken for four over flights of Lake Minnetonka. The following film/filter combinations were used at scales of 1:6000 and 1:3000:

70 mm Aerochrome Infrared - 2443/Wratten 12
70 mm Aerochrome - 2448/Wratten 2A
70 mm 2402 Plus-X Aerographic/Wratten 25A
70 mm 2402 Plus-X Aerographic/Wratten 58.

Significant correlations existed between film density and the water quality parameters color, turbidity, sediment, secchi disk and chlorophyll.

During the 1975 field season, the project was expanded to include five additional lakes, White Bear, Bald Eagle, De Montreville, Olson and Jane, located in Washington and Ramsey counties. Aerial photographs were taken in June, August and October at scales of 1:2000, 1:3000, and 1:6000. Four film/filter combinations using 70 mm film were evaluated including 2443/12, 2448/2A, 2402/25A and 2402/58. The correlation between film density readings, obtained with a VP-8 image analyzer, and ground truth data were then evaluated. The water quality parameters studies were color, turbidity, secchi disc depth, sediment, estimated chlorophyll content and for Lake Minnetonka only, phytoplankton numbers. Ground truth data at each lake were collected simulatneously with the remote sensing flights.

Based on the analysis of data for the 1975 field season, the following results were apparent:

1. Secchi disc depths, color, and turbidity values indicated that the lakes could be categorized as follows:

   a. Oliogotrophic - Jane
      White Bear

   b. Mesotrophic - DeMontreville
      Olson

   c. Eutrophic - Bald Eagle
      Minnetonka

2. Significantly higher and more consistent correlations were obtained for the eutrophic and mesotrophic lakes.

3. The late summer months appear to be better for obtaining correlations between the remotely sensed data and the water quality parameters color, turbidity, secchi disc depth, and sediment.

4. Filmtype 2402/58 provided the best estimator of the water quality parameters examined. The number of significant correlations (at the 5% level) between film/filter types and the four water quality parameters are listed below:

	Film			
Parameter	2443	2448	2402/58	2402/25A
Color	4	5	3	7
Turbidity	3	7	5	4
Secchi disc	4	2	8	4
Sediment	3	2	8	3

5. The scale of 1:3000 gave the best results and the 1:6000 scale gave the poorest correlations.

6. Ground truth data on chlorophyll did not correlate well with any of the film-filter types.

(B) Publications

None.

(C) Project Status

Aerial photographs will be taken until the fall of 1976. Water quality analyses will be run and statistical tests made on the data during the winter of 1976. The results will be then documented and a final report will be completed by June 30, 1977.

(D) Application of Research Results

If aerial photography can be used to assess the water quality of lakes, several state and federal governmental agencies will benefit. Such a tool would be of particular use for the U.S. Forest Service in assessing the water quality of the more remote lakes in northern Minnesota.

(E) Work Remaining and Progress Contemplated During Next Year

The same six lakes will be evaluated during the 1976 Field season with five overflights planned. One of these flights has been completed. Several changes involving data collection and analysis are planned including: A conversion to monthly overflights, no more 1:6000 scale photographs, phytoplankton samples will be taken from all lakes, and the chlorophyll analysis will be discontinued. Attempts will be made to evaluate and quantify algae and other aquatic vegetation status in the various lakes.

Upon completion of all flights and subsequent data analysis, recommendations will be made with respect to the months best suited for analysis, the scale and film/filter combinations best suited for lake-water quality analysis, and perhaps which types of lakes (in terms of eutrophication) may be better suited for such an analysis.

MATCHING GRANT PROGRAM

NARRATIVE PROGRESS REPORTS

Form OW-1 (1972)

OWRT Project No.: B-087-Minn

Matching Grant Agreement No.: 14-31-0001-4096

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

Student Assistants	Degree	Discipline or Academic Background
Michael Lynch	M.A.	Ecology (Limnology)
Vincent Lamarra	M.A.	Ecology (Limnology)
Sheryl Perley	B.A.	Pharmacology
Leland Comb	B.A.	---
Gunilla Lindmark	M.A.	Ecology (Limnology)
Bruce Forsberg	M.A.	Ecology (Limnology)
George Zoto	Ph.D.	Botany

Narrative Statements

(A) Research Project Accomplishments

The last progress report described in detail the basic sorts of experiments that have been undertaken to demonstrate and understand the mechanism of the shift of algae from blue-greens to greens, and the preliminary findings thereof. Since that time various other experiments have been done and considerable analysis of the data has been undertaken, particularly with regard to specifics of the changes in the algal population. In addition, the findings have been used to provide input to experiments aimed at understanding why artificial circulation of lakes is frequently a benefit to them.

Among the experiments done since the last report, one deals with the possibility of manipulating algal populations by the so-called "one-shot" method, i.e. during the course of our studies we have found that it may not be necessary to continually maintain the conditions that cause the shift from

blue-greens to greens, but that if these conditions are established for a relatively short period the phenomenon occurs. To the extent that the data have been analyzed the approach appears to be a feasible one. If further analysis continues to support these results they will be of real practical significance as well as being of theoretical import. That is, if a relatively short period of appropriate conditions favors green algae, then their success probably is not due to successful competition for such a substance as carbon dioxide, but rather would tend to support the "virus" hypothesis we have been testing.

The virus hypothesis has been the subject of continuing study. As noted in the last report the virus hypothesis says that the blue-green to green shift results from lysis by the normally occurring cyanophage of the blue-greens with subsequent release of nutrients to the greens. Several features of the shift suggest this may be true. First, the shift may be very rapid, the population changing from predominantly blue-greens to predominantly greens within a week or even less (Fig. 1). Second, the "annihilation" of the blue-greens is frequently virtually complete and very rapid. Third, when the shift is not complete it is always the same blue-green forms left, indicating resistance to the lytic agent. Fourth, the shift is very often accompanied by a sudden appearance of inorganic nitrogen and phosphorus. As the systems are closed these nutrients must result from lysis of the blue-green cells. Fifth, although we have been able to show that both nutrients and low pH are necessary for a rapid and complete shift, the nutrients may be added several days before the pH is lowered. Even though the nutrients are completely taken up by the blue-greens they still end up in green algae.

In order to determine the role of viruses, last summer we performed experiments in which their role was studied with particular care. We are still analyzing the results. In addition to these field studies, various laboratory studies are underway. Examples include the effects of various pH conditions on the algal/virus relationship; effects of the rate of change of pH on the relationship; the role of nutrients in the relationship, etc.

The manner in which these results are believed to be important in lake restoration, particularly that resulting from artificial circulation, is shown in Figure 2. Thus, in analyzing 20 experiences in the literature (Table 1), of 13 in which the blue-green/green shift occurred, 10 involved a drop in pH, and the pH was low in the other 3. In the case of the 7 unsuccessful circulations, where blue-greens remained abundant or increased, in 3 the pH rose and in 1 the pH went down but still was relatively high. Therefore, we feel that the algal shift experiments provide the key to the success or failure of lake circulation. This summer we have begun a series of circulation experiments in deep plastic cylinders with the intent of testing these ideas on a pilot scale. If the experiments prove that our hypotheses are correct then next summer we will go full-scale.

(B) Publications

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

(C) Project Status

The project will be terminated September 30, 1976.

(D) Application of Research Results

As described in the last report there has been a great deal of interest in our work. The findings are directly applicable to lake restoration and we are proceeding in that direction.

(E) Work Remaining and Progress Contemplated During Next Year

This summer we are doing various experiments aimed at practical application along with more detailed investigation of the role of viruses. In addition, a great deal of time will be spent analyzing and writing up the data in final form.

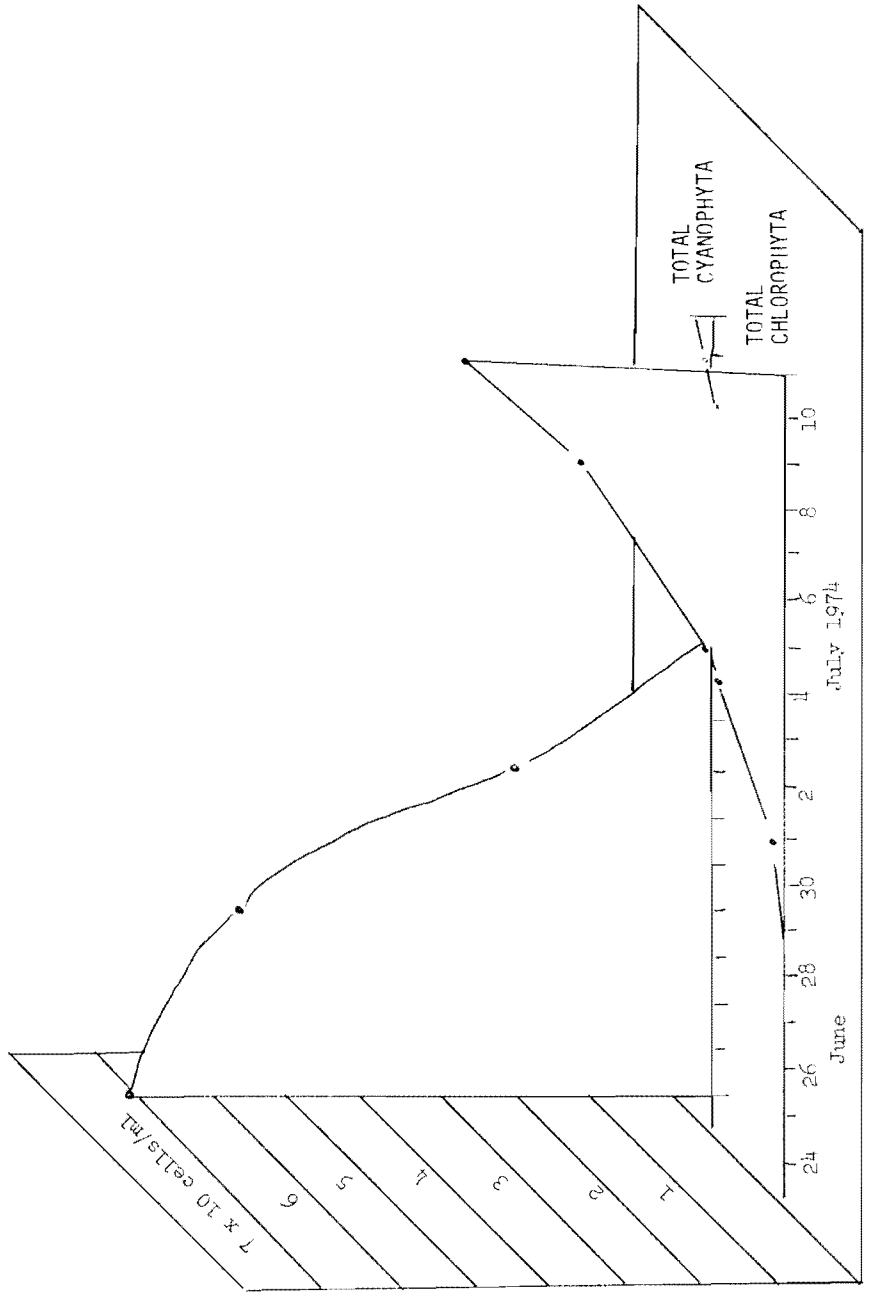

Figure 1. Shift from blue-green algae to greens caused by adding CO_2 and nutrients.

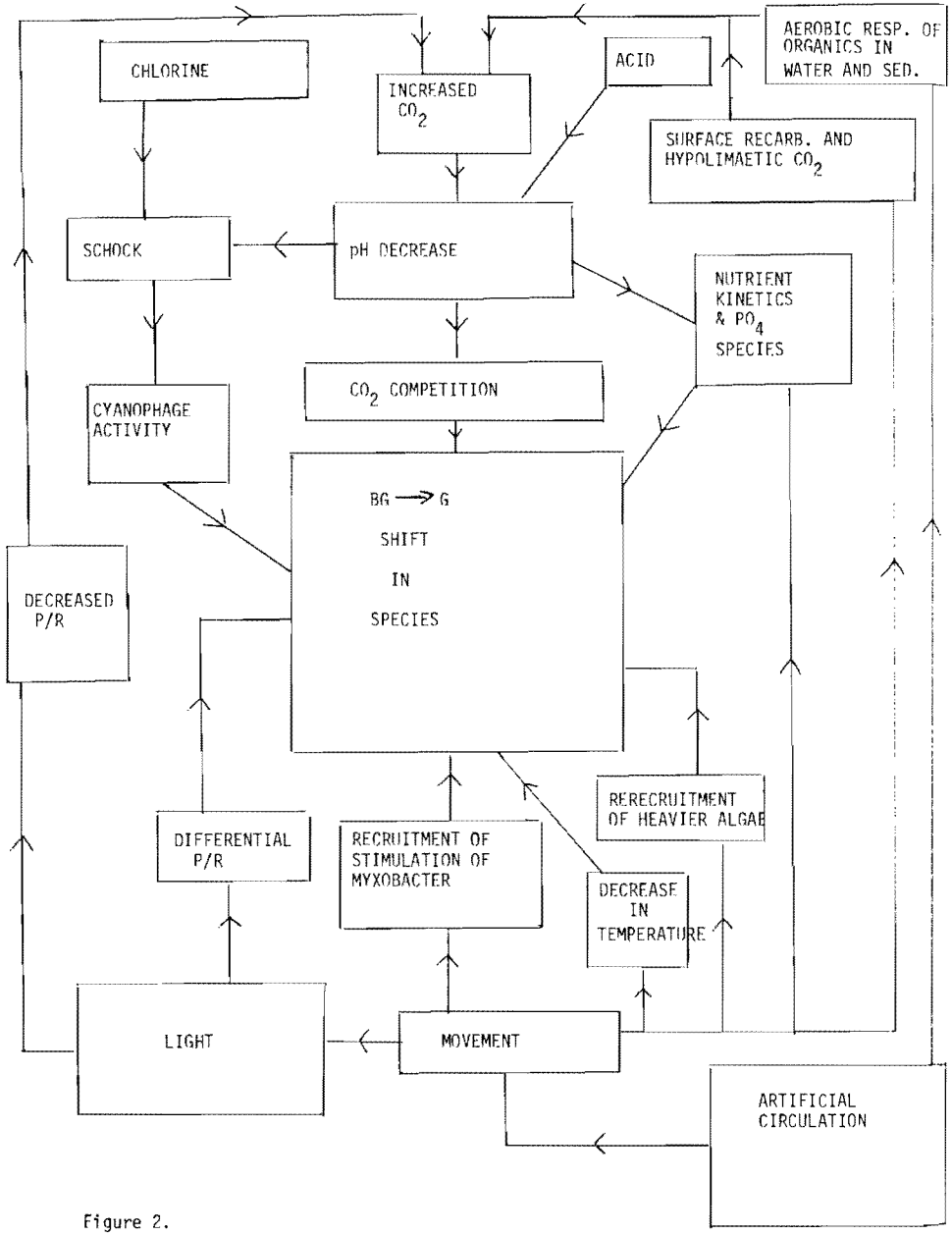

Figure 2.

Table 1. Data from the literature on artificial circulation.

Investigator	Lake	Year	BG-G Shift	pH Change
Haynes	Kezar	1968	yes	-
Haynes	Kezar	1969	yes	-
NHWSPCC	Kezar	1970	yes	+ (1)
NHWSPCC	Kezar	1972	yes	+ (2)
Malueg	Clines Pond	1969	yes	-
Slack	Lake Cochuma	1966	yes	-
Weiss	University Lake	1970	yes	-
Weiss	University Lake	1971	yes	-
Irwin	Vesuvius	1964	yes	-
Irwin	Stuart Hollow	1964	yes	-
Irwin	Pine	1964	yes	-
Irwin	Caldwell	1964	yes	+ (3)
Symons	Boltz	1966	yes	-
NHWSPCC	Kezar	1971	no	- (4)
NHWSPCC	Kezar	1973	no	- (5)
Drury	Hyrum	1972	no	+
Knoppert	Reservoir I	1968	no	+
Knoppert	Reservoir II	1968	no	+
Steichen	Ham's	1973	no	- (6)
Shapiro	Calhoun	1972	no	+

1. pH 6.3 → 6.6
2. pH 6.0 → 6.6
3. pH 7.3 → 7.5
4. pH 6.8 → 6.6
5. pH 6.6 → 6.0
6. pH 8.7 → 8.2 (one month interval)

Form OW-1 (1972)

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 Northeastern Minnesota

FCST-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

Student Assistants	Degree Held	Discipline or Academic Background
John Borovsky	B.S.	Forestry
David Holtschlag	M.S.	Forest Hydrology

Narrative Statements

(A) Research Project Accomplishments

1. Project Design and Soil Solution data.

Spray irrigation of secondary sewage effluent was evaluated on sixteen 70' x 70' plots established on overburden material at Erie Mining Company, Hoyt Lake, Minnesota. The experiment was designed as a 4 x 4 split plot, latin square to analyze both soil and soil solution differences among control, and maximum, medium, and minimum effluent applications. The quantity of effluent, precipitation and soil water contents were measured at the different treatment plots. The large rock and boulder volume (in excess of 30%) in addition to the low-lying topography limited drainage at the site and consequently limited the amount of effluent application. The results indicated that the application of effluent had no consistent effect on the concentrations of nitrogen, phosphorus, calcium, magnesium, sodium, potassium and chloride in the soil solution. Site conditions and the amount of rock material present were considered to limit the application of effluent at more practical levels.

2. Soil Nutrients.

The overburden soil material was sampled to determine the effects of effluent irrigation on the amount of nutrients in the soil profile. Soil samples were collected on June 10, 1975, before effluent irrigation, and on October 18, 1975 after the final effluent application. The soil profile was sampled at 1, 10, 20, 30, 60, 90 and 120 centimeters below the soil surface

on the maximum, minimum and control plots. The following analyses were made on the soil samples: total nitrogen, exchangable phosphorus, calcium, magnesium, sodium, potassium, manganese, chloride, pH and cation exchange capacity.

The results of the soil analyses indicate that only chloride was significantly (0.05) affected by effluent irrigation. Specifically, the amount of chloride increased with the level of effluent application. The amount of total nitrogen, exchangable phosphorus, sodium, potassium, manganese, and chloride changed significantly (0.05) with depth. Generally, the amount of nutrients decreased with increasing depth in the soil profile. This may be due to residual nutrient accumulation from the previous plant community.

3. Vegetation Analysis.

Survival data, one year after planting, were obtained for six tree species planted during the summer of 1975. The species evaluated were Northern white cedar (Thuja occidentalis), white spruce (Picea glanca), a hybrid poplar (Populus spp.), eastern white pine (Pinus strobus), jack pine (Pinus banksiana), and green ash (Fraxinus pennsylvanica). The level of effluent application had no significant effect on survival of any one species, however, there were significant differences (at the .05 level) in survival among species. Green ash and the poplar showed the greatest survival. Northern white cedar was heavily defoilated but appeared to be resprouting. The superior survival of green ash and poplar may be explained by the absence of browsing damage by deer, whereas the conifers were heavily browsed.

(B) Publications.

Holtschlag, David J. 1976. The feasibility of using an iron ore overburden site in northeastern Minnesota for the renovation of secondary effluent. M.S. Plan B paper. University of Minnesota. 59 p.

(C) Project Status

The original project work plan scheduled two field seasons (May-September). The 1976 field season will continue through September and the project will be completed December 31, 1976.

(D) Application of Research Results

Results from this project will assist mining companies and local communities in making decisions concerning amelioration of unproductive overburden sites. Also, the feasibility of using such sites as a means of renovating secondary effluent will be of interest to small communities in northern Minnesota which may not be able to meet future water quality standards by the more traditional methods.

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

The iron ore overburden material constituting the initial study site contained excessive volumes of rock. Owing to the infiltration problems associated with this characteristic, the site was considered adverse for sprinkler irrigation of secondary effluent. A more typical overburden material was identified within the confines of an active taconite mine and approximately 300 cubic yards of this material were transported to the study site. During the 1976 field season (May-September) the essence of the original study will be relicated on the new overburden material.

Specifically, the 1976 field season will consist of:

1. Establishment of experimental plots on new site with four replications of three treatments (minimum,maximum, control).

   The procedures will be to:

   a. Collect soil samples (bulk density and nutrients).
   b. Install soil solution samplers.
   c. Install neutron probe access tubes.
   d. Establish vegetation (1 replication per plot) consisting of wildlife shurbs (2 species), a grass mixture, and containerized forest tree seedlings (4 species).
   e. Construct irrigation system.

2. Apply secondary effluent by spray irrigation:

   a. At weekly intervals, apply approximately three and nine centimeters of secondary effluent for the minimum and maximum treatments respectively.
   b. Collect weekly samples of secondary effluent.

3. Monitor the effects of effluent treatments on the plant-soil-water system:

   a. Collect daily estimates of natural precip.
   b. Collect weekly estimates of soil moisture status.
   c. Collect monthly samples of soil solution.
   d. Collect annual measurements of vegetation growth and mortality.
   e. Collect annual soil samples.

4. Chemical analysis of soil and solution samples

5. Data summary and analysis. Prepare final report based on two field seasons and involving two contrasting sites.

Based on the results of the two year experiment, the feasibility of utilizing overburden material to renovate secondary effluent and the ameliorative potential of secondary effluent for the establishment of grass, forest trees and wildlife shrubs will be evaluated.

OWRT Project No.: B-120-Minn

Matching Grant Agreement No.: 14-31-0001-6091

Project Title: Effects of Silt and Turbidity from Agricultural Drainage on Benthic Invertebrates in Streams in Western Minnesota

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, 1975 Scheduled Completion: June 30, 1977

Principal Investigator: T.F. Waters Degree: Ph.D.

Discipline: Entomology, Fisheries and Wildlife

Student Assistants	Degree Held	Discipline or Academic Background
Paul C. Marsh	M.S.	Fisheries
James Luey	B.S.	Fisheries

Narrative Statements

(A) Research Project Accomplishments:

The objective of the research is to determine the effect of waterborne silt and turbidity upon the bottom-living invertebrate animals in streams receiving waters from drainage for agricultural purposes. Originally, it was planned to select a series of streams in Minnesota's portion of the watershed of the Red River of the North; however, extensive flooding in this part of the state in early summer of 1975 precluded all field research in that area.

Consequently, the field research was changed to streams in southwestern Minnesota, a region which had not been subject to extraordinary spring flooding but which did meet the criterion of providing drained and undrained watersheds for study.

Following examination in July and August 1975 of 98 potential locations, two clear-water sites (Cottonwood River in Garvin County Park, Lyon County and Highwater Creek in Highwater Township Park, Cottonwood County) and two drainage-water sites (Fort Ridgely Creek in Fort Ridgely State Park, Nicollet County and Ramsey Creek in Ramsey City Park, Redwood Falls, Redwood County) were selected on the bases of similar physical characteristics (gradient, discharge, and substrate) and ease of access. The two clear-water sites receive little agricultural drainage waters (8 to 23% of the stream lengths are ditched) while the 2 drainage-water sites have large areas of intensively drained land within their watersheds (93 to 97% of the stream lengths are ditched).

Routine stream sampling was begun in August 1975 at each of the above sites. Duplicate invertebrate drift samples (24 hr), 10 benthos samples (Surber square foot samples), water chemistry (total alkalinity, dissolved oxygen, carbon dioxide, pH, total hardness), turbidity (analysed by a Hach 2100A Turbidity Meter), and suspended solids (Imhoff Cone) samples have been collected at approximately monthly intervals. Winter sampling was reduced due to logistic problems caused by low temperatures and high water from early thaw runoff. A full sampling schedule was resumed in March 1976. Beginning in April 1976 stream discharge has been measured and sediment traps have been set out and collected on a monthly basis. Preliminary field invertebrate collections have been examined but complete laboratory analysis of the regular collections described above are not complete at this time. Physiochemical data obtained thus far substantiate the similarity of all 4 streams, while qualitative observational surveys and topographic map analysis have been used to describe the differences between drained and undrained watersheds. Problems of low flow are anticipated in all streams during summer 1976 because of severe drought throughout the region. Statistically, the spring of 1976 was the 4th dryest on record for southwestern Minnesota.

Full scale laboratory experiments, critical to the success of this project, is intended to commence in mid-June 1976. Initial development of experimental requirements during this phase of the research (establishment of invertebrate populations in the artificial laboratory streams, maintainence of desired water velocity, quantitative methods for introduction and maintainence of predictable levels of silt and turbidity, and others) has been largely completed. Silts to be used were obtained from drainage ditches in the field study area during early spring 1976 and additional tests also will be run using pure bentonite or montmorillonite clays. Invertebrates for stocking have been obtained at each of the field sites and can be replenished as required. Preliminary data confirm the utility of artificial stream ecosystems for this study since invertebrate populations can be successfully established, and silt/turbidity levels can be satisfactorily minipulated.

A secondary purpose of this project is to determine the effects of silt and turbidity on potential fish production so an additional phase of research, aimed at studying fish communities at the 4 sites described above, was initiated in October 1975. Monthly samples (Oct., Nov. 1975, resumed March 1976) of fish were collected from a specified length of each stream with a Homelite generator modified for stream electrofishing. All fish have been preserved in 10% formalin for laboratory analyses to include, in addition to routine fish population dynamics parameters, stomach analysis for invertebrate food items. These data and individual fish life history information will be correlated with physico-chemical data and benthic invertebrate information to characterize differences between stream ecosystems in drained and undrained watersheds. This phase of the study is intended to continue through fall 1976.

(B) Publications

None.

(C) Project Status

Project will continue through FY 1977.

(D) Application of Research Results

It is anticipated that the results from this project will be useful to the Minnesota Pollution Control Agency in assessment of non-point source pollution.

(E) Work Remaining and Progress Contemplated During Next Year

Work remaining includes continued monitoring of invertebrate population dynamics and drift of benthic invertebrates, the relation to food-utilization by fish, and physico-chemical parameters in the four study streams, and completion of the laboratory stream experiments. It is anticipated that the field work in the streams will be terminated in late fall 1976, the laboratory experiments will continue through winter of 1977, and the analysis of all samples will be completed by spring of 1977.

Figure 1. Highwater Creek, Cottonwood County, illustrating meandering course and wooded perimeter of streams in undrained watersheds.

Figure 2. Ditched tributary of Fort Ridgely Creek, Renville County, representative of streams in drained watersheds.

Form OW-1 (1972)

OWRT Project No.: B-122-Minn

Matching Grant Agreement No.: 14-31-0001-6092

Project Title: Effects of Drainage Projects on Surface Runoff from Wetland Topography of the North Central Region

FCST-COWRR Research Category: 02-E

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

Project Began: July 1, 1975 Scheduled Completion: June 30, 1978

Principal Investigator: C.L. Larson Degree: Ph.D.

Discipline: Agricultural Engineering

Student Assistants	Degree Held	Discipline or Academic Background
Ian D. Moore	M.S.	Civil Engineering

Narrative Statements

(A) Research Project Accomplishments

A brief literature survey and review was conducted. Findings from previous studies appear to be different and conflicting. Many of these conflicts, however, can be traced to special characteristics or features of the individual watersheds under study. The basic conclusion from this survey is that at the present time no categorial statement can be made as to whether or not drainage projects adversely affect flood runoff.

Peak discharge data for over 100 stations (including crest-stage stations) in the four-state region consisting of Minnesota, Iowa, North Dakota, and South Dakota have been collected. The average catchment slope and the percent area of lakes and swamps was estimated for those watersheds where topographic maps were available. On the basis of the data collected (above) about 73 station records were analyzed to determine the mean annual flood for each.

Regression analyses were made to determine the relationship, if any, of watershed parameters to flood flows for the region. Watershed slope was not found to be a significant factor for the watersheds studied (relatively flat watersheds). A regression analysis of the flat-land watersheds in southern and western Minnesota yielded the relationship

$$Q_{mean} = 58.4\ A^{0.677}\ (W + 1)^{-0.506}$$

where Q is the mean annual flood, A is the watershed area in square miles and W is the percentage of the catchment in lakes and swamps. This

equation explained about 82% of the variance. Although the percent of land area drained may be related to the factor W in the above equation for a given region, there are insufficient data to make such a substitution in the above equation and generalize from the result. In general, it is evident that statistical analyses alone will not be sufficient to fulfill the objectives of the project.

We are currently in the process of developing a mathematical model, using the hydraulic routines of the Iowa State Model as a starting point. Measurable parameters are being used where possible. In addition we are choosing 4 or 5 actual watersheds as study areas on which to test and apply the model. These watersheds should have long records so that the model output can be compared to recorded flows for conditions existing before and after drainage.

(B) Publications

None.

(C) Project Status

Project will continue during FY 1977.

(D) Application of Research Results

Keen interest has been expressed, especially by personnel of the Division of Waters, Minnesota Department of Natural Resources, which has been attempting to develop general criteria for regulating drainage development. Interest has been expressed by similar groups in North Dakota.

(E) Work Remaining and Progress Contemplated Next Year

The coming year (FY 1977) will be devoted mainly to completing development of the mathematical model for watersheds with depressional topography, including "proving" the model on several actual watersheds. Following this, the model will be used to determine flood flows for various degrees and types of drainage, varying from no drainage to complete surface and subsurface drainage.

Other work remaining includes using the model to determine the extent to which any hydrologic effects of drainage projects are transmitted downstream; and to investigate means of reducing any adverse effects of drainage projects on flow rates.

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

Student Assistants	Degree Held	Discipline or Academic Background
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. Accomplishment to date includes:

1. Letters have been mailed to individuals and organizations to obtain general information, documentation and source programs. Responses have been obtained from various organizations such as: 1) Battelle, 2) EPA, National Environmental Research Center, 3) HEC, Davis, California, 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 has been made through professional journals in the water resources field.

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, groundwater, reservoirs and dams, flow routing, water quality, water resources systems, and others.

2. So far 28 programs have been selected for special study and summarized for inclusion in the final report. These represent programs of special interest and merit a fairly detailed description.

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 with four sets of urban runoff data.

4. The University of Cincinnati Urban Runoff (UCUR) model has been obtained, compiled and run with urban runoff data. 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 models. These four catchments are 1) Bloody Run Watershed, Cincinnati, Ohio, 2) Oakdale (12.9 Acre), Chicago, Illinois, 3) 10 Acre Tract, Chicago, Illinois, and 4) Northwood, Baltimore, Md. For the Bloody Run Watershed, a complete data set is now available for the 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 RUNØFF BLOCK is complete.

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

(B) Publications

Final report is in preparation. Title: "Computer Programs and Simulation Models in Water Resources: Scope and Availability" by C.S. Chu and C. Edward Bowers.

(C) Work Remaining and Progress Contemplated During Next Year.

Complete annotated bibliography.
Prepare and distribute final report.

PROGRAM UNDER P.L. 88-379

Courses Developed

OWRT Project A-032-Minn. A new course, on community development and change with primary focus on environmental management as a developmental goal has been added to the curriculum of the Resource and Community Development Program in the College of Agriculture.

OWRT Project No. A-029-Minn. 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 were incorporated into the curriculum in a course in analytical methods utilizing advanced microanalytical techniques.

Additional Water Resources Related Staff Members Added

None.

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

Donald C. Slack, Assistant Professor Ph.D. Agricultural Engineering

New Research and Training Facilities Other Than Research Equipment Items

none.

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) Undergraduates	Chemistry	1
	Sociology	2
(2) Master's Students	Biological Sciences	1
	Biology	6
	Chemistry	1
	Civil Engineering	2
	Forestry	1
	Geography	1
	Geology	1
	Mathematics	1
	Pharmacology	1
	Sociology	1
	Fisheries	1
(3) Doctoral Students	Civil Engineering	1
	Ecology	4
	Environmental Health	1
	Forest Hydrology	1
	Fisheries	1
	Public Health	1
(4) Post Doctoral Students		
	Botany	1

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.

Form OW-9 (1972)

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	2	2	1	5
Federal Agencies	1	2		3
State and Local Agencies	1			1
University or College			1	1
Other - Including private enterprise				0
2. No. graduates returning to school for advanced degree	8	4		12
3. No. going into military service	0	0	0	0
4. No. unempolyed or working in other fields	0	0	0	0
5. No. status unknown	9	4	0	13
6. Totals	19	10	1	30

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; 1975-14; 1976-19;

Form OW-9 (1972)

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

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

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

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

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