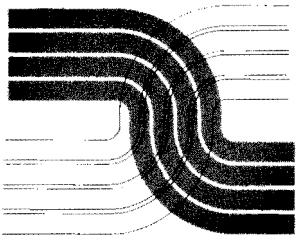
WRRC Bulletin 104

SIXTEENTH ANNUAL REPORT WATER RESOURCES RESEARCH CENTER

A Report of Activities Supported by the Graduate School and the Office of Water Research and Technology, U.S. Department of the Interior During the Fiscal Year Ending September 30, 1980.

Prepared by

George R. Blake, Director
Elizabeth Espointour, Secretary



WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

866 BioScience Center
St. Paul, Minnesota 55108
Telephone 612—376-5668

October 1980

PREFACE

This is the Sixteenth Annual Report of the Minnesota Water Resources Research Center. It covers the period October 1, 1979 through September 30, 1980.

The Report describes the research activities of the Center, its involvement in training of water scientists and its efforts in transferring technologic information to potential users. It lists the project, the cooperators and the Advisory Committee of the Center. These activities were carried out under Allotment Agreement No.14-34-0001-0125 of the Office of Research and Technology.

The work upon which this publication is based was supported in part by funds provided by the Unites States Department of the Interior as authorized under the Water Research and Development Act of 1978, P.L. 95-467.

PUBLICATION ABSTRACT

During fiscal 1980 the Water Resources Research Center sponsored ten projects funded through programs of the U.S. Department of Interior, Office of Water Research and Technology and two funded through grants from the Upper Mississippi River Basin Commission. These research projects dealt with the following topics: (1) Water conservation through reuse of agricultural drainage waters and through prediction of irrigation scheduling by use of climatic data; (2) Wetlands as related to county drainage ditches and to agricultural runoff; (3) Water quality for towns in rural areas, methods for measuring aquatic organics, removal of heavy metals by zeolites, and propagation of hydrocarbon spills to shallow aquifers; (4) Groundwater recharge rates as related to rainfall, predicting recharge rates in surficial aquifers (5) Economics of water use for irrigation; (6) Flood prevention through hydrologic simulation of critical watersheds; and (7) Septage disposal on land by defining loading rates.

Research sponsored by the Upper Mississippi River Basin Commission consisted of a Summary Resource Description of the Upper Mississippi River System and an Evaluation of the Impacts of Navigation and Associated Operation and Maintenance Procedures on Recreation, Cultural Resources and Potential Wilderness Areas of the River System.

Two project-related bulletins were published by the Water Resources Research Center in 1979-80. Bulletins are sent to a mailing list of about 300 people initially. The Center answers around 500 requests each year for copies of bulletins published both this year and past years. The Center also publishes and distributes four Newsletters each year.

Through Water Research Centers projects, two professors, three research associates and about 28 students, mostly graduate students, were given part-time employment. A seminar series was sponsored on the University's Twin City Campus.

The Center's budget was $395,736 derived from the University of Minnesota, the University Graduate School, the Office of Water Research and Technology of the U.S. Department of Interior and grants from the Upper Mississippi River Basin Commission.

Publication Descriptors: Water Resources/Minnesota/Water Management/ Water Pollution/Water Conservation/Wetlands/Water Quality/Groundwater/ Economics of Irrigation/Watershed Simulation/Septage Disposal

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Minnesota
Water Resources Research Center
University of Minnesota

ADMINISTRATION

President of the University . . . . . C. Peter Magrath
Dean of the Graduate School . . . . . Warren E. Ibele
Director, Water Resources Research Center . . . . . George R. Blake
Secretary . . . . . Elizabeth Espointour

Advisory Committee

University of Minnesota

C. Edward Bowers	St. Anthony Falls Hydraulic Laboratory
Kenneth N. Brooks	College of Forestry
Dwight A. Brown	Department of Geography
K. William Easter	Department of Agricultural & Applied Economics
Lowell D. Hanson	Department of Soil Science
Warren E. Ibele	Graduate School
Curtis L. Larson	Department of Agricultural Engineering
Walter J. Maier	Department of Civil & Mineral Engineering
William P. Martin	Department of Soil Science
Gordon D. Rose	Institute of Agriculture
Richard J. Sauer	Agricultural Experiment Station
Thomas E. Straw	Division of Science & Mathematics (Morris)
Matt S. Walton	Minnesota Geological Survey
Thomas F. Waters	Department of Entomology, Fisheries & Wildlife
Thomas J. Wood	Lake Superior Basin Studies Center (Duluth)
Herbert E. Wright	Limnological Research Center

State and Private Colleges

Norman J. Baron	Dept. of Geography, Winona State University
Charles H. Fuchsman	Center for Env. Studies, Bemidji State University
A. Joseph Hopwood	Dept. of Biology, St. Cloud State University
James T. Jack	Dept. of Geography, Mankato State University
Robert T. Moline	Dept. of Geography, Gustavus Adolphus College

State, Local, and Federal Agencies

Clarence Oster	Environmental Protection Agency
Rollin M. Dennistoun	Minn. Department of Agriculture
F.H. Geisenhoff	Minn. Department of Economic Development
Gene H. Hollenstein	Minn. Department of Natural Resources
Edwin H. Ross	Minn. Department of Health
Joseph E. Sizer	Minn. State Planning Agency
Jack C. Ditmore	Minn. Water Planning Board
Erling M. Weiberg	Minn. Water Resources Board

Marcel Jouseau	Metropoligan Council
Donald R. Albin	U.S. Geological Survey
Forrest T. Gay, III	U.S. Army Corps of Engineers
Harry M. Major	U.S. Soil Conservation Service
Joseph Scott	U.S. Bureau of Sport Fisheries & Wildlife
Elon S. Verry	U.S. Forest Service

Interest Groups and Private Concerns

Douglas W. Barr	Consulting Hydraulic Engineer
Jeanne Crampton	League of Women Voters
Raymond A. Haik	Attorney
Ken Kadlec	MPIRG
Ford Robbins	Sierra Club
Paul Toren	Izaak Walton League of America

Research Faculty

The following University faculty members were principal investigators on Water Resources Research Center Projects in FY 1980.

Evan R. Allred	Professor of Agricultural Engineering
Donald G. Baker	Professor of Soil Science
George R. Blake	Professor of Soil Science
Donald E. Gilbertson	Associate Professor of Ecology & Behavioral Biology
Roman Kanivetsky	Hydrologist, Minnesota Geological Survey
Timothy J. Kelly	Research Associate, Water Resources Research Center
Richard A. Kottke	Research Assistant, Water Resources Research Center
Curtis L. Larson	Professor of Agricultural Engineering
Walter J. Maier	Professor of Civil & Mineral Engineering
Robert T. Moline	Professor of Geography, Gustavus Adolphus College
Hans-Olaf Pfannkuch	Associate Professor of Geology & Geophysics
Gordon G. Plorin	Research Assistant, Water Resources Research Center
Henry W. Quade	Professor of Biology, Mankato State University
Michael J. Semmens	Associate Professor of Civil & Mineral Engineering
Rex D. Singer	Associate Professor of Environmental Health
Craig C. Sheaffer	Assistant Professor of Agronomy
Donald C. Slack	Assistant Professor of Agricultural Engineering
Conrad P. Straub	Professor of Environmental Health
James B. Swan	Professor of Soil Science
Matt S. Walton	Professor, Minnesota Geological Survey

DIRECTOR'S SUMMARY STATEMENT, 1980

Coincidence of two propitious conditions for water resources exist in Minnesota. On the one hand there is sufficient water for much of the State, due less to a high annual rainfall than to a favorable precipitation-evapotranspiration ratio. On the other hand there is a social-political-economic climate that is enlightened and responsible, and is favorably inclined toward orderly protection, regulation and development. It follows from this public attitude that there is a diverse number of local, State and private agencies and organizations continuously enlightening and educating the public on water issues and water policy. The Water Resources Research Center is pleased to be a unique member of this group whose business is research, education and research dissemination.

Pressing Current Water Problems

Despite the favorable circumstances, our State has pressing current need for scientific data and reliable information on several questions. There is need to protect groundwater for urban, small town and rural household uses as well as for the supply of quality water for irrigation and urban industries.

Land and land use water problems are far from satisfactorily resolved. The interactions of land surface and groundwaters are dynamic. Questions of non-point pollution of groundwaters as well as surface waters urgently need investigations and consideration. The establishment of safe procedures for use of farm chemicals that prevent serious water pollution require attention. The reuse of surface and drainage waters from farmlands passes both opportunities and problems that need addressing.

The protection of our abundant wetlands often seems bogged down in controversy. Clearly we need a concensus of protection and wise use of this resource. Criteria that distinguish between preservation and development need to be recognized and established. Social, economic and legal questions are of utmost importance to progress in leading to a publicly agreed upon course of action and the legal and institutional implementation of the policies agreed upon.

Thrust of Current Program

The current research carried out under auspices of the Water Resources Research Center relates to water problems on lands and land use, irrigation and drainage, water supplies for rural areas and small towns, the replenishment of groundwater from surficial aquifers and the protection of surface and groundwaters. Methods for routine measurement of aquatic organics, identification of naturally-occurring zeolites for removal of heavy metals from waters and the fate of hydrocarbon spills are all under study in Center projects.

Likely Future Research Trends

In addition to the current research effort, it is probably that the Water Resources Reseach Center will become more involved in studies of

wetlands, their protection, criteria for development and their economic and social value. Engagement in activities that lead to public awareness and development of public policy for Water Resources are likely to continue or increase in future years. In addition, the interdependence of water and energy related to heating buildings, and in groundwater heat storage are likely to become much more prominent in our program.

Examples of WRRC Research and its Application

1. Professors Allred and Slack (A-037) have found that air-leaf temperatures relate to net radiation, relative humidity and available soil water and have potential for determining when crops should be irrigated.

2. A trend toward deteriorating quality of drinking water as shown by Nitrate levels in small towns is shown in data by Professors Straub and Singer (A-038).

3. County drainage ditches carry an increased chemical load as flow increased, nitrate and orthophosphate increasing directly. Ditches more than double the effective length of rivers and result in an overall loss in lakeshed and lakes in South Central Minnesota according to data of Professor Quade (A-040).

4. Phenols and napthalene dispersion in sands differ from one another the latter showing characteristic sorption,studies by Professor Pfannkuch show (A-041).

5. Studies by Professor Blake (A-042) showed that despite 27 percent greater than normal rainfall, corn responded to midseason soil water recharge on fine-textured soil.

6. When moist, fine sandy soil receives as little as 0.5 inch of rain a rise in groundwater level was observed in surficial aquifer recharge studies by Professors Slack and Larson (A-043).

7. Professor Maier (B-138) has developed a method for measuring organically combined chlorine in waters and has found substitute analysis that predict biological oxygen demand (BOD) and can be carriedout in a matter of minutes.

8. Pan evaporation is one of the best methods of 12 tested for predicting evapotranspiration from a soybean crop growing on a lysimeter is shown in data collected by Professors Baker and Swan (B-147).

9. The removal of heavy metals from waters can be accomplished by the zeolite clinoptilolite, reports Professor Semmens (B-150), who has shown that it works best at pF 5-7 and can be regenerated.

10. Professors Walton and Kanivetsky (B-153) are comparing water levels in around 200 wells with various precipitation parameters to determine relationships between precipitation and groundwater recharge rates.

Service and Training Activities

The Center sponsored a successful seminar series for faculty and graduate students during 1979-80, a copy of which follows.

The Center published three Bulletins and four Newsletters that were distributed to about 300 people. Several bulletins from earlier years continue in demand.

Employment for 17 graduate and 11 undergraduate students on water resource projects contributed to the education mission of the Center.

Two cooperative proposals with Illinois and Wisconsin Water Resources Centers were submitted to and funded by the Upper Mississippi River Basin Commission. One consists of preparing a Summary Resource Description of the upper river system, and includes the following resource components: physical, biological, water quality, recreational, wilderness and cultural. Professor Donald Gilbertson of the University of Minnesota and Professor Robert Moline of Gustavus Adolphus College are aided by Timothy Kelly, Gordon Plorin and Richard Kottke in the Minnesota portion of this endeavor.

The second project in which we are cooperating with the Illinois and Wisconsin Centers is being carried out by Prof. Leo McAvoy for Minnesota. The two-year project is an evaluation of the impacts of navigation on recreation, cultural resources and potential wilderness areas of the river system.

WATER RESOURCES SEMINARS

1980

The Water Resources Research Center is coordinating a series of Interdisciplinary Seminars on water-related topics between February 5 and March 19. The seminars will be individually announced on bulletin boards around campus. Faculty and students are invited. The Seminars will be held in various locations on the University of Minnesota campus at 3:30 p.m. Tuesdays or Wednesdays. There is no charge for attending.

The tentative schedule is as follows:

Tuesday February 5.

1. The New Minnesota River Forecast Center. John Seeman, Deputy Director, Minnesota River Forest Center, National Weather Service.

2. The Effect of Different Operating Plans for the Six Mississippi Headwaters Dams. Carl W. Stephan, Hydrologist, Planning Division, St. Paul District Corps of Engineers and Prof. C. Edward Bowers, St. Anthony Falls Hydraulic Laboratory and Department of Civil and Mineral Engineering.

Lind Hall, Room 217.

Wednesday February 13

Aquifer Thermal Energy Storage and the Recovery of Lost Energy. Matt Walton, Prof. and Director, Minnesota Geological Survey.

Classroom Office Building, Room 230.

Tuesday February 19

Seasonal Storage of Thermal Energy in Aquifers. Prof. Olaf Pfannkuch, Geology & Geophysics and Prof. Perry Blackshear, Dept. of Mechanical Engineering.

Mechanical Engineering, Room 102.

Tuesday March 4

Irrigation Development in Minnesota - past, present, future. Prof. Fred Bergsrud, Dept. of Agricultural Engineering.

Classroom Office Building, Room 230.

Wednesday March 19

Organics in the Mississippi River. Profs. Walter Maier, Steven Eisenreich and Michael Hoffmann, Dept. of Civil and Mineral Engineering.

Lind Hall, Room 217.

Wednesday March 19

Minnesota's Framework for a Water and Related Land Resources Strategy, Jack Ditmore, Research Director, Minnesota Water Planning Board

Classroom Office Building, Room 230.

FISCAL YEAR 1980 OWRT BUDGET

Annual Allotment Program

Project Title, Principal Investigator and OWRT Project Number	Federal Funds $
Center Director's Office	50,000
A Study of the Use of Selected Climatic Measurements for Predicting Irrigation Scheduling, E.R. Allred, Department of Agricultural Engineering (A-037-Minn)	10,000
Water Quality Studies: Southwestern Minnesota, C.P. Straub, School of Public Health, (A-038-Minn)	10,000
The Effects of County Drainage Ditches on Water Quality and Quantity in South Central Minnesota, H.W. Quade, Department of Biology, Mankato State University (A-040-Minn)	10,000
Hydrocarbon Spills, Their Retention in the Subsurface and Propagation to and into Shallow Aquifers, H.O. Pfannkuch, Dept. of Geology and Geophysics (A-041-Minn)	10,000
Re-Use of Agricultural Drainage Waters for On-Site Soil Water Recharge and Irrigation, G.R. Blake, Soil Science Department, (A-042-Minn)	10,000
Predicting Direct Recharge of Surficial Aquifers, D.C. Slack and C.L. Larson, Dept. of Agricultural Engineering, (A-043-Minn)	10,000
TOTAL	110,000
Annual Allotment Non-Federal Contribution	100,595

Matching Grant Program

Project Title, Principal Investigator and OWRT Project Number	Federal Funds $	Non-Fed. Funds $	Total Funds $
Application of New Methods for Routine Measurement of Aquatic Organics, W.J. Maier, Dept. of Experimental Engineering (B-139-Minn)	15,249	15,221	30,470
The Measurement of Evapotranspiration and Comparison with Empirical Calculation Methods for Use in Minnesota and Similar Climatic Regions, D.G. Baker, Dept. of Soil Science, (B-147-Minn)	11,800	18,417	30,217
A Study to Identify the Potential of Naturally Occurring Zeolites for Removing Heavy Metals from Water, M.J. Semmens, Dept. of Environmental Engineering, (B-150-Minn)	17,400	17,313	34,713
Ground-Water Recharge Rates in Minnesota as Related to Precipitation, M. Walton and R. Kanivetsky, Minnesota Geological Survey, (B-153-Minn)	20,536	17,805	38,341
TOTAL	64,985	68,756	133,741

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
SOURCES OF FUNDS

Fiscal Year	Center's Budget $	Federal (OWRT) $	Matching Monies				
			U of M $	State College $	Private College $	Grad. School U of M $	Special Grants
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	
1977	340,910	177,441	163,468	0	0	3,500	
1978	307,949	152,962	154,986	3,724	0	3,500	
1979	320,922	176,575	144,347	2,232	0	3,500	
1980	395,736	174,985	169,351	3,900	0	3,500	44,000
1981	438,654	189,776	171,118	0	5,700	3,500	68,560

WATER RESOURCES RESEARCH CENTER

Distribution of Federal Research Monies[1/]

1974-1980 incl

University Unit	Amount $	Percent of Total
College of Agriculture	246,045	26.18
Agricultural Engineering	119,213	
Agriculture & Applied Economics	12,145	
Entomology Fisheries and Wildlife	23,395	
Soil Science	92,292	
College of Biological Sciences	14,406	1.53
Ecology and Behavioral Biology	14,406	
Limnology (see IT)		
College of Forestry	77,981	8.30
Forest Resources	77,981	
College of Liberal Arts	103,132	10.97
Anthropology	43,532	
Sociology	59,600	
Health Sciences	81,083	8.63
Public Health	81,083	
Institute of Technology	330,019	35.12
Civil and Mineral Engineering	114,032	
Geology and Geophysics	55,692	
Limnology Center	118,933	
St. Anthony Falls Hydraulic Lab	41,362	
Minnesota Geological Survey	11,902	1.27
Gustavus Adolphus College	3,816	0.41
Mankato State University	30,000	3.19
University of Minnesota, Duluth	41,362	4.40
	939,746	100.00

[1/] Excludes Administrative costs of the Water Resources Research Center

ANNUAL ALLOTMENT PROGRAM

NARRATIVE PROGRESS REPORTS

Annual Report -- Title I Projects

OWRT Project No.: A-037-Minn

Project Title: A Study of the Use of Selected Climatic Measurements for Predicting Irrigation Scheduling

Agreement No.: 14-34-0001-0125

FCCSET Research Category: 02-D, 02-I, 06-D; 1

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

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigators	Degree	Discipline
E.R. Allred	M.S.	Agricultural Engineering
Donald Slack	Ph.D.	Agricultural Engineering

Student Assistants	Degree	Discipline or academic background
Kenneth Stange	B.S.	Agricultural Engineering
Gina Miller	B.S.	Agricultural Engineering
David Bosch	Undergrad	Agricultural Engineering

(A) Research Project Accomplishments

Regression analyses were made of field data collected during the 1978 and 1979 growing seasons, to determine those physical parameters having significant impact on air-leaf temperature difference (ΔT). From these analyses, it was found that net radiation, relative humidity and available soil moisture were factors most significantly affecting the value of ΔT. On this basis, the following model was obtained:

$$\Delta T = 3.290\ (R) + 0.027\ (H) + (4.0 \times 10^{9})\ (AW)^{5} - 0.053\ (AW) - 1.065$$

where,

R - Net radiation, expressed in Langleys/min.
H - Relative humidity, in percent
AW - Available water, in percent

The above model is being tested during the current growing season, to determine its validity for irrigation scheduling on corn. Sixteen field plots, 30' x 30', were established at the Sand Plains Irrigation Field at Becker, Minnesota. The plots were randomly placed in one of four irrigation scheduling treatments with four replications of each treatment. Methods of irrigation scheduling included the "checkbook method," electrical resistance (gypsum) blocks, and by air-leaf temperature difference. Another set of four plots served as a dry-land control to which no irrigation water was added.

Instrumentation was installed in the field plots to measure net radiation, relative humidity and air-leaf temperature difference (ΔT).

For the given crop and soil, it was assumed that irrigation water be applied at the fifty percent (50%) soil moisture depletion level. From this assumption, the value of (AW) became a constant and critical values of (ΔT) were calculated from the model equation for different levels of net radiation and relative humidity.

In this study, actual field values of net radiation, relative humidity and ΔT for given days were determined. Irrigation was scheduled for the four plots, using the air-leaf temperature difference method, on those days when the measured value of (ΔT) corresponding to the measured levels of net radiation and relative humidity exceeded the critical level of (ΔT) as determined by the model equation.

(B) Publications

Geiser, Kurt, D.C. Slack, E.R. Allred and K. Stange. "Irrigation Scheduling Using Crop Canopy - Air Temperature Difference" to be presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 1980. Copies of the paper to be made available for general distribution.

(C) Project Status

Project is presently at the end of the third year of a three-year study. Field data for the remainder of the 1980 growing season will be collected and analyzed along with data obtained during the 1978 and 1979 growing seasons. A final report will then be made of the complete project with plans to have the results published in scientific journals.

(D) Application of Research Results

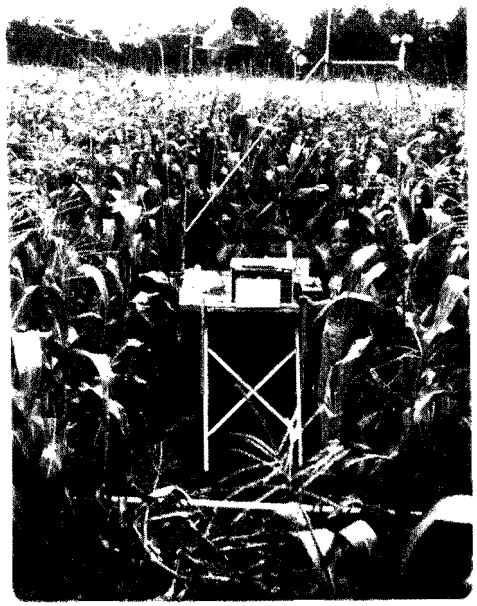
Principal interest in the results obtained in the study thus far has been expressed by the Barnes Engineering Co., Stamford, Connecticut; professional workers in the Water Conservation Laboratory (USDA), Phoenix, Arizona; and by various U.S. Agricultural Experiment Station personnel.

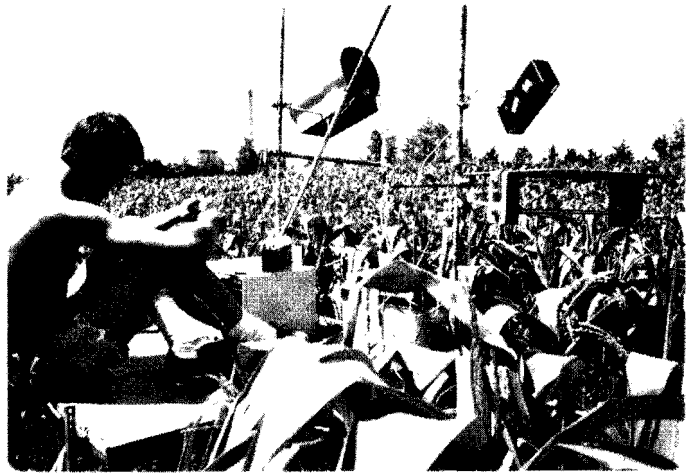
One of the major applications of this study is the development of a possible method to determine when crops should be irrigated. Some interest has also been expressed in using the method of air-leaf temperature differences to evaluate crop moisture stress conditions resulting from high weed populations.

(E) Work Remaining and Progress Contemplated

Field data for the remainder of the 1980 growing season must be collected and analyzed. Data for all three years will be compiled and analyzed for the final project report.

Lora Veidel, student research assistant in Agricultural Engineering measuring air-leaf temperature differences in field plots at Becker.





Air-leaf temperature difference and other crop environmental conditions being measured in field plots at Becker by David Bosch, student research assistant in Agricultural Engineering.

OWRT Project No.: A-038-Minn Project Title: Water Quality Studies: Southwestern Minnesota

Agreement No.: 14-34-0001-0125

FCCSET Research Category: 07-B; 8, 13

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

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigators	Degree	Discipline
Conrad P. Straub	Ph.D.	Environmental Health
Rexford D. Singer	M.S.	Environmental Health

Student Assistants	Degree	Discipline or Academic Background
Jack Sahl	M.S.	Environmental Health
Theodore Spies	Medical student	
Michael Ponto	Medical student	

(A) Research Project Accomplishments

The sample collection and analytical test programs related to the study have been completed and we are now in the process of preparing our final report on this study. The final report is expected to be completed on or before September 30, 1980.

(B) Publications

None.

(C) Project Status

The project has been completed except for the preparations of a final report.

(D) Application of Research Results

The study has shown that in many instances the quality of the water is deteriorating; particularly in that nitrate levels have increased at least in some wells serving as sources of municipal supply. In several instances, the wells are producing waters that exceed the current EPA Drinking Water Standard for NO_3-N. In the City of Adrian, as an example, one well that was particularly high in nitrate-nitrogen has not been used as a source of water supply for more than one year. Also on the basis of our findings, the well-known Adrian Spring has been "posted" indicating that nitrate-nitrogen levels exceed permissible drinking index standards. At the request of the City of Magnolia, analyses were performed on the Municipal supply as well as the water supplied by the Rural Water Service. Special studies have been carried out on

the Adrian well that is no longer being used and it has been shown on the two test occasions, where sampling was carried out over a 24 hour period, that nitrate-nitrogen levels increased as pumping continued.

(E) Work Remaining and Progress Contemplated During Next Year

Although the study is officially concluded as of September 30, 1980, a number of samples have been saved and it is hoped to analyze, at least some of these, during the current year for organic constituents.

OWRT Project No.: A-040-Minn

Agreement No.: 14-34-0001-1025

Project Title: The Effects of County Drainage Ditches on Water Quality and Quantity in South Central Minnesota

FCCSET Research Category: 05-C, 05-A; 4

Name and Location of University Where Project is Being Carried Out: Mankato State University, Mankato, Minnesota

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigator	Degree	Discipline
Henry W. Quade	Ph.D.	Biology

Student Assistants	Degree	Discipline or Academic Background
William Thompson	B.S.	Biology
Clay Pierce	B.S.	Biology
Dave Smith	B.S.	Biology
Sue Boyum	B.S.	Art
Cathy Larson Albers	B.S.	Biology
David Favero	B.S.	Geography
Kevin King	B.S.	Biology
Kent Boyum	M.S.	Limnology

(A) Research Project Accomplishments

Thirteen agricultural drainage ditches and four natural streams in Blue Earth, LeSueur, Nicollet, and Brown Counties were sampled during the ice free season of 1979. The water was sampled and analyzed for total orthophosphate-phosphorous, total Kjeldahl-nitrogen, nitrate nitrogen and total dissolved solids. This field and laboratory data was statistically treated with the aid of SPSS computer language during this past year. Results revealed that as flow increased the chemical load carried by the water increased but not in equal proportions for each parameter. Nitrate nitrogen and total ortho-phosphate-phosphorous concentrations directly increased corresponding to rainfall events. Analysis of rivers and ditches according to Strahler's "stream order" revealed the greatest variability in water quality present in second order ditches.

The quantitative goemorphic data developed during the past two years was statistically treated to show interrelationships between geomorphic parameters and descriptors such as origin, termination, soils, decade of construction, etc. This study showed that the impact of artificial drainage ditch development in South Central Minnesota has been to greatly increase the riversheds functional size. It was found that 78.8 percent of the ditches terminate eventually into a river or stream. A 1.53 ratio of open ditch length to rivers more than doubles the effective length of rivers. Furthermore 21.2 percent of ditches terminate into lakes which increases the effectiveness of lakeshed drainage without necessarily taking drainage from riversheds.

This research found that 28.6 percent of the ditches originate from lakes and lake-marsh environments which indicates an overall loss of lakeshed and lakes.

A study component entitled "A history of drainage law in Minnesota with special emphasis on the legal status of wet lands" has been completed. Drainage law in Minnesota is traced from 1858 to present with special consideration given to the constitutionality of public waters designation, the constitutionality of drainage, riparian rights, and present drainage pursuant to Minnesota state statutes Chapter 106.

A study component which involves the limnological analysis of all Minnesota Pollution Control Agency water monitoring data on the Minnesota River Watershed has been completed. This study was intended to potentially indicate water quality changes in river stretches most heavily influenced by agricultural drainage. A remarkable equilibrium in water quality was found.

(B) Publications

Silis, Ainars Z. A Quantitative Geomorphological Study of Public Drainage Ditches in South Central Minnesota, Thesis, M.A., Mankato State University, December 1979. 69 pp.

Boyum, Kent W. A Comparative Water Quality Study of Man-Made Drainage Ditches and Natural Streams in South Central Minnesota, Thesis, M.A., Mankato State University, August 1980. 97 pp.

Pierce, C. and B. Thompson. A survey of water flow in public drainage ditches and streams in South Central Minnesota, Paper presented and submitted at the Minnesota Academy of Science Meetings, April 25-26, 1980.

(C) Project Status

This project will be completed this fiscal year.

(D) Application of Research Results

The water quality and quantitative geomorphic data and results has generated a wide range of interest from the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, Region 9 Development Commission, the Environmental Quality Board, and the local counties. The legal history of drainage in Minnesota has attracted the attention of the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service and many levels within the Minnesota Judicial System. The Minnesota River water quality analysis has been requested by the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, the U.S. Army Corps of Engineers, and Power Plant Siting Staff of the Environmental Quality Board. Numerous requests have also come in from private consulting companies.

(E) Work Remaining and Progress Contemplated During Next Year

The technical completion report will be written and submitted.

OWRT Project No.: A-041-Minn

Agreement No.: 14-34-0001-1025

Project Title: Hydrocarbon Spills, their Retention in the Subsurface and Propagation to and into Shallow Aquifers

FCCSET Research Category: V-B

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

Project Began: October 1, 1978

Scheduled Completion: September 30, 1981

Principal Investigator	Degree	Discipline
Hans Olaf Pfannkuch	Ph.D.	Geology and Geophysics

Student Assistants	Degree	Discipline or Academic Background
Gary B. Cohen	B.A.	Geology
Valerie A. Eames	B.A.	Geology

(A) Research Project Accomplishments

Oil Retention Experiments

Oil retention determinations have been carried out on sand packed columns simulating oil infiltration into saturated soil. The experiments consist of first saturating the column with 100 percent water, then introducing oil under a ponded head until an equilibrium situation is reached, i.e., only residual water remains and all inflowing oil is accounted for at the outflow. The column is then allowed to drain. Experiments with four synthetic sand packs (Ottawa, with sizes 1, 1.25, 1.5 and 2.25) have been completed. The smallest grain size 2.25 shows highest retention, but the range of the larger sizes 1-1.5 may have been too narrow to fully show the trends. Therefore five more column experiments with synthetic sands of a larger size range are underway presently. Also three field samples are being investigated.

Much of the experimental efforts was to refine the methodology - overcome the effects of evaporation both in sample handling and in the column and in control of the saturation determination process.

The experiments with two phase flow are much more time consuming both in column preparation as well as in drainage time than the simpler dry-invasion experiments reported on earlier.

Dispersion and Adsorption Experiments

Dispersion and adsorption of dissolved hydrocarbons during flow through packed columns was investigated by using a frontal displacement method or step input function.

A considerable amount of time was spent in making the experimental set-up operational, especially the direct sampling and analysis by gas chromatography of aqueous hydrocarbon solutions without lengthy extraction or other preparation methods.

Three different materials were used--a clean quartz sand (Ottawa), a quartz sand from a Twin Cities location (St. Peter) and a locally derived glacial outwash sand. Experiments were run with conservative tracers (NaCl), phenol and naphthalene solutions.

The tracer and the phenols give typical S shaped effluent concentration curves with no retardation, i.e., the 50 percent concentration point emerges at exactly one pore volume fluid injected. The napthalene is retarded, i.e., its 50 percent concentration point emerges at pore volumes larger than 1, and it shows the assymetric effluent curves characteristic for sorption phenomena. The results are summarized on Figures 1 through 3. The somewhat unexpected finding is that the cleanest sample (Ottawa) seems to adsorb most. This will be further investigated by scanning electron microscope study of the grain surfaces.

From all literature indications it seems that these experiments with typical hydrocarbons such as found in most spills are the first to have been carried out.

(B) Publications

Convery, M.P. and Pfannkuch, H.O. Experimental Study of Hydrocarbon Retention Capacities in Synthetic Porous Media and Glacial Drift. Presented at: Symposium on Organic Contaminants in Groundwater, AGU, Fall meeting, December 6, 1979.

(C) Project Status

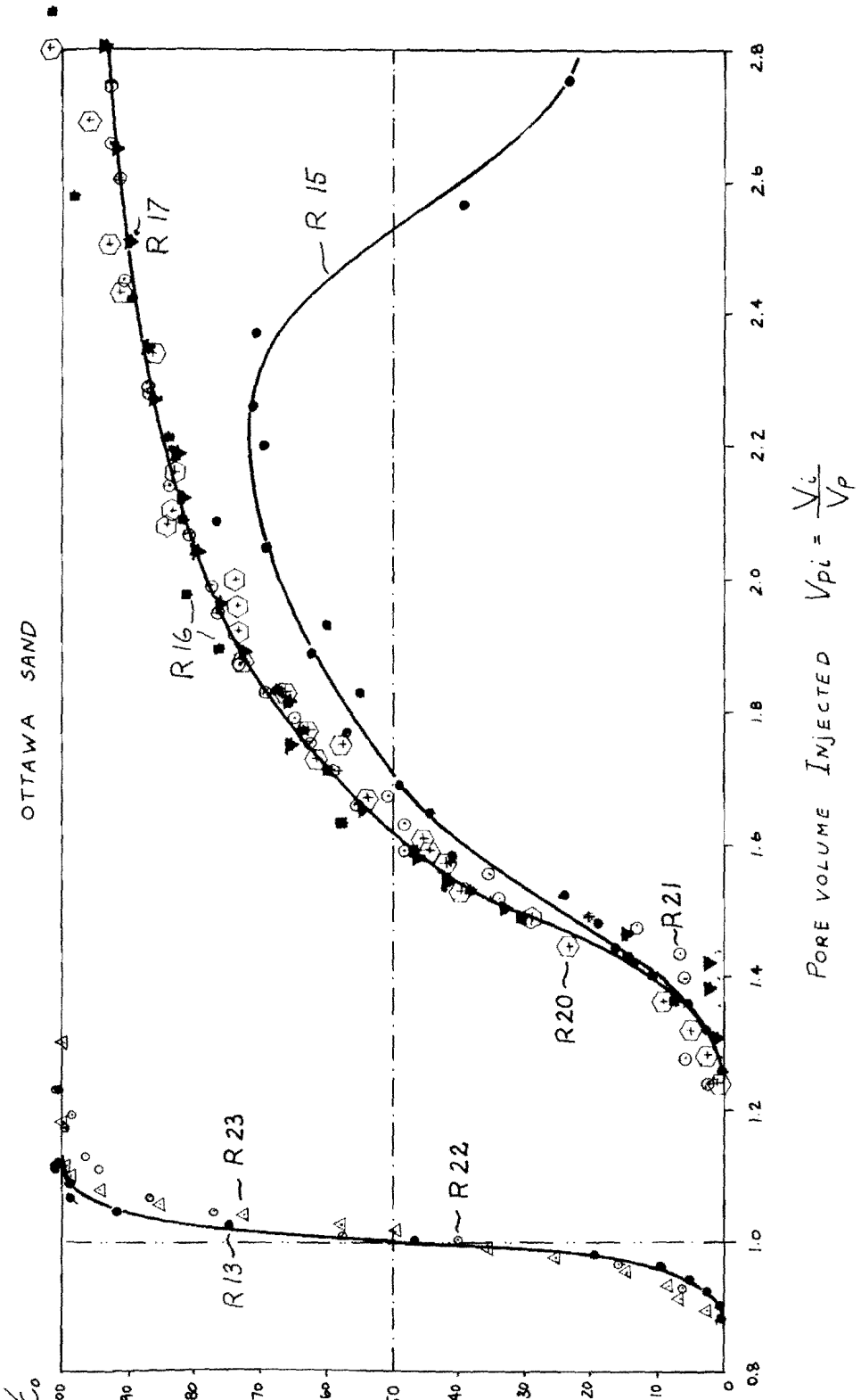
The project completed its second year and will continue for another year.

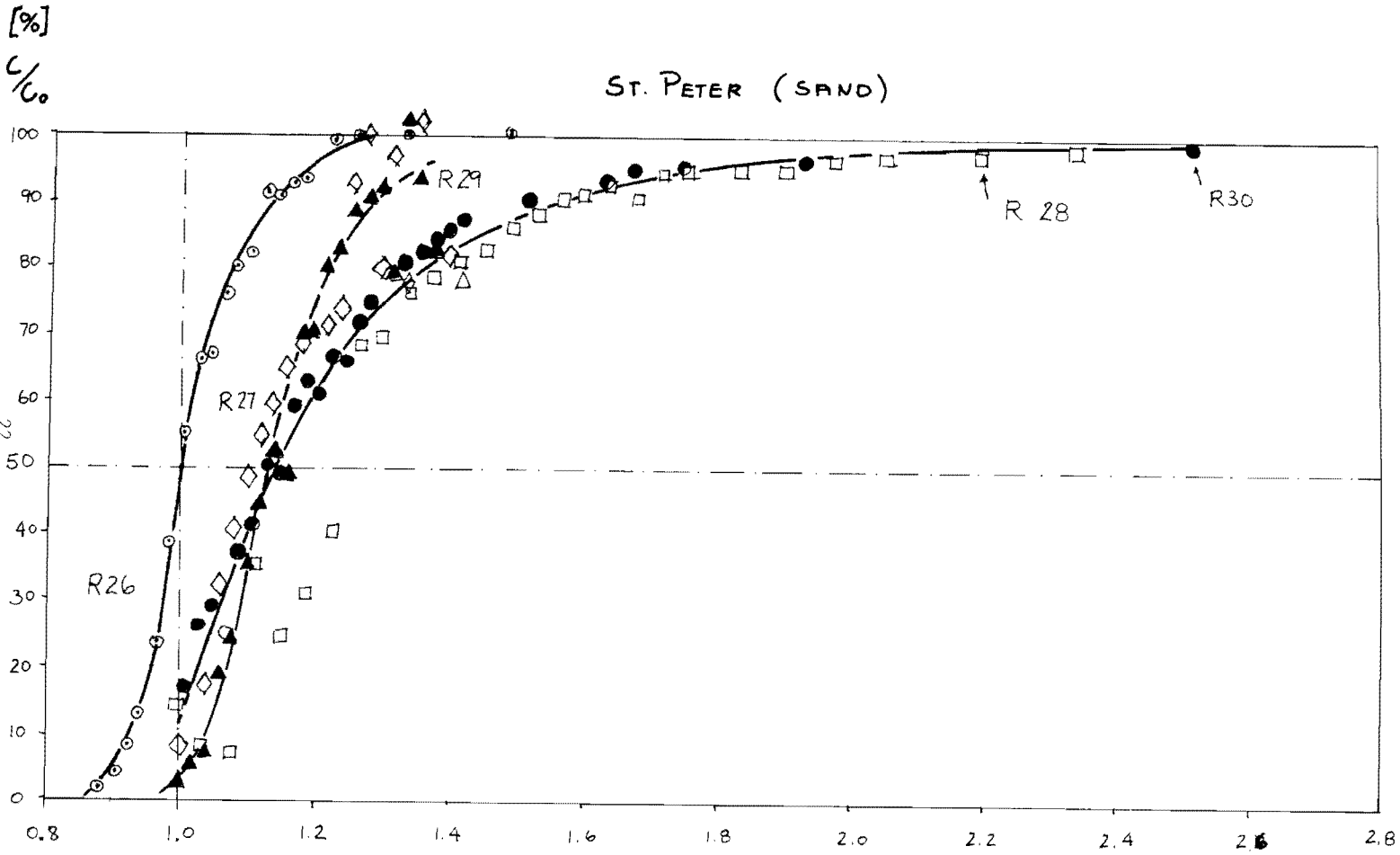
(D) Application of Research Results

Results will be disseminated to Minnesota Pollution Control Agency, Spills Section (John Aho); EPA - Industrial Environmental Research Lab, Oil and Hazardous Materials Spills Branch, Edison, N.J., John Farlow (Chief Oil Spills Staff); American Wildlife Federation; American Petroleum Institute (T. Nanney).

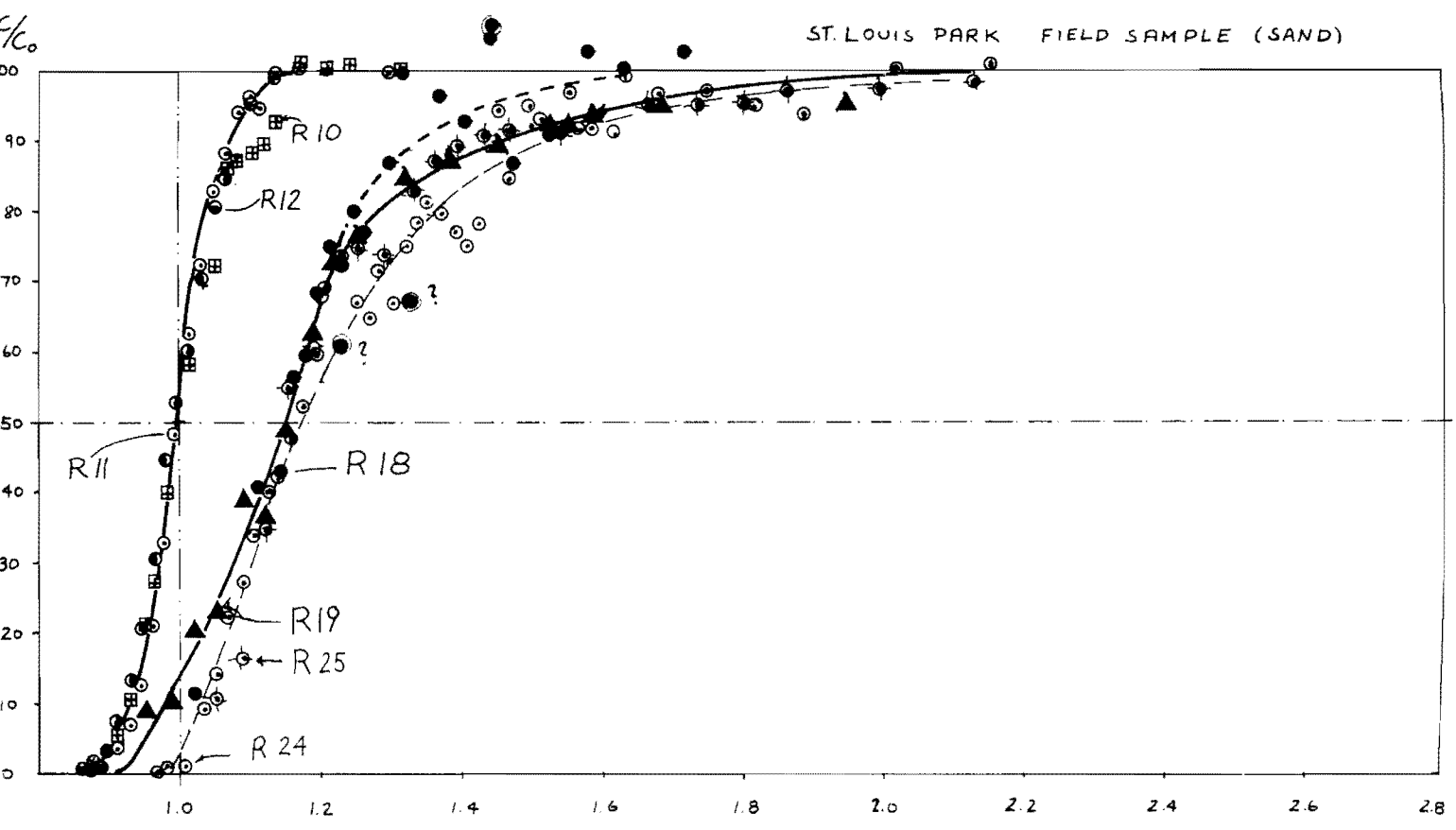
(E) Work Remaining and Progress Contemplated During Next Year

Next years work will concentrate on finishing the experiments dealing with retention capacity as indicated under research project accomplishments, and to run further displacement experiments with different hydrocarbons (3-ring aromatics). A numerical model will be put on line to simulate spreading of dissolved phase as a function of spill shape and orientation with respect to the groundwater flow field.





PORE VOLUME INJECTED $V_{pi} = \frac{V_i}{V_p}$



PORE VOLUME INJECTED $V_{pi} = \frac{V_i}{V_p}$

OWRT Project No.: A-042-Minn

Project Title: Re-Use of Agricultural Drainage Waters for On-site Soil Water Recharge and Irrigation

Agreement No.: 14-34-0001-0125

FCCSET Research Category: 03-F

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

Project Began: October 1, 1978 Scheduled Completion: September 30, 1981

Principal Investigator	Degree	Discipline
George R. Blake	Ph.D.	Soil Science

Student Assistants	Degree	Discipline or Academic Background
Brad Johnson	B.A.	Soil Science
Marvin Yahnke	Undergrad	Plant Pathology
Theresa Myers	Undergrad	Soil Science

(A) Research Project Accomplishments

Continuation of our on-site soil water recharge project is currently under way at the Lamberton Agricultural Experiment Station of the University of Minnesota. Investigation of the potential for increasing corn production with sprinkler irrigation using excess surface and tile waters stored in a reservoir will be continued. Six irrigation treatments consisting of timing and amount variables were rerandomized within each replication at the start of the present growing season.

Improvements in our experimental procedure have been instituted such that plant available water and soil water potential may be monitored more thoroughly. A more thorough installation of neutron probe access tubes and tensiometers in each plot, will allow us to more effectively assess crop response to various irrigation treatments.

Although precipitation from May through September was 27 percent greater than normal in 1979, irrigation increased corn grain yield by 30 percent (69.6 vs. 90.4 Bu/A). Response depended on timing and amount of sprinkler irrigation.

Evapotranspiration-rainfall balance showed ample soil water at critical tasseling stage under all treatments in 1979. In fact, during a 100-day period between May 20 and August 31, plant available water was depleted by a mere 1.5 inches even without irrigation. Matric water potential rarely fell below -400 mb at a depth greater than 20 cm. Indeed a positive pressure potential (indicating the presence of a water table) was observed on some plots at 100 cm depth, even in August.

In 1980, precipitation from April through August has been slightly above normal (15.58 vs. a long term average of 15.05 inches of precipitation for the period). However, no significant precipitation occurred from

June 27 to August 2. The soil profile also contained less plant available water during the spring of 1980 than in the spring of 1979 when the soil profile was virtually at field capacity. These factors in combination with unusually warm day-time air temperatures created a stressful situation for the corn at the critical reproductive stage in 1980.

As an indication of the seriousness of the moisture deficiency, available water in the 5 ft. profile was as much as 70 percent depleted in our non-irrigated plots by the beginning of August. In addition, matric potential was less than -0.8 bar in each of the 3 surface 1-foot soil profiles. Crop response to the irrigation in 1980 is expected to exceed that observed in 1979 as a result. In fact, physiological differences in the corn plants between treatments were readily apparent shortly after tasseling. Corn height averaged 5 ft. in the check plots as opposed to 6 ½ ft. for the corn in the treatment receiving 3 weekly applications of 1 in. each. Contrasting degrees of corn leaf rolling in response to moisture stress were also evident between treatments.

(B) Publications

None.

(C) Project Status

The project will continue during the 1981 fiscal year.

(D) Application of Research Results

Research results will be used by farmers wherever soil types, slope and topography allow the impoundment of water for midseason application to crops. Farmers in those areas where fine textured sub-humid soils are found will be particularly interested in these results since ground water availability is often insufficient for large-scale irrigation development. Thus the impoundments could serve as flood control structures as well as a convenient source for irrigation water and also offer the possibility of recycling some soluble plant nutrients.

Regional climatic conditions must dictate a need for soil water recharge. In those regions where moisture stress is commonly experienced during the growing season, irrigation could be a worthwhile undertaking. By investigating the relationship between meteorological conditions, soil moisture, plant stress, and crop yield for corn, we expect to improve irrigation scheduling and maximize water use efficiency.

(E) Work Remaining and Progress Contemplated During Next Year

Grain yield with respect to the various irrigation treatments will be measured as in the previous year. Laboratory data on the hydraulic characteristics of the soil and such properties as density and particle size will be determined for use in more precise interpretation of results. Hydraulic conductivity measurement may be of particular interest so that soil water flux can be calculated using the tensiometer information.

The reservoir level will be monitored for the remainder of the present growing season. The nutrient content of the irrigation water will also be assessed by determining reservoir-water quality periodically.

Neutron radiation probe for determining water content of soil.

Tensiometer manometers give soil water potentials in soils to 2 meter depths.

OWRT Project No.: A-043-Minn Project Title: Predicting Direct Recharge of Surficial Aquifers

Agreement No.: 14-34-0001-0125

FCCSET Research Category: 02-A, 02-F, 02-G; 1, 5, 11

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

Project Began: October 1, 1979 Scheduled Completion: September 30, 1982

Principal Investigators	Degree	Discipline
Donald C. Slack	Ph.D.	Agricultural Engineering
Curtis L. Larson	Ph.D.	Agricultural Engineering

Student Assistants	Degree	Discipline or Academic Background
Francis I. Idike	M.S.	Agricultural Engineering
Thomas F. Scherer	B.S.	Agricultural Engineering
Martha Zirbel	B.S.	Agricultural Engineering
Stephen M. Copeland	B.S.	Agricultural Engineering
Gina R. Miller	B.S.	Agricultural Engineering Technology
Lora Veidel	Undergrad	Agricultural Engineering

(A) Research Project Accomplishments

A cluster of three observation wells was constructed on the Anoka Sand Plain. The wells include a 4" diameter main well and two 2" diameter wells located 90° apart and 200 ft. from the main well. These wells were constructed for the project by the USGS (St. Paul Office). The wells were completed in late March and a water level recorder installed in the main well on April 18, 1980. Access tubes for neutron soil moisture measurement were installed around the main well. Additional instrumentation at the site includes a recording rain gage, a hygrothermograph and a microbarograph. With the exception of soil moisture, all data is continuously recorded. Soil moisture data are observed at weekly intervals.

The soil above the water table at the site is a fine sand with a bulk density of 1.562 gm/cc, saturated hydraulic conductivity of 1.496×10^{-2} cm/s and a saturated water content of 30.63 percent by volume. Upon completion of the wells in early April, the water level was 6.90 ft. below the surface in the main well.

All data are stored in a computer file and are accessible for use by USGS and Minnesota Geological Survey. Although not yet fully analyzed, the limited data obtained so far show that the groundwater rises in response to rainfall amounts as low as 0.5 inch when the soil is moist while more than one inch of rainfall is required to produce groundwater rise under dry soil conditions. Between rains, the groundwater level declines steadily at a rate which varies seasonally.

Development of the recharge model has been initiated. Basically, the model is a soil moisture model which accounts for infiltration and evapotranspiration. Water movement through the profile is governed by Darcy's law applied to unsaturated flow. Water moving vertically downward below the 5 ft. level is considered to be recharge to the aquifer. The model will incorporate a snowmelt submodel. Data from the Sand Plain well site are being used to test and develop various model components.

(B) Publications

None.

(C) Project Status

Project is at the end of the first year of a three-year study. Work to be continued during the next fiscal year.

(D) Application of Research Results

The U.S. Geological survey and Minnesota Geological survey have cooperated on the data collection phase of the project and will utilize the soil moisture and groundwater data in their programs. In addition, the USGS has expressed considerable interest in the evapotranspiration portion of the model and may utilize it in some watershed studies.

The Minnesota Department of Natural Resources, Division of Waters, have expressed interest in using the model to assess groundwater recharge in irrigated areas utilizing water from surficial aquifers. The model should be equally useful to other states with similar aquifers.

(E) Work Remaining and Progress Contemplated During FY 1981

Groundwater, meteorological, and soil moisture data collection will continue throughout FY 1981. Primary efforts will be focused on development of the first generation recharge model and preliminary testing with data from the Sand Plain observation well site.

Data from USGS wells, in the "Bonanza Valley" area in west central Minnesota will be studied and where suitable used for additional testing and application of the model.

U.S.G.S. crew assisted by Thomas Scherer, graduate student, Agricultural Engineering, drilling 4" observation well near Constance, Minnesota, March 1980.

MATCHING GRANT PROGRAM

NARRATIVE PROGRESS REPORTS

Annual Report -- Title I Projects

OWRT Project No.: B-139-Minn Project Title: Application of New Methods for Routine Measurement of Aquatic Organics

Agreement No.: 14-34-0001-8092

FCCSET Research Category: 04-A; 4

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

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigator	Degree	Discipline
Walter J. Maier	Ph.D.	Environmental Engineering

Student Assistants	Degree	Discipline or Academic Background
Christine Macko	Ph.D.	Environmental Engineering
Nancy Pelt	M.S.	Environmental Engineering
Pitsumai Nath	Ph.D.	Computer Science
Theodore Miller	undergrad	Physics
Mark McCahill	undergrad	Chemistry
Doug Fullen	B.A.	Environmental Engineering

(A) Research Project Accomplishments

A comprehensive analysis of Mississippi River water from four geographical locations at different times of the year has been carried out. Organic materials and trace metals were measured. Organic constituents were size fractionated to determine molecular size distributions, analyzed for organic nitrogen, carbon and metal complexation. Preliminary results were summarized in last year's progress report. Since the last report, research has focused on (a) measuring the concentration of organically combined chlorine, and (b) utilization of UV absorbance measurements for characterizing organic fractions. (a) Procedure for measuring organically combined chlorine (TOCI) has been developed and used to analyze Mississippi River water as well as sewage treatment plant effluents. TOCI is measured after preconcentrating the water, photolyzing the organics to mineralize the chlorine and measuring the released chloride. The results show that Mississippi River water contains very low concentrations of TOCI. However chlorination of sewage treatment plant effluents was found to be a significant source of TOCI.

(B) UV absorbance characteristics of Mississippi River organics have been characterized in terms of pure model compound chromophores. UV absorbance of the 1000-10000 molecular size fraction is remarkably similar at all geographical locations and seasons. Five model compound chromophores (Vanillin, Anisic acid, Tannic acid, Acetephenone and Mellitic acid) are consistently identified by a computerized absorbance matching technique. The absorbance matching calculations also estimate the respective concentration of the matching chromophores.

A related development in this phase of the research program is that a strong correlation has been found between biochemical oxygen demand (BOD) measurements and the combined measurements of organic carbon (TOC) and UV absorbance. The latter are easily measured on a continuous basis or on spot samples in a matter of minutes whereas BOD measurements require 5 days.

(B) Publications

McCahill, M., L.E. Conroy and W.J. Maier. I. Determination of Organically Combined Chlorine in High Molecular Weight Aquatic Organics; Environmental Science and Technology, 14:2, 201, 1980.

McCahill, M., L.E. Conroy and W.J. Maier. II. Determination of Organically Combined Chlorine in High Molecular Weight Aquatic Organics; Presented at ACS Houston, March 1980 Meeting and in press in "Chemistry in Water Reuse", edited by W.J. Cooper.

Maier, W.J. and L.E. Conroy, Edited by W.J. Cooper. UV Multiwavelength Absorbance Measurements in Monitoring Trace Organics in Water. Presented at ACS Houston, March 1980 meeting and in press in "Chemistry in Water Reuse".

Conroy, L.E., W.J. Maier, and Y.T. Shih, Edited by W.J. Cooper. Determination of Carbohydrates and Primary Amines in River Water, Presented at ACS Houston, March 1980 meeting and in press in "Chemistry in Water Reuse".

Maier, W.J., L.E. Conroy, S.J. Eisenreich, M.R. Hoffmann, C.A. Macko and P.D. Nath. Multicomponent UV Spectral Analysis of Aquatic Organics. Proceedings Int. Congress on Analytical Techniques in Environmental Chemistry; Edited by Albaiges, Barcelona, Spain, Nov. 1978.

Pelt, N. and W.J. Maier. The Use of TOC Measurements and UV Spectroscopy to Predict BOD Measurements in Primary and Secondary Effluents in Municipal Wastewater Plants; presented at 53rd Annual Central States Water Pollution Control Federal Meeting, Waukesha, Wisconsin, May 1980.

(C) Project Status

Funding for this project terminates on September 30, 1980. A final project report is in preparation and is due September 30, 1980.

Research efforts on three projects initiated under this grant are continuing, namely (a) Development of Methodologies for Characterizing Aquatic Organics Using Multiwavelength Absorbance Measurements, (b) Analysis and Comparison of Measuring Techniques for Aquatic Organics and (c) Determination of Organically Combined Chlorine in High Molecular Weight Organics. Additional funding is being sought.

(D) Application of Research Results

The newly developed method for measuring organically combined chlorine (TOCl) has been used by the Metropolitan Waste Control Commission to study the effects of chlorination on effluent quality. The results show that significant amounts of chlorinated organic residues are formed and discharged to the Mississippi River. This practice is now under review and reductions in chlorination with attendent savings in treatment costs are anticipated.

The most important long range benefits of this study stem from the scientific value of the data base and comprehensive description of trace contaminant transport in the Upper Mississippi River. The data base has been developed in a coordinated program that emphasized selection of representative sampling sites; seasonal sampling sequences, utilization of advanced as well as conventional analytical methods. Precise measurement of physical-chemical characteristics of the aquatic organics and metal complexes are important in terms of setting water quality standards, implementation of water quality standards through design and construction of water supply and waste treatment facilities and enforcement actions by state and federal agencies.

There have been two practical applications of the results to date, one concerns development of a more effective water treatment process for drinking water supplied, the other concerns utilization of more effective analytical protocols in water treatment process research.

A process using strong base anion exchange resins to remove aquatic organics and certain trace metals from drinking water supplies has been developed. The need for using strong base resins was suggested by the measured physical-chemical characteristics of the aquatic organic constituents in Mississippi River water. Process performance characteristics and design data have been published. Use of anion exchange resins appears to be effective for reducing organics in drinking water and hence reducing halomethane problems. Comparison with data on activated carbon adsorbtion shows that the ion exchange process is economically attractive.

Another practical application of research results concerns the utilization of the newly developed analytical protocols for measuring and characterizing trace organics in engineering studies of alternative methods for treating public water supplies. Engineering process variable studies aimed at evaluating the effectiveness of alternative treatment processes (alum flocculation, filtration, and adsorbtion) for removing trihalomethane precursors have been carried out. Organics were measured using the analytical protocols developed in this study. Another spin off benefit that has been developed from the study of UV absorbance characteristics is the finding that Biochemical Oxygen Demand (BOD) can be predicted from UV absorbance and TOC measurements; the latter measurements are easily obtained in a matter of minutes and in fact can be monitored continuously at low cost whereas BOD measurements take 5 days and are not amenable to continuous monitoring.

(E) Work Remaining and Progress Contemplated Next Year

The project terminates this fiscal year.

OWRT Project No.: B-147-Minn

Agreement No.: 14-34-0001-9119

Project Title: The Measurement of Evapotranspiration and Comparison With Empirical Calculation Methods for Use in Minnesota and Similar Climatic Regions

FCCSET Research Category: 02-D; 03-F

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

Project Began: October 1, 1978 Scheduled Completion: September 30, 1981

Principal Investigators	Degree	Discipline
Donald Baker	Ph.D.	Soil Science
James B. Swan	Ph.D.	Soil Science

Student Assistants	Degree	Discipline or Academic Background
Jon E. Ljungkull	B.A.	Physics
Martin MacGregor	Undergrad	Agronomy
Diane Fiehr	Undergrad	Soil and Water

(A) Research Project Accomplishments

Daily evapotranspiration (Et) amounts from a soybean crop were measured during the 1978 and 1979 growing seasons. Measurements are continuing during the 1980 growing season; the crop, however, has been switched to alfalfa. Though measurements are taken every day, only days on which the ground cover is greater than 50 percent, no precipitation occurs, and no irrigation is done, are deemed suitable for comparison with calculated E values. There were 52 such days during the 1978 growing season and 48 in 1979. Daily Et amounts have been compiled for the 1980 season but no comparisons with calculated values have been made. Data on climatic variables including solar radiation, wind, temperature and relative humidity are collected simultaneously with the Et measurements. The measurements necessary for using the formulae being tested are listed in table 1. Tensiometers are used to monitor soil moisture conditions both in the lysimeter and in the surrounding plot. Irrigation water is applied to the entire plot when necessary to maintain Et conditions as near the potential as possible.

A statistical regression analysis was undertaken to compare the estimates of Et obtained from climatic data to the measured values. Due to a hailstorm which inflicted severe damage on the crop in June 1979, full cover was not reached until late July. Because of this, the data from the two years has been analyzed separately. Regression parameters for the equations tested are given in table 2 for 1978 and table 3 for 1979. Measured Et is the dependent variable. The summary statistics for the measured and calculated Et values are given in tables 4 and 5 for 1978 and 1979, respectively.

It is evident from tables 2 and 3 that the performance of the methods in 1978 was superior to 1979. This is due in part to the fact that full cover was not established until the middle of the 1979 growing season. Lack of full cover allowed rapid drying of the soil surface and thus the Et rates measured were less than the potential. Nine of the thirteen methods consistantly over-estimated Et in 1979 while only four of the methods did so in 1978.

In both years pan evaporation was the method that agreed most closely with the measured values. This method is the simplest, requiring only a single measurement that any irrigator can take readily. The methods of Jensen and Haise, Turc, and Stephens and Stewart also showed good performance during both years, and should be adequate for irrigation scheduling purposes in this climatic region.

Collection of data on Et from crops will continue in the future. The researchers wish to broaden the data base and obtain new data with which the methods can be retested. Winter time measurements will also continue in an effort to detect sublimation of snow. Due to problems in maintaining the surface conditions, sublimation measurements so far have been only partially successful. The few good measurements obtained during the winter of 1979-1980 support those made during the winter of 1978-1979, which indicated a daily sublimation loss of approximately 0.25 mm (0.01 inch).

(B) Publications

None.

(C) Project Status

This project will continue for one more fiscal year.

(D) Application of Research Results

Members of the U.S. Department of Agriculture, SEA, AR, from both the Tempe, Arizona and Morris, Minnesota, unit were here in July, 1980 in order to compare experimental results and to obtain data for their respective evapotranspiration and crop growth models.

The pan evaporation and lysimetric measurements are used by the Extension Agricultural Climatologist in his bi-weekly agricultural advisories.

(E) Work Remaining and Progress Contemplated During Next Year

The thesis work was not completed as early as planned but will be completed this autumn. This will determine the one most useful evapotranspiration calculation method out of the 12 that were tested. Studies are now directed to a full cover crop (alfalfa) as opposed to a row crop (soybeans) and the winter snow studies (sublimation rather than evapotranspiration) are continuing.

Table 1. Measurements necessary to compute Et by the methods tested.

Method	Solar (or net) Radiation	Air Temperature	Wind	Relative Humidity	Day Length
Penman	X	X	X	X	
van Bavel	X	X	X	X	
Blaney-Criddle		X			
Grassi	X	X			X
Stephens-Stewart	X	X			
Turc	X	X			
Jensen-Haise	X	X			
Makkink	X	X			
Papadakis		X			
Hamon				X	X
Thornthwaite		X			

Table 2. Comparison of methods, 1978 data. Measured Et is the dependent variable. The coefficient of variation is expressed as percent of mean Y value.

Method	Regression Coefficients Intercept	Slope	r	σ	Cv
Evaporation pan	-0.22	0.80	.827	1.25	27.2
Penman	0.27	1.08	.803	1.32	28.8
van Bavel	0.60	0.65	.753	1.46	31.8
Blaney-Criddle	-0.61	1.06	.686	1.61	35.1
Grassi	-1.13	1.25	.777	1.39	30.2
Stephens-Stewart	-0.40	1.55	.822	1.26	27.5
Turc	-1.38	1.46	.816	1.28	27.9
Jensen-Haise	-0.29	0.96	.823	1.26	27.5
Makkink	-0.85	1.58	.798	1.33	29.0
Papadakis	1.26	0.96	.543	1.86	40.5
Hamon	-0.55	1.44	.732	1.51	32.9
Thornthwaite	-0.82	1.64	.615	1.75	38.1

Table 3. Comparison of methods, 1979 data. Measured Et is the dependent variable. The coefficient of variation is expressed as percent of mean Y value.

Method	Regression Coefficients Intercept	Slope	r	σ	Cv
Evaporation pan	-0.14	0.77	.763	1.10	29.8
Penman	1.36	0.69	.652	1.29	35.0
van Bavel	1.36	0.46	.538	1.43	38.8
Blaney-Criddle	0.99	0.66	.539	1.43	38.8
Grassi	-0.41	0.95	.698	1.22	33.1
Stephens-Stewart	0.62	1.21	.723	1.17	31.7
Turc	-0.16	1.12	.726	1.17	31.7
Jensen-Haise	0.71	0.74	.721	1.18	32.0
Makkink	0.17	1.22	.718	1.18	32.0
Papadakis	1.60	0.71	.397	1.56	42.3
Hamon	1.07	0.91	.586	1.38	37.4
Thornthwaite	0.97	0.95	.429	1.53	41.5

Table 4. Summary statistics for the 1978 data. Cv is in percent, all other values are in mm.

Method	Mean	St. Dev.	Cv.	Min.	Max.
Lysimeter	4.59	2.19	48	0.46	8.86
Evaporation pan	6.05	2.28	38	1.32	11.2
Penman	3.98	1.63	41	0.00	6.47
van Bavel	6.09	2.52	41	0.00	11.4
Blaney-Criddle	4.92	1.42	29	1.97	7.31
Grassi	4.57	1.36	30	0.77	6.57
Stephens-Stewart	3.22	1.16	36	0.50	5.30
Turc	4.10	1.23	30	0.97	6.03
Jensen-Haise	5.11	1.88	37	0.78	8.53
Makkink	3.45	1.11	32	0.47	5.16
Papadakis	3.48	1.24	36	1.05	6.68
Hamon	3.57	1.11	31	1.34	5.61
Thornthwaite	3.30	0.82	25	1.54	4.55

Table 5. Summary statistics for the 1979 data. Cv is in percent, all other values are in mm.

Method	Mean	St. Dev.	Cv	Min.	Max.
Lysimeter	3.69	1.68	46	0.66	6.81
Evaporation pan	4.91	1.65	34	1.47	8.89
Penman	3.37	1.59	47	0.00	7.47
van Bavel	5.05	1.97	39	0.20	9.78
Blaney-Criddle	4.09	1.38	34	2.22	6.92
Grassi	3.92	1.23	31	1.01	6.25
Stephens-Stewart	2.54	1.01	40	0.57	4.95
Turc	3.43	1.09	32	1.07	5.73
Jensen-Haise	4.01	1.63	41	0.87	7.95
Makkink	2.88	0.99	34	0.63	4.89
Papadakis	2.95	0.95	32	1.06	5.30
Hamon	2.88	1.08	38	1.48	5.22
Thornthwaite	2.84	0.98	35	1.72	4.18

OWRT Project No.: B-150-Minn Project Title: A Study to Identify the Potential of Naturally Occurring Zeolites for Removing Heavy Metals From Water

Agreement No.: 14-34-0001-9078

FCCSET Research Category: 05-D, 4

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

Project Began: October 1, 1978 Scheduled Completion: September 30, 1980

Principal Investigator	Degree	Discipline
Michael J. Semmens	Ph.D.	Civil and Mineral Engineering

Student Assistants	Degree	Discipline or Academic Background
William Martin	B.S.	Civil Engineering

(A) Research Project Accomplishments

The removal of heavy metals by climoptilolite has continued and greater attention has been given to the impact of solution pH on the removal behaviour of the ion exchanger. The zeolite generally works best at pH 5-7 and shows significantly less affinity for metals at low pH.

Regeneration of the zeolite has been studied and varying salt and acid concentrations were tested for their effect on the rate and extent of metals elution.

Cadmium exchange behaviour has been studied in detail. Copper, lead and other metals are being studied at the present time.

(B) Publications

Semmens, M.J., Cadmium Removal by Clinoptilolite. Part 1. Column and Batch Studies. Submitted to Journal of Water Pollution Control Federation. 1980.

Semmens, M.J. Cadmium Removal by Clinoptilolite. Part 2. Regeneration Studies. Submitted to Journal of Water Pollution Control Federation, 1980.

Semmens, M.J. and W. Martin. "Studies on Cadmium, Lead and Silver Removal from Saline Water by Clinoptilolite". Water 1979. (AIChE Symposium Series).

Martin, W. and M.J. Semmens, "The Ion Exchange Behaviour of Cadmium on Clinoptilolite". Presented at an American Institute of Mining Engineers Conference, October 1979.

(C) Project Status

The project will extend to March 31, 1981.

(D) Application of Research Results

The results are applicable to many industries faced with increasingly stringent requirements for cadmium discharge. The information collected in this study will be useful in the design of ion exchange facilities for heavy metal removal.

(E) Work Remaining and Progress Contemplated During Next Year

The impact of base pretreatment and pH on metal removal behaviour will be completed. The comparative performance of selected zeolites will be evaluated under controlled conditions and the behaviour of the zeolite in complex wastewaters will be studied.

OWRT Project No.: B-153-Minn

Agreement No.: 14-34-0001-0268

Project Title: Ground-Water Recharge Rates in Minnesota as Related to Precipitation

FCCSET Research Category: II-B, 11

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

Project Began: October 1, 1979

Scheduled Completion: September 30, 1981

Principal Investigator	Degree	Discipline
Matt Walton	Ph.D.	Geology
Roman Kanivetsky	Ph.D.	Engineering Geology and Hydrogeology

Student Assistants	Degree	Discipline or Academic Background
Wendy Engstrom	B.S.	Geology
Brian Johnson	undergrad	Geology
Mark Dobin	undergrad	Geology
Randy Moore	undergrad	Geology

(A) Research Project Accomplishments

A data base of precipitation records and observation well water level records (hydrographs) had already been assembled for the report, Regional Approach to Estimating Ground Water Resources of Minnesota (Kanivetsky, 1979, MGS Report of Investigations 22).

For the current project active well hydrographs were updated and additional observation well records of discontinued USGS wells in Minnesota and of observation wells in North Dakota, South Dakota and Wisconsin near the Minnesota border were collected. A complete set of U.S. Environmental Data Service climatological records for Minnesota from 1940 to 1980 also was obtained.

Water table condition observation well locations were plotted on the Quaternary Hydrogeologic Map of Minnesota (R. Kanivetsky, 1979) in order to identify outwash and alluvial aquifers inadequately represented by observation wells and to compare aquifer lithology given in the observation well logs with the generalized hydrogeologic map units.

Of 200 active and inactive observation wells, more than half are located in Wadena, Ottertail, Hubbard, Morrison, Sherburne, and Stearns Counties. All areas other than central Minnesota are poorly represented. According to well logs, two water table condition observation wells tap the Prairie du Chien aquifer, two draw from till and the remainder are in alluvium and outwash ranging from fine sand to gravel. A few of these latter wells are located in moraine or lake bed areas, at the 1:500,000 scale of the Quaternary Hydrogeologic Map.

Isohyets of mean annual precipitation were superimposed on this map in order to determine the distribution of observation wells with regard to this major climatological factor in recharge. Average precipitation in Minnesota ranges from less than twenty inches in the northwest corner to greater than thirty inches in the southeast. It is expected that aquifer recharge, if dependent primarily on precipitation, will also increase from the northwest to the southeast.

The distribution of wells is as follows: less than 20 inches precipitation, 6 wells; 20-22 in., 0 wells; 22-24 in., 6 wells; 24-26 in., 37 wells; 26-28 in., 115 wells; 28-30 in., 25 wells; more than 30 inches, 6 wells.

On the one hand, the poor distribution of wells over the range of precipitation found in Minnesota may be an obstacle to determining the relationship between aquifer recharge rate and climatological factors. If the importance of secondary factors such as fall soil moisture or length of winter frozen soil period significantly varies with the amount and distribution of annual precipitation, the few wells at the precipitation extremes may be an inadequate sample to produce a representative result.

On the other hand, so many wells within one precipitation interval may allow easier identification of secondary factors in recharge rates.

In order to test whether the recharge determined from static water level fluctuations does follow the expected general geographical pattern, the average annual recharge rate over the period 1967-1977 was computed from annual static water level high and low points of all wells located within each precipitation interval.

The results are as follows: less than 20 in. precipitation, 3.5 in. recharge; 24-26 in. precipitation, 2.6 in. recharge; 26-28 in. precipitation, 3.9 in. recharge; 28-30 in. precipitation, 4.3 in. recharge; 30+ in. precipitation, 3.3 in. recharge. It is unknown whether the results for the precipitation extremes are representative or anomalous due to few observation well records available in those areas.

Individual wells or groups of proximate wells are analyzed in this manner:

1. Well site evaluation by construction of cross sections from the well to the nearest water bodies, showing the geomorphic setting of the well; marshes, lakes and streams to which the aquifer might be hydraulically connected; and static water level and aquifer lithology of neighboring wells. Aquifers that recharge from water bodies must be identified and excluded from use in this project.

2. Piezometric analysis, as described by R.A. Freeze in Regional Ground Water Flow - Old Wives Drainage Basin, Saskatchewan (Canada, Inland Waters Branch, Sci. Ser. 5) in order to distinguish aquifer recharge and discharge areas. The depth to the static water levels of the observation

well and its neighbors in the same aquifer are plotted on the ordinate of a graph and the well depths are plotted on the abscissa. A concave upward or positive slope of the resulting curve indicates decreasing hydrostatic pressure with increasing depth, i.e., flow downward or recharge. Conversely a negative slope indicates discharge of the aquifer toward the surface. If the range of observation well static water levels fits in such a negative curve, the well should be excluded from further analysis.

3. Correlation of static water level and cumulative departure of precipitation, as described by James Marie in Preliminary Evaluation of Ground-Water Data Network in Indiana (USGS, WRI 76-24). The graph of cumulative departure (CD) of monthly precipitation from normal at a nearby weather station is superimposed on the hydrograph and graphical or statistical correlation is done to get an equation relating the two variables. For Minnesota's climate, modification of the CD curve may be necessary to get a better fit with the hydrograph.

In terms of aquifer recharge, effective precipitation during the winter frozen soil period may be zero, depending on how much ice clogs the soil. Thus, in calculating the CD curve, precipitation for winter months could be taken as zero so that there is a negative departure from the normal during winter months corresponding to the decline in static water level. Conversely, during snow melt in the spring, some of winter's stored snow is added to the spring effective precipitation, depending on when the soil thaws. Some of the winters precipitation may be added to precipitation for April in order to give a positive departure from normal corresponding to the spring rise in static water levels found in most well records.

For conditions of high positive departure of precipitation from normal, such as for spring recharge or for summer high intensity rainfall, an arbitrary limit on the number of inches of positive departure may be made to improve the fit of the CD graph to the hydrograph. Under conditions of high intensity rainfall the infiltration capacity of the soil may be exceeded, so that some precipitation must run off, again limiting effective precipitation in terms of aquifer recharge. This limit to infiltration capacity will show up as the limit on positive departure of precipitation from normal which gives the best fit to the hydrograph.

If verification of the modifications done to the CD graph can be made by examining records of soil moisture, soil temperature, snow on the ground and soil infiltration capacity, then secondary environmental factors affecting aquifer recharge have been identified and quantified.

(B) Publications

None.

(C) Project Status

The project is on schedule; it will continue during the next Fiscal Year.

(D) Application of Research Results

Water-table aquifer recharge rates and storage coefficients are of interest to Minnesota Pollution Control Agency, Department of Health, Department of Natural Resources, watershed districts; U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Department of Agriculture (Soil Conservation Service and Forest Service), county and urban government units.

Individual well analyses will be of interest to those agencies maintaining the wells. For example water levels of two wells used on this analysis are reported in the U.S.G.S. Monthly Water Resources Review as representative of the whole state.

(E) Work Remaining and Progress Contemplated Next Year

1. Decide whether to use border state well records. For example, North Dakota has wells in till and Wisconsin has wells in Ordovician-Cambrian bedrock close to Minnesota's border which could be used to supplement Minnesota's well records.

2. Finish well site evaluations using the cross section and piezometric analysis methods previously discussed.

3. Compute and graph cumulative departure of precipitation from normal for all weather stations close to observation wells.

4. Modify these graphs as necessary to obtain a good fit with the hydrograph and correlate the two variables.

5. Search climatological and environmental records for secondary factors in aquifer recharge, and see if they show the CD graphs.

6. Compute estimates of recharge rates for hydrogeologic areas.

7. Determine storage coefficients of various aquifers identified on Quaternary Hydrogeologic Map of Minnesota (R. Kanivetsky) using pumping test data and other sources.

8. Compare results of this investigation with recharge rates and storage coefficients computed by other means.

Roman Kanivetsky, Minnesota Geological Survey, with Quaternary Hydrogeologic Map of Minnesota.

Courses Developed:

No new courses have been developed.

Research results and other findings have been incorporated in all courses dealing with water, wastewater, and their analyses in the School of Public Health as a result of Dr. C.P. Straubs project A-038-Minn.

Additional Water Resources Related Staff Members Added:

Bradley Hansen - B.S. in Agricultural Engineering Technology. Junior Scientist position formerly was in waste management, now evenly divided between waste management and soil and water area. (A-043-Minn, D. Slack, Dept. of Agricultural Engineering).

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

None.

New Research and Training Facilities Other Than Research Equipment Items:

None.

Name of University: University of Minnesota, Minneapolis, MN.

A. Number of students receiving employment as research project or program assistants through the P.L. 88-379 program.

		Scientific Discipline of Student	Number
(1)	Undergraduates		
		Agricultural Engineering	2
		Chemistry	1
		Agronomy	1
		Physics	1
		Geology	3
		Plant Pathology	1
		Soil Science	2
(2)	Master's Students		
		Agricultural Engineering	6
		Geology	3
		Soil Science	2
		Civil Engineering	1
		Environmental Engineering	1
(3)	Doctoral Students		
		Agricultural Engineering	1
		Environmental Engineering	1
(4)	Postdoctoral Students		
		Computer Science	1
		Environmental Engineering	1

B. 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:	4	7	1	12
Federal Agencies	1	2		3
State & Local Agencies	1	3		4
University or College	2	1		3
Other - Including private enterprise		1	1	2
2. No. graduates returning to school for advanced degree	1	2	3	6
3. No. going into military service	1			1
4. No. unemployed or working in other fields				
5. No. status unknown				
6. Totals	6	9	4	19

C. Type of employment of those school year graduate 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:				
a. Primarily Research		1		1
b. Primarily Planning		1		1
c. Primarily Development	1			1
d. Primarily Operations				
e. Primarily Management				
f. Other or not known				
1B. State & Local Agencies:				
a. Primarily Research		1		1
b. Primarily Planning				
c. Primarily Development		1		2
d. Primarily Operations	1	1		1
e. Primarily Management				
f. Other or not known				
1C. University or College:				
a. Primarily Teaching				2
b. Primarily Research	2	1		1
c. Primarily Research & Teaching				
d. Other or not known				
1D. Other - Including Private Enterprise				
a. Primarily Research				
b. Primarily Planning		1	1	2
c. Primarily Development				
d. Primarily Operations				
e. Primarily Management				
f. Other or not known				
Totals	4	7	1	12

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

Research (1Aa, 1Ba, 1Cb, 1Cc & 1Da)	4
Planning (1Ab, 1Bb & 1Db)	2
Development (1Ac, 1Bc & 1Dc)	3
Operations (1Ad, 1Bd & 1Dd)	2
Management (1Ae, 1Be, & 1De)	1

PROJECT-RELATED REPORTS
PUBLISHED DURING FY 1979

Blake, G.R. Fifteenth Annual Report, Water Resources Research Center. Bulletin 101. Water Resources Research Center, University of Minnesota. October 1979.

Boyum, Kent W. A Comparative Water Quality Study of Man-Made Drainage Ditches and Natural Streams in South Central Minnesota, Thesis, M.A., Mankato State University, August 1980.

Conroy, L.E., W.J. Maier, and Y.T. Shih, edited by W.J. Cooper. Determination of Carbohydrates and Primary Amines in River Water, Presented at ACS Houston, March 1980 meeting and in press in "Chemistry in Water Reuse".

Convery, M.P. and Pfannkuch, H.O. Experimental Study of Hydrocarbon Retention Capacities in Synthetic Porous Media and Glacial Drift. Presented at: Symposium on Organic Contaminants in Croundwater, ACU, Fall meeting, December 6, 1979.

Easter, K.W. and J.J. Waelti. The Application of Project Analysis to Natural Resource Decisions. Bulletin 103, Water Resources Research Center, University of Minnesota. June 1980.

Geiser, Kurt, D.C. Slack, E.R. Allred and K. Stange. Irrigation Scheduling Using Crop Canopy - Air Temperature Difference, to be presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 1980.

McCahill, M., L.E. Conroy and W.J. Maier. I. Determination of Organically Combined Chlorine in High Molecular Weight Aquatic Organics; Environmental Science and Technology, 14:2, 201, 1980.

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Maier, W.J. and L.E. Conroy, Edited by W.J. Cooper. UV Multiwavelength Absorbance Measurements in Monitoring Trace Organics in Water. Presented at ACS Houston March 1980 meeting and in press in "Chemistry in Water Reuse".

Maier, W.J., L.E. Conroy, S.J. Eisenreich, M.R. Hoffmann, C.A. Macko and P.D. Nath. Edited by Albaiges, Barcelona, Spain. Multicomponent UV Spectral Analysis of Aquatic Organics. Proceedings Int. Congress on Analytical Techniques in Environmental Chemistry.

Martin, W. and M.J. Semmens, The Ion Exchange Behaviour of Cadmium on Clinoptilolite. Presented at an American Institute of Mining Engineers Conference, October 1979.

Moore, I.D., C.L. Larson and D.C. Slack. Predicting Infiltration and Micro-Relief Surface Storage for Cultivated Soils. Bulletin 102, Water Resources Research Center, University of Minnesota, June 1980.

Pelt, N. and W.J. Maier. The Use of TOC Measurements and UV Spectroscopy to Predict BOD Measurements in Primary and Secondary Effluents in Municipal Wastewater Plants; presented at 53rd Annual Central States Water Pollution Control Federation Meeting, Waukesha, Wisconsin, May 1980.

Pierce, C. and B. Thompson. A survey of water flow in public drainage ditches and streams in South Central Minnesota, paper presented and submitted at the Minnesota Academy of Science Meetings, April 25-26, 1980.

Semmens, M.J. Cadmium Removal by Clinoptilolite. Part 1. Column and Batch Studies. Submitted to Journal of Water Pollution Control Federation. 1980.

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Silis, Ainars Z. A Quantitative Geomorphological Study of Public Drainage Ditches in South Central Minnesota, Thesis, M.A., Mankato State University, December 1979.