BOOKS
PUBLICATIONS
PROJECT COMPLETION REPORTS
M.S. and Ph.D. THESES

research supported by

IOWA STATE WATER RESOURCES RESEARCH INSTITUTE

under the
WATER RESOURCES RESEARCH ACT of 1964
U. S. Public Law 88-379

U. S. DEPARTMENT OF THE INTERIOR
OFFICE OF WATER RESOURCES RESEARCH

IOWA STATE WATER RESOURCES RESEARCH INSTITUTE
IOWA STATE UNIVERSITY
AMES, IOWA 50010

JUNE 30, 1970

BOOKS

PUBLICATIONS

PROJECT COMPLETION REPORTS

M.S. AND PH.D. THESES

research supported by

IOWA STATE WATER RESOURCES RESEARCH INSTITUTE

under the

WATER RESOURCES RESEARCH ACT OF 1964

U.S. PUBLIC LAW 88-379

Don Kirkham, Director

Norris L. Powell, Administrative Assistant

to the Director

Iowa State Water Resources Research Institute (ISWRRI)

Iowa State University, 206 Agronomy Bldg.

Ames, Iowa 50010

June 30, 1970

FOREWORD

Books, publications, project completion reports and M.S. and Ph.D. theses listed relate to research program activities supported under Office of Water Resources Research (OWRR) annual allotments and matching grants to the Iowa State Water Resources Research Institute (ISWRRI).

Books are available from the publisher.

Reprints of publications are available from the author.

Project completion reports marked with an asterisk are available from the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Virginia 22151 at $3 per copy in paper or 65¢ in microfiche. When odering reports from CFSTI the PB number should be given to expedite the orders. Prepayment of all orders is required. Checks or money orders should be made payable to the Clearinghouse.

Information concerning project completion reports which are not marked with an asterisk should be requested from the authors.

Copies of Ph.D. theses are available from University Microfilms, A Xerox Company, 300 North Zeeb Road, Ann Arbor, Michigan 48106. A copy of each thesis (M.S. or Ph.D.) is available at the library of the sponsoring university.

Copies of the annual reports for fiscal years 1968, 1969, and 1970 are available from the Iowa State Water Resources Research Institute, 206 Agronomy Building, Iowa State University, Ames, Iowa 50010.

Questions concerning specific projects supported by ISWRRI should be directed to the principal investigators.

ISWRRI maintains one file copy of each book, publication, project completion report, and annual report.

BOOKS

Pierre, W. H., Don Kirkham, John Pesek and Robert Shaw (ed.)
1965. Plant environment and efficient water use. Book based on symposium held at Iowa State University, Nov. 30 and Dec. 1, 1965. American Society of Agronomy, Madison, Wisconsin. xii + 295 pages.

This book, published jointly by the American Society of Agronomy, Soil Science Society of America, and Iowa State University, presents the papers that were given at a symposium held at Ames, Iowa, on November 30 and December 1, 1965, on the general topic "Plant Environment and Efficient Water Use." The symposium was cosponsored by the Agricultural Experiment Station of Iowa State University, the National Plant Food Institute, the American Society of Agronomy, the Soil Science Society of America, and the Iowa State Water Resources Research Institute.

The purpose of the symposium was to bring together the most authoritative and significant research information on the important role of water in plant development and on ways for achieving more efficient use of water in crop production. The thirteen papers, which constitute the thirteen chapters in this book, were prepared by recognized leaders in interrelated fields, including climatology, plant physiology, plant nutrition, soil fertility, and soil and crop management. The topics covered are of wide diversity, ranging from basic consideration of such phenomena as energy conversion, transpiration control, water stress in plants, moisture movements to roots, and the adsorption of water and nutrient by plants to the problems of conserving rainfall by reducing runoff and of increasing water use efficiency through soil and crop management practices.

The chapters of the book are arranged in logical sequence. The first two chapters are somewhat general in nature and include a consideration of the distribution and variability of precipitation, soil moisture reservoir and moisture recharge, the U.S. water budget, and water use planning. The next seven chapters deal largely with basic information regarding plant-water and soil-plant-water relationships, including a detailed consideration of factors affecting evapotranspiration, plant response to water stress, root environment, moisture movement in soils, nutrient and water adsorption by plants and the interactions of water supply, soil fertility, and crop yields.

In chapters 10, 11, and 12 the authors discuss underlying principles and management practices involved in water conservation and in increasing water use efficiency through improved soil and crop management practices. Among the water conservation

measures discussed are those for controlling runoff, increasing infiltration, and reducing irrigation water losses. Emphasis is given to the large potentials for increasing water use efficiency through practices that increase crop yields per acre, such as the use of fertilizers, better crop varieties, and improved cultural practices.

In chapter 13 the authors discuss the importance of plant environment research and present in detail an example of the commercial utilization of climatological and soil moisture information in promoting more efficient crop production.

Willrich, T. L. and N. William Hines (ed.)
1967. Water pollution control and abatement. Book based on an Iowa Water Resources Pollution Control and Abatement Seminar held at Iowa State University, Ames, Iowa, November 9-11, 1965. Iowa State University Press. Ames, Iowa. xiii + 194 pages.

No more important single problem faces this country today than the problem of "good water." Water is our greatest single natural resource. The issue of pure water must be settled now for the benefit not only of this generation but for untold generations to come. The need for good quality water for all of our Nation's uses-public and private-is a paramount one.

So spoke the House Committee on Public Works in reporting on the federal Water Quality Act of 1965. The deep concern manifested by this pronouncement accurately reflects the current high level of public awareness and anxiety relating to the deplorable state of many of our waters. No longer is water pollution control a subject of interest only to public health officers and a few wildlife conservation enthusiasts; it has ascended to a position among the most prominent of current domestic issues.

Although recognition of water pollution as a problem of national concern is important to generation of the support essential to its solution, water pollution control is still primarily a local matter. If meaningful headway is to be made against water pollution, it must be accomplished at the state level. State and local regulatory agencies must police the quality of our waters, investigate complaints, create and apply the water quality standards, and, when necessary, enforce the penalties against violators.

Effective pollution control requires the coexistence of at least three factors: (1) a sincere state commitment to clean waters manifested in a workable regulatory scheme, (2) high levels of knowledge and dedication on the part of the state offi-

cials charged with administration of the control program, and (3) public understanding of the nature of the pollution problem and support for the control efforts.

In 1965 Iowa took a great stride in the direction of effective pollution control with the passage, by the Sixty-first General Assembly, of the Water Pollution Control Law and the subsequent creation of a new control commission. This new water pollution control scheme holds great promise for cleaning up Iowa's waters. The regulatory scheme is modern, the personnel charged with administration of the program are energetic public servants of the highest caliber, and the whole attitude of the state government toward pollution control appears more vigorous.

However, several of the important factors mentioned above cannot be built into a control program. The decisions of a control commission can be no sounder than the basic information and insights concerning water pollution upon which they act. Assuring that the decision makers have ready access to current knowledge in the many areas involved in pollution control decisions is a matter of extreme importance. Contained in the following pages are papers and comments prepared by some of the most learned men in their fields in the country. Here there will be found an unusually complete collection of the knowledge and views of scholars and practitioners in the fields most directly involved in water pollution control. In marshalling and making available the learning of specialists in these many areas, a conference such as the one reported in this book may make an invaluable contribution to the cause of water pollution control.

Another essential to an effective water pollution control program is an informed and sympathetic public. Even if the control commission is deliberately engaged in extensive public relations work, it is doubtful that it could achieve the same impact on the public mind and conscience as is worked by the cumulative effect of the papers published in this book. This conference and the publication of its proceedings should serve to stir the interest of Iowans in the protection of their precious water resources and thereby help mobilize public opinion to support the activities of the new control commission.

The three parts of this book are designed to overlap somewhat. It was hoped that this approach would insure reasonably full coverage of this multifaceted problem. Part I presents the pollution problem as seen through the specialized vision of four different disciplines: engineering, economics, law, and political science. Part II is concerned with the Iowa situation. Part III shifts the analysis from the various disciplines to the interest groups most often involved in conflicts over pollution issues: municipalities, industry, agriculture, and outdoor recreation.

The materials contained in this volume should be both informative and useful. However, this book is a mere scratch on the surface of the body of knowledge that will be required to cope adequately with the present and emerging problems of water pollution control. It is hoped the information and ideas contained herein will stimulate others to undertake research in this most vital and challenging field--water resources management.

Dougal, Merwin D. (ed.)
1969. Flood plain management Iowa's experience. Papers presented at the conference on Flood Plain Management, Sixth Water Resources Design Conference, Iowa State University. Iowa State University Press. Ames, Iowa. xxi + 270 pages.

The nation needs a broader and more unified national program for managing flood losses. Flood protection has been immensely helpful in many parts of the country--and must be continued. Beyond this, additional tools and integrated policies are required to promote sound and economic development of the flood plains.

The Task Force on Federal Flood Control Policy made this opening statement in its report to Congress in 1966. This call for a policy change followed 30 years of national effort in the construction of flood protection works designed specifically to reduce the nation's flood losses. For in the Flood Control Act of 1936 Congress launched its broad flood control program, relying primarily upon engineering works both in the tributary watersheds and in the large river valleys. However, the rapid urban expansion and more intensive agricultural practices which followed World War II expedited new flood plain development. Soon the leaders in the flood plain management movement recognized and publicized the nature of the losing battle. As rapidly as flood protection works alleviated the flood problem at one location, new developments elsewhere canceled the contemplated reduction in national flood losses.

Dr. Gilbert F. White, Department of Geography, University of Chicago, and his dedicated group of researchers gained national attention as they pursued the problems of increased urban occupancy of the flood plains. The Tennessee Valley Authority, through its local flood relations program led by James E. Goddard, pioneered a federal-state-local program of flood plain regulation in an area noted for its multipurpose water control dams and reservoirs. These early efforts encouraged Congress to review its construction program, and in 1960 a flood plain information program was initiated. But the increased pace of urbanization and lack of comprehensive flood plain planning led to the 1966 study and report. A more vital program is proposed which will involve all the disciplines--technical, socioeconomic, and legal--and

which concentrates on local government involvement, with state coordination and federal support.

Iowa is in a unique position which should permit it to move ahead rapidly with an expanded flood plain management program. Flood plain regulation was included in the organic act which in 1949 created the Iowa Natural Resources Council. The state regulatory role concerning flood plain development and construction has been strengthened by subsequent amendments and court rulings. More recent amendments in 1965 and 1967 further recognized the need and necessity of involving local planning and zoning agencies in the flood plain management program. Therefore, the state of Iowa today has provided adequate authority for achieving a sound program of flood plain management.

However, authority by itself does not accomplish results. Success of the Iowa flood plain management program depends upon three factors. First, technical coordination must be achieved not only across the local-state-federal hierarchy but also across the spectrum of disciplines involved--planners, engineers, attorneys, economists, educators, scientists, financing agencies, administrators, and public officials of the communities and counties in Iowa. Second, comprehensive planning of flood plains is a clear prerequisite to successful control and regulatory phases of flood plain management. The relatively non-urbanized and unoccupied lands in cities and in counties deserve immediate and rapid consideration; urban areas already developed present nonconforming use problems which will deserve detailed and concentrated attention. Third, local people must become involved in the planning process, and local acceptance of flood plain management including the regulation concept must be achieved. There is a great need for convincing property owners, developers, realtors, and public officials that flood plain management programs are of benefit to them as well as to the public. Community desire for guided growth should insist on such participation by those directly involved in flood plain development and use.

This seven-part volume brings together in one integrated text the available information concerning the many phases of flood plain management. Much more will be needed before the task is completed, but it is designed to show that methods are available for beginning positive programs today. Each of the chapters is devoted to a specific phase or aspect of the subject. In all, they cover the many problems which arise in enacting local action programs for achieving optimum and wise use of the flood plains.

Part I presents the philosophy and need for flood plain management and leaves little justification or reason for not accepting public regulatory measures.

Part II presents the physical flood problem and the future flood potential in Iowa. Recognition of the full potential is necessary in evaluating the hazard in Iowa communities.

Part III is devoted to the development of action programs for flood plain management; the various elements are listed and discussed.

Part IV deals with the planning role and its many facets. Included are concepts and methods, compatible land uses, regional and city planning and zoning coordination problems, federal assistance programs in planning and urban renewal, and open-space possibilities.

Part V presents the legal aspects of flood plain management. Included are Iowa programs in planning and zoning, state statutory control, model flood zoning regulations, subdivision regulations, and building code provisions.

Part VI is devoted to technical flood plain information studies upon which communities can base their planning and regulatory controls.

Part VII concludes the text with two reports on the success of management programs in other states.

The Appendix includes a list of all cities in Iowa and a preliminary evaluation of the flood problems and availability of information.

This volume provides an extensive inventory of the problems and potentialities encountered to date in flood plain management. Additional information and newer methods will be needed in the future to provide for stronger programs and to cope with problems which will surely emerge. Thus a challenge remains for continued research in this important area of water resources.

PUBLICATIONS

Willrich, T. L.
1966. Management of agricultural resources to minimize pollution of natural waters. Proceedings of the National Symposium on Quality Standards for Natural Waters: 303-314. (A-013-IA)

Potential water pollutants of major concern at the present time which may result from crop and livestock production include: (a) sediment; (b) pesticides; (c) inorganic dissolved solids, particularly total salt content and nitrogen; and (d) oxygen-demanding materials. Each is discussed and recommendations of good management practices to prevent water pollution by these are given.

Willrich, T. L.
1966. Water quality improvement program. Farmstead Water Qaulity Improvement Seminar (Conference Proceedings). P. 50. Published by Amer. Soc. Agri. Eng., St. Joseph, Mich. (A-013-IA)

Chronological development of the extension program in Iowa during the past ten years is given. The situation, problem, objectives and plan of work of water pollution control and sanitation (a community service program) are discussed.

Dougal, M. D. and E. R. Baumann.
1967. Mathematical models for expressing the biochemical oxygen demand in water quality studies. Proceedings of the Third Annual American Water Resources Conference, 242-253. (A-001-IA)

The development and application of the widely-used monomolecular model for biochemical oxygen demand (B.O.D.) is reviewed. Results of laboratory B.O.D. studies are used to reveal that the monomolecular model fails to satisfy its fundamental assumptions. Temporal variations in the rate constant and the ultimate B.O.D. value are explored for three types of wastes: (a) raw domestic sewage, (b) final effluents from various waste treatment processes, and (c) contents of an agricultural waste lagoon.

Two different mathematical models for B.O.D. are presented which statistically are superior to the monomolecular model. These models may be useful in future studies of stream water quality and in the determination of stream assimilative capacities.

Kirkham, Don.
1967. Explanation of paradoxes in Dupuit-Forchheimer seepage theory. Water Resources Research 3: 609-622. Also published in Engineering News 12: 22-39; Quarterly Journal of West Pakistan Engineering Congress, Lahore, Pakistan. (B-002-IA)

Cutting into a porous medium of a large number of vertical, parallel, infinitely permeable, equally spaced, infinitesimally thin slots produces a fictitious soil that follows exactly and without paradoxes Dupuit's assumptions and hence Dupuit-Forchheimer (D.F.) drainage theory in two dimensions. A soil having these infinitesimally thin slots is designated a D.F. soil. For this fictitious soil, a formula for the proper depth and spacing of ditches and drain tiles is derived. The formula is the same one found in conventional D.F. literature. The formula, valid for both tiles and ditches and known to hold approximately for actual soils, is exact for a D.F. soil. Dupuit's two-dimensional "parabolic seepage problem" and others may now be considered as exactly solvable for D.F. soils. For three-dimensional axially symmetric seepage flow, as into wells, the fictitious slots of a D.F. soil become concentric coaxial rings. D.F. streamlines are not horizontal; they converge in a special way. (Key words: Drainage; groundwater; seepage; hydraulics).

Kirkham, Don.
1967. Physical model for Dupuit-Forchheimer drainage theory. Proceedings of the International Soil Water Symposium (Prague, Czechoslavakia), Vol 2: 385-395. (B-002-IA)

The cutting into a soil of a large number of vertical, infinitely permeable, infinitesimally thin slots produces a fictitious soil that follows exactly Dupuit's assumptions and hence Dupuit-Forchheimer (D.F.) drainage theory. A soil having these infinitesimally thin slots is designated a "D.F. soil." The land drainage problem of the proper depth and spacing of ditches or of drain tiles in soil over a barrier is solved for a D.F. soil with the result

$$S^2 = 4(b^2 - a^2)/(R/k)$$

in which R = rainfall rate or rate of excess irrigation water to be drained, k = soil hydraulic conductivity, b = maximum height above the barrier of the water table, a = height above the barrier of the water in the drains and S = drain spacing. The formula is valid for both tiles and ditches and is known in Holland and the U. S. A., etc. to hold, approximately, for actual soils. The formula is exact for a D. F. soil. Dupuit's "parabolic seepage problem" and others, may also be solved exactly for D. F. soils.

Kirkham, Don, D. E. Rolston, and D. D. Fritton.
1967. Gamma-radiation detection of water content in two-dimensional evaporation prevention experiments. Isotopes and Radiation Techniques in Soil Physics and Irrigation Studies, 1: 3-16. Published by International Atomic Energy Agency, Vienna, Austria. (A-003-IA)

A ^{137}Cs gamma scintillation detector system (gamma apparatus) was used to measure water contents in a two-dimensional soil model. The gamma apparatus was built into a lifting apparatus, which accommodates both vertical and horizontal 150-cm-long columns and 150-x35-cm two-dimensional soil models. The lifting apparatus was constructed by using a vertical rectangular frame with internal dimensions of 80-cm width and 70-cm height. Lead cubes, 25 cm on a side, containing a 251-mCi ^{137}Cs source and a NaI scintillation detector are offset to one side of the vertical rectangular frame in order to scan a vertical cylindrical column. The faces of the lead cubes are 24 cm apart and attached to the rectangular frame so that the gamma beam is midway between the base and top. There are no attachment parts that cross the 24-cm gap between the lead cubes, and this leaves a 24-cm-wide by 70-cm-high space that will allow a two-dimensional model or horizontal column to be moved horizontally through this space. Vertical movement of the gamma apparatus and horizontal movement of the model then allow two-dimensional scanning of a model. To demonstrate the ability of this design for a gamma apparatus to scan two dimensions, a 92-cm-long, 30-cm-tall, and 10.15 $\pm$ 0.05-cm-wide model with three equal 30-cm-long compartments was used to evaluate potential water conservation. A vertical sand mulch, 2 cm thick, was placed on each side of each compartment, a 3-cm-thick sand layer was placed on the bottom, and soil was packed in the rest of the model. The surface treatments were: bare soil, 1 cm soil over 1 cm of sand mulch, and 1 cm of sand mulch. Water contents in two dimensions were determined for 2-cm simulated rainfall applications for the three treatments. When a subsurface-sand mulch was used, the mulch acted as a barrier to infiltration. Therefore, the surface-sand mulch conserved more water than did the subsurface-sand mulch, but both the surface and the subsurface sand mulches conserved water as compared with no sand mulch layers.

In addition, soil columns, 6.9 cm in diam. and 33 cm tall, were used to study the effectiveness of various thicknesses of surface-sand mulches in preventing evaporation. Thickness of sand mulches did not greatly influence the amount of water conserved if the sand layer was 1 cm or more thick.

Merritt, C. A., D. B. McDonald and W. L. Paulson.
1968. The effect of photosynthesis on the oxygen balance in a midwestern

stream. Proc. of the 23rd Industrial Waste Conference, May 7-9, 1968. pp. 1089-1102. (A-016-IA)

Photosynthesis is a contributing factor to the oxygen resource in the Iowa River. This is evidenced by the relationship between plankton counts versus DO levels in the river, by the observed diurnal oxygen curves and by the light and dark bottle test results.

Its relative importance in this basin appears significant since photosynthetic oxygen production exceeds total respiration by almost two times. The photosynthetic production and respiration values presented when compared to those of the other studies appear relatively low. This is probably due to the low respiration levels and the small photosynthetic base of the Iowa River. Other streams researched had high respiration levels due to heavy organic loadings and high photosynthetic rates due to rooted aquatic plants and attached and benthic algae. However, the relative significance of the oxygen factors are comparable to other studies.

When evaluating the oxygen resource of a stream, photosynthesis must be considered although its reliability may be variable. This is especially true in a stream such as the Iowa River where the bulk of the photosynthesis is due to planktonic algae whose numbers may show a wide variation. In the present study plankton counts were less than 500 organisms/ml 23 percent of the time in the river above the impoundment and 13 percent of the time below the reservoir. However, whether or not the photosynthetic effect can be relied upon quantitatively, it remains an important factor of the oxygen balance in streams.

O'Loughlin, Emmett M. and David Squarer.
1967. Areal variations of bed-form characteristics in meandering streams. Twelfth Congress of the International Association for Hydraulic Research, 2: 118-127. (A-015-IA)

The reliability of expressions for resistance coefficients and sediment discharge in alluvial channels is open to question when they are applied to sinuous channels because no account is taken of the distorted channel section and the secondary currents induced by channel curvature. Bed-form geometry is related in a fundamental way to resistance and sediment discharge, and it is shown in this paper that channel curvature results in significant variations in bed-form geometry.

Following a procedure similar to that described by Nordin and Algert, autocovariance and spectral density functions of a process defined by the bed elevation as a function of the dis-

tance along the channel are computed in several zones in a laboratory model of an alluvial channel having an equilibrium bed configuration. These data are compared with other data of the same type obtained with nominally identical flow conditions (same mean depth and mean velocity) and bed material in a straight flume.

Details of spectrum computations are discussed in terms of the length of record and the variability of the estimated spectral density.

Stationarity requirements indicate that future analyses should probably be made in the time domain, and in such cases the possibility of relating time and space spectra needs close examination.

Powers, W. L., Don Kirkham, and G. Snowden.
1967. Seepage of steady rainfall through soil into ditches of unequal water level heights. Soil Sci. Soc. of Amer. Proc. 31: 301-312. (A-003-IA)

A theoretical solution and numerical results for the seepage of steady rainfall into soil laying above an impermeable layer and drained by ditches of unequal water level heights is obtained for the ditches just reaching or penetrating into the impermeable layer. This is done by using a finite series of orthonormal functions generated from products of trigonometric and hyperbolic functions. The theoretical solution gives the potential function and stream function for a range of water level heights, ditch spacings, and a range of ratios R/K of rainfall rate R to hydraulic conductivity K. If R/K is increased from 0 to 0.05, for 10-cm spacing of ditches and for 1 ditch having water maintained 1 m above the barrier and the other ditch 1.5 m; then the maximum water table height in the soil will increase from 1.50 m to 1.82 m. Also, as R/K increases, the position of the maximum water table hieght will approach a position midway between the ditches. Flow nets and other results computed for a number of geometries from the theory bring out additional information.

Powers, W. L., Don Kirkham and G. Snowden.
1967. Orthonormal function tables and the seepage of steady rain through soil bedding. J. of Geophysical Research 72: 6625-6637. (B-002-IA)

Tables of functions are developed for generating, with the aid of a digital computer, sets of general orthonormal functions useful in solving some potential flow problems. As an example of the use of the tables, a flow problem of seepage of ground water through soil bedding (which is a series of formed

parallel mounds and depressions used in land drainage design when soil overlies an impermeable layer) is solved. Flow nets are presented for a number of geometries for the bedding problem. It is noted that the bedding problem corresponds to the problem of seepage of ground water into a shallow river between sloping hillsides when horizontal bedrock underlies the river valley.

Schmidt, Donald J. and Everett Fee.
1967. Planktonic diatoms from the Coralville Reservoir. Iowa Academy of Science 74: 17-19. (A-008-IA)

A list of sixty-two planktonic diatom species is presented. These diatoms were collected from the Coralville Reservoir, a variable level flood control reservoir, located in east central Iowa. The collections were made during a sixteen-month, ecological study conducted during 1965 and 1966.

Asseed, M. and Don Kirkham.
1968. Advance of irrigation water on the soil surface in relation to soil infiltration rate: a mathematical and laboratory model study. Ia. Ag. Exp. Sta. Research Bul. #565, Iowa State Univ., Ames, Iowa. (A-003-IA)

Mathematical equations describing the horizontal advance of an irrigation stream on a soil surface are derived and discussed for different types of infiltration equations corresponding to different known field conditions. Complex variable theory is applied to transform certain complicated forms of infiltration equation solutions to algebraic forms. An irrigation model having a visible plexiglas photographic front was constructed and operated to test the theory and obtain data not covered by the theory. Glass beads or soil aggregates constitute the porous medium; water is used as the seepage fluid. Potassium dichromate dye is injected into the porous medium to trace the direction and velocity of the stream lines when the water moves within the body of the porous medium. The model data are recorded by photography and show a good agreement between theory and experiment for both the calculated position of the "irrigation" front on the porous media and the "wetted" front below the surface. Comparisons were made between experimental data and theory for two slopes of land, for five porous media, for two irrigation rates, and for two surface conditions, rough and smooth. Dimensionless functions are developed to present the model data.

Blair, David.
1968. Model flood plain regulations for Iowa - a progress report. p. 167-182. In M. D. Dougal (ed.) Flood plain management, Iowa's experience. Iowa State University Press, Ames, Iowa. (A-019-IA)

This article reviews and reports briefly on the legal and administrative problems and prospects of flood plain regulation. This will provide the flood plain planner and/or manager with a good idea of the law concerning flood plain regulation.

Dodd, John D., Ruth M. Webster, Gary Collins and Larry Wehr.
1968. A consideration of pollen, diatoms and other remains in post-glacial sediments. Iowa Academy of Science 75: 197-209. (A-008-IA)

The significance of pollen and diatoms in post-glacial sediments from a shallow bay of Lake Okoboji, Iowa, is considered. The presence of other microfossils is noted with emphasis on those of Cretaceous origin: foraminifera, coccoliths, radiolarians, and hystrichosphacrids. Problems encountered and discussed include recognition of Chrysophyte statospores, redeposition, interpretation of data from lower levels, and reliability of radiocarbon dates applied to organic matter from aquatic vegetation.

Kirkham, Don.
1968. Reply. Water Resources Research 4: 221-222. (B-002-IA)

Reply of the author to a note by E. C. Childs and E. G. Youngs on the paper "Explanation of paradoxes in Dupuit-Forchheimer seepage theory" published in Water Resources Research 3: 609-622.

Lenning, Richard E.
1968. Waterfowl populations and recreational use patterns in the proposed Saylorville Reservoir as related to pre-impoundment conditions. Iowa Coop. Wildl. Res. Unit Quart. Report 33(4): 10-12; 34(1): 21-24; 34(2): 10-13; 34(3): 3-8. (A-023-IA)

These articles report progress on project A-023-IA of the Iowa State Water Resources Research Institute.

Lofgreen, Harold A. Jr. and Jerald R. Barnard.
1968. Economics of water quality: an application to the Des Moines River Basin. Iowa Business Digest, 40(1): 3-11. (A-018-IA)

The need for an effective program for water quality control is becoming increasingly evident. This article examines some possible alternatives for water quality control in light of costs and water quality requirements.

Selim, H. M. and Don Kirkham.
1968. Temperatures and moisture changes under evaporation in laboratory soil profiles as influenced by cracks. Agro. Abstract p. 78. (A-003-IA)

A model was built to study the influence of soil shrinkage cracks on heat and moisture redistribution in three soils subject to wind and radiation evaporation under controlled laboratory conditions. The model consisted of three identical compartments each 30 cm long, 30 cm deep and 10.14 cm wide. Vertical cracks of 30 cm in depth were formed by placing a plexiglas strip at the middle of each compartment before soil was added. The plexiglas strips were removed after one day of evaporation, leaving a crack width of zero, 0.64, and 1.91 cm.

In each compartment temperatures were measured at 36 locations using thermocouples, and moisture contents were measured at 52 positions using gamma radiation at times of 1, 4, 8, 12, and 20 days. With zero crack width, the two-dimensional model behaved as a one-dimensional column. With 0.64 and 1.91 cm crack width, decreased temperatures and moisture contents occurred near the crack surfaces for both wind and radiation treatments as compared to the zero crack width. In the radiation treatment for 0.64 and 1.91 cm crack widths, the moisture content was lower by about 5-10% throughout the soil as compared to the zero crack width.

Sendlein, Lyle V. A.
1968. Seismic refraction and electrical resistivity: tools in groundwater exploration. Trans. Am. Soc. Agr. Engr. 11: 890-892. (A-012-IA)

The coordinated use of geophysics and geology applied to groundwater problems helps provide maximum geologic information from a minimum investment. The reliability of the study depends on data density, which is related to the amount of money invested in the study. A coordinated approach will also supply more information per dollar invested than a study composed of bore-hole information alone. It should also be added that application of geophysical methods without additional geologic information reduces the level of reliability of geophysical data.

Sohn, Arnold J.
1968. Time lapse movie camera for recording recreation activity. Iowa Academy of Science 75: 184-189. (A-005-IA)

An 8-mm time-lapse movie camera was developed to secure data on daily, weekly and seasonal cycles and fluctuations in

recreational activity on selected Iowa lakes. The unit was self-contained in a waterproof and dustproof aluminum box and functioned automatically for 12 days on a single 50-foot roll of super 8 mm. Kodachrome film. Data were obtained on use cycles by boaters, water skiers, fishermen and swimmers. The most satisfactory data were obtained when the zoom lens of the camera was set at full telephoto (focal length of 35 mm) and positioned to cover rather small, but popular, use areas for the various recreational activities. Counting and identification of boats was much easier under these conditions than when the camera was set at a wide angle setting (11 mm).

Timmons, J. F. and Merwin D. Dougal.
1968. Economics of water quality management. International Conference on Water for Peace Proceedings 6: 667-678. U.S. Government Printing Office, Washington, D. C. (A-001-IA)

The major propose of this paper is to identify and articulate water quality problems. This is accomplished within an economic framework which has as two primary objectives, first, maximizing the satisfaction of human wants from the use of water including the waste water phase and, second, minimizing the costs of producing these satisfactions, considering both the direct as well as derived demands for water including the goods and services water helps produce. A second purpose is to formulate an economic framework within which water quality problems may be analyzed in full perspective of the difficulties which are encountered in reaching optimum solutions.

Tsao, G. T.
1968. Simultaneous gas-liquid interfacial oxygen absorption and biochecmial oxidation. Biotechnology and Bioengineering 10: 765-785. (A-032-IA)

Two experimental methods were used in measureing oxygen-transfer rates. The results indicate that two possible mechanisms are operating in simultaneous gas-liquid interfacial oxygen absorption and biochemical oxidation. One of the mechanisms, the direct absorption mechanism, has not been much studied in bioengineering. Mathematical equations are derived to describe the simultaneous mechanisms.

Vreeken, W. J.
1968. Stratigraphy, sedimentology, and moisture contents in a small loess watershed in Tama County, Iowa. Iowa Acad. Sci. Proc. 75: 225-233. (A-014-IA)

A traverse across a small first-order watershed in loess has been studied. The loess is Wisconsin in age and has a vertical tripartition that can be explained on a regional basis.

Clear stratification is present in the middle loess increment. Moisture distribution patterns correlate highly with differences in particle-size distribution. The explanatory physical phenomena must be moisture-tension relationships.

Johnson, H. P., K. E. Saxton and D. W. DeBoer.
1969. The effect of man on water yield, peak runoff and sedimentation. Iowa Academy of Science 76: 153-166. (A-024-IA)

Man can alter several facets of the hydrologic cycle appreciably. Those facets most easily altered are related to vegetative cover and surface geometry either on the land or in the drainage system. Changes brought about by man affect surface runoff and base flow, timing and peak discharges of flood flows, and water yields. Cover changes and more efficient drainage systems increase sediment delivery to streams. This paper attempts to define evidence of changes, and to comment on our present understanding of the extent of changes.

Kirkham, Don and H. Bakr.
1969. Some recent research on land drainage. Symposium on the Reclamation of Sodic and Soda-Saline Soils, Yerevan. p. 295-306. Agrokemia es Talajton Tom. 18. (1969) Supplementum. Budapest.

Some recent theoretical and laboratory research at Iowa State University, Ames, Iowa, U.S.A. is reported under the headings: (1) removal of sodium salts from soil by different methods of application of water, (2) drainage of stratified soils, (3) drainage of land underlain by an artesian aquifer, (4) improvements in the theory of the piezometer method for assessing soil drainability, and (5) depth of moisture penetration in soil due to irrigation water advancing over the soil surface. Some studies not included under these headings are referred to in a literature list separate from that of the five subjects.

McDonald, D. B., N. B. Fisher and K. R. Long.
1969. Causes and significance of taste and odors in Iowa City Water. Journal of Iowa Medical Society 59: 414-416. (A-028-IA)

This paper presents the results of investigations conducted in an effort to determine the factors contributing to the high chlorine demand and the reduced water quality of water taken from the Iowa River for use by Iowa City and the University of Iowa.

Mitzner, L. R. and D. B. McDonald.
1969. The effects of sedimentation on the water quality of the Coralville Reservoir. Iowa Academy of Science 76: 173-179. (A-028-IA)

The Coralville Reservoir is a flood control impoundment located on the Iowa River just upstream from Iowa City. Since being placed in operation in 1958 its capacity at conservation pool level has been reduced nearly 20% by sedimentation. Studies of the reservoir's fishery have been conducted since 1961. Fish population surveys do not indicate a noticeable modification of the fish population due to siltation. A decrease in the total fish population, primarily sport fish, occurring early in 1965, was due to oxygen depletion caused by heavy farm land runoff.

Limnological studies of the Iowa River and the reservoir have been in progress since 1964. These indicate that gradual increases in plankton populations and threshold odor values have occurred in the reservoir and the river below the impoundment. Studies of the biological productivity of the reservoir indicate that maximum production frequently accompanies increased water level and inundation of littoral areas. Thus, increasing reservoir conservation pool level to compensate for loss of capacity due to sedimentation could contribute to water quality problems due to eutrophication.

Ritter, W. F. and C. E. Beer.
1969. Yield reduction by controlled flooding of corn. Trans. Am. Soc. Ag. Engineers. 12: 46-50. (A-002-IA)

This paper reports the results of an experiment conducted at Iowa State University to evaluate flood damages to corn that was in-undated for variable periods of time at different stages of growth.

Tsao, G. T.
1969. Simultaneous gas-liquid interfacial mass transfer and uptake by small particles. Biotech. & Bioeng. 11: 1071-1087. (A-032-IA)

The presence of active small particles, such as bacterial cells, in a liquid will affect the rate of gas-liquid interfacial mass transfer. A theoretical analysis of the situation is presented in this article.

Fritton, D. D.
1970. Resolving time, mass absorption coefficient and water content with gamma-ray attenuation. Soil Sci. Soc. of Amer. Proc. 33: 651-655. (A-026-IA)

A method is described that was used to experimentally determine an intensity correction for gamma-ray attenuation. The correction is determined by using the minute nonlinearity of a semi-log plot of gamma-ray intensity versus the thickness or the product of thickness and density of a material. The experimentally determined correction is expressed in terms of resolving time and varied with both material and counting rate. A correction of 5.0 μsec/count was determined experimentally as the best resolving time to correct the observed counting rates for water content determination. Part of the 5.0 μsec/count correction was evidently due to causes other than resolving time. Mass absorption coefficients of water and soil were 0.08105 and 0.07309 cm^2/g, respectively, with no correction and were 0.0871 and 0.0773 cm^2/g with a 5.0 μsec/count correction. The difference between gravimetric water content and gamma-ray water content dropped from 3.02% to 0.60% when this correction was used.

Fritton, D. D., Don Kirkham and R. H. Shaw.
1970. Soil water evaporation, isothermal diffusion, and heat and moisture transfer. Soil Sci. Soc. of Amer. Proc. 34: 183-189. (A-026-IA)

Temperature and moisture distribution data were taken for a 9- by 11- by 20-cm soil column where wind was the evaporation agent and for a similar soil column where radiation was the evaporation agent. A Webster silty clay loam soil characterized by a soil water retention curve and an inflow diffusivity versus moisture content curve was used in the experiments. The experimental results were compared with results calculated from a solution of the diffusion equation normally used to describe isothermal movement of soil water and from a heat and mass transfer solution which accounted for temperature effects. It was found that the isothermal diffusion equation would describe the cumulative evaporation for the wind and for the radiation treatments. The isothermal diffusion equation did not predict the formation of a surface layer of dry soil, and thus, did not describe the moisture distributions for the radiation treatment for times greater than 20 hrs. or for the wind treatment for times greater than 200 hrs. A heat and mass transfer equation did predict the development of a dry surface layer and did describe the moisture distribution where temperature gradients were important.

Kirkham, Don.
1970. The importance of water resources research. p. 159-175. In P. J. Horick (ed.) Water Resources of Iowa. Iowa Academy of Science, Inc., Cedar Falls, Iowa. (B-002-IA)

This paper gives a list of 141 areas of research that are important to Iowa. These areas of research were suggested to the Iowa State Water Resources Research Institute (ISWRRI) by the ISWRRI Advisory Board in 1966, 1967 and 1968.

Selim, H. M. and Don Kirkham.
1970. Soil temperature and water content changes during drying as influenced by cracks: a laboratory experiment. Soil Sci. Soc. of Amer. Proc. 34: 565-569. (A-026-IA)

A container consisting of three identical compartments each 30 cm long, 30 cm deep, and 10 cm wide, was used to study the influence of artificial soil shrinkage cracks on heat and water content redistribution in three soil materials subjected to wind or radiative drying of 1.18 and 2.54 cm of water per 24 hours evaporation potential, respectively. Three crack widths were used, 0, 0.64 and 1.91 cm. Moisture content and temperature distributions were measured with time up to 12 days. The cracks decreased water content as much as 5 to 10% by volume. Evaporation through crack walls caused lateral movement of water for a distance of 4 to 5 cm from the wall of a 0.64 cm crack after 12 days of radiative drying. These distances were greater up to 14 cm (for the sand). Under wind, distances of lateral movement of water were about 5 cm, for all drying times. For all three soils with cracks, after 4 days of wind drying, soil temperature was cooler (1^{o} to 2^{o} C lower) than for the soils with no cracks. Under radiation all three soils were warmer (5^{o} to 10^{o} C higher) than soils with no cracks, after 4 days. In general, shrinkage cracks increased evaporation from bare soil 12-16% with cracks 0.64 cm wide and about 30% with cracks 1.91 cm wide as compared to evaporation from soils with no cracks.

Additional key words for indexing: unsaturated water flow, soil temperature, lateral water movement, soil shrinkage cracks.

Selim, H. M., Don Kirkham and M. Amemiya.
1970. A comparison of two methods for determining soil water diffusivity. Soil Sci. Soc. of Amer. Proc. 34: 14-18. (A-026-IA)

Two methods were used concurrently to determine the soil water diffusivity from horizontal infiltration of water into a soil column. In the first (recent), water content measurements were taken at a fixed position as a function of time by using the gamma attenuation technique. In the second, water content distance distributions were determined as a function of distances from the water source at a fixed time by sectioning the same column. A comparison by the two methods of the diffusivity function for three soil materials showed that the first method is as reliable as the second. Agreement of the diffusivities obtained from the two methods is considered evidence of the validity of the unsaturated water flow equation.

Squarer, David.
1970. Friction factors and bed forms in fluvial channels. Journal of the Hydraulics Division, ASCE 96: 995-1017. (A-029-IA)

Bed-form geometry in a curved channel and a straight flume which are subject to the same nominal flow conditions is investigated by statistical analysis of records of stream bed profiles. A quantitative comparison between bed geometry in curved and straight channels is made in terms of the auto-correlation, spectral density and probability density function of a process defined by the bed elevation. The same statistical functions are used to evaluate the bed-friction factor and ripple celerities. It has been found from experiments that the total rate of sediment transport in the curved channel is approximately 15 times as much as that of a straight flume which is subject to nominally identical flow conditions.

Timmons, John F.
1970. Some economic considerations in planning for Iowa's future needs for water. pp. 142-157. In P. J. Horick (ed.) Water resources of Iowa. Iowa Academy of Science, Inc., Cedar Falls, Iowa. (A-036-IA)

The purpose of this paper is to explore some of the major economic considerations which appear essential in the planning process for meeting Iowa's future water needs.

This purpose presents three major questions (1) how can Iowa gain access to sufficient water supplies to meet its growing needs in the years ahead (2) how may water be allocated among competing uses and users in a manner that will facilitate rather than obstruct a growing economy within the state in the years ahead and (3) how may these development, allocation and use processes be managed through decision making and decision implementation?

In formulating possible answers to the above questions the remarks are organized under the following headings: (1) projecting demands and supplies of waters, (2) allocating water among competing uses, and (3) organizing water use and development management entities.

Planning is considered an intermediate but conjoint step between research and action. Research is necessary to yield data and ideas for planning. And planning in using these data and ideas is basic to action in ameliorating the state's water problems.

Tsao, George T.
1970. Oxygen absorption in microbiological systems of zero order reaction rate. Biotechnology and Bioengineering 12: 51-61.

A model of oxygen absorption in microbiological systems of zero order reaction rate is proposed. The partial differential equation was solved to predict the profile of the oxygen concentration boundary layer next to a gas-liquid interface. Generally speaking, the presence of microbial cells always helps to increase the oxygen absorption rate over that of physical absorption. Only when the microbiological reaction is slow as judged by the fact that the reaction time, t_r, is much larger than the diffusion time, t_p, can one rightfully approximate the oxygen absorption in microbiological suspensions by physical absorption.

PROJECT COMPLETION REPORTS

*A-001-IA.
Dougal, Merwin D., E. Robert Baumann and John F. Timmons.
1970. Physical and economic factors associated with the establishment of stream water quality standards. Iowa State University, Engineering Research Institute, Completion Report, ISU-ERI-Ames 64000, Vol. I. 343 p.
Available from CFSTI as PB 191 167

A comprehensive study is reported of water pollution control and stream water quality as they relate to the establishment of stream and effluent standards. The ability of Iowa streams to assimilate organic wastes was determined on a state-wide basis, with three hydrologic-water quality regions being identified: Ideal, Good, and Poor. Quantitative values were assigned for low flow discharges in each region. The preliminary results indicate that the BOD loading in the streams must be limited to 10-15 mg/l to maintain the established dissolved oxygen standard of 4 mg/l. The physical characteristics of effluents from typical waste treatment processes were determined and related to mathematical models for BOD progression. A more refined BOD model was developed. A case study of the Skunk River at Ames revealed the nature of the response of an Iowa stream to discharge of effluents from a water pollution control plant. A digital computer model was developed for simulating, verifying and forecasting stream water quality. The results indicate three major factors influence stream quality; oxidation of the carbonaceous organic wastes contained in effluents, nitrification of nitrogenous compounds, and the effect of nutrient levels in causing a substantial algal response. The economic value of water pollution control was evaluated for the City of Ames. Present annual expenditures will double or triple in the future depending on the desired level of stream water quality. (Key words: Economics, mathematical models path of pullutants, waste assimilative capacity, water quality, water pollution biochemical oxygen demand, computers, dissolved oxygen, quality standards, rivers, sewage treatment, simulation, streams).

A-002-IA.
Beer, Craig E.
1968. Evaluation of flood damage to corn from controlled depth and frequency of flooding. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 12 p.

The controlled flooding experiment was conducted during the summers of 1966, 1967, and 1968 on Colo soil, a floodplain soil with a permeable subsoil.

In 1966, corn was inundated for 24, 48, and 72 hours, with approximately 6 inches of water. The first flooding treatment was applied when the corn was about 6 inches high. Other treatments were applied when the corn was 30 inches high and when the corn was in the silking stage.

In 1967, the flooding periods were changed to 48, 72, and 96 hours.

Two different levels of nitrogen fertility were used on the plots. The high-nitrogen plots received 350 pounds per acre of nitrogen, and the lower fertility plots received 50 pounds of nitrogen per acre.

A-003-IA.
Kirkham, Don.
1968. Moisture movement to vertical sinks in water unsaturated soil. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 12 p.

In laboratory containers containing soil with artificial cracks, and subjected to either wind evaporation or radiation evaporation, it was found that wind energy dries the soil faster and cools the soil faster than does an equal amount of radiation energy; also, the wider the cracks, the faster the cooling and drying; also cracks in soils containing much sand result in faster drying than do cracks in soil with little sand. [Selim and Kirkham, 1970 of Publication List]. In other laboratory soil containers to which irrigation flooding water was applied at one end, the vertical penetration of water and advance of wetted front agreed well with theory developed for the problem. [Asseed and Kirkham, 1968 of Publication List]. In measuring soil moisture content with gamma ray apparatus, dead time of the ray counter, when not taken into account gave errors of 2.4 moisture percentage points; a dead time correction was worked out. [Fritton, 1969 of Publication List].

A-004-IA.
Howe, J. W.
1968. Recession characteristics of Iowa Streams. The University of Iowa, Iowa State Water Resources Research Institute, Completion Report. 32 p.
(Obtainable from the Department of Publications, The University of Iowa, Iowa City, Iowa -- $1.00)

The behavior of Iowa streams in low-water periods during the crop-growing season, May to September inclusive, is herein determined. The flow records in all such periods of ten days or more

in length were first analyzed to determine the recession constants. The results of this part of the investigation are shown on a map of the state and indicate a considerable uniformity of behavior during each of the summer months. In the second part, the flow at the beginning of the periods was related to the area and soil permeability of the drainage basin and to the antecedent temperature and precipitation by means of correlation techniques.

A-005-IA.
Haugen, Arnold O. and Arnold J. Sohn.
1968. Competitive recreational uses of selected Iowa lakes. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 173 p. Available from CFSTI.

A study to determine cycles and fluctuations in recreational activity was conducted during 1966 and 1967 on Clear, Spirit, Okoboji, and Little Wall lakes. Major emphasis was placed on summer activities, with checks of waterfowl hunting intensities on Eagle Lake and Ventura Marsh conducted during the fall hunting seasons. In addition to describing activity cycles, an attempt was made to analyze areas of present or future conflict between users. Primary sources of data included: Time-lapse movie camera records as indices to activity cycles; questionnaires to short-term visitors and permanent residents on the lakes; pneumatic car-counter records at park entrances and boat-launching ramps; line intercept counts of boat traffic; counts and location plottings of boats on the lakes; and interviews with lake personnel including Water Safety Patrol officials, resort operators, and other businessmen located near the lakes.

A-006-IA.
Salisbury, Neil E., James C. Knox and Richard A. Stephenson.
1968. The valleys of Iowa -1: valley width and stream discharge relationships in the major streams. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 107 p.
(Obtainable from the Department of Geography, The University of Iowa, Iowa City, Iowa -- $3.00).

This study examined the relationship between valley bottom width and stream discharge, particularly as revealed in the changes in width over distance, or the distance decline relationship. It is a general study of spatial relations between valley form and stream discharge, and does not purport to describe the physical geography of each basin or valley.

A-007-IA.
Johnson, R. L. and Owen Sletten.
1968. Collection, characterization, and study of biodegradability and chemical oxidation of carbon-absorbed materials from effluents from sewage treatment plants. Iowa State University, Engineering Research Institute, Final Report ERI-369. 96 p.

Organic materials found in sewage treatment plant effluents were adsorbed on activated carbon filters. The adsorbed material, after solution and concentration from the activated carbon, was fractionated according to solubility. Attempts were made to identify and characterize the organic materials, but the task was almost impossible. Most fractions were capable of further biodegradation as well as chemical oxidation when in the more concentrated form. A new tertiary or secondary biological treatment process of Pulsating Adsorption Beds (PAB) was developed using the adsorption phenomena as a concentration effect to enhance biodegradability. The process showed removals of 80 to 90% of the soluble organic carbon in a synthetic sewage at 125 million gallons per acre per day hydraulic loading and 265 pounds BOD per thousand cubic foot per day organic loading. (Key words: adsorption, biological treatment effluents, similitude).

A-008-IA.
Dodd, John D.
1968. Pollen and diatoms in sediments of a Post-Pleistocene Lake. Iowa State University, Iowa State Water Resources Research Institute, Project Report. 16 p.

This project supported initial phases of a three part analysis of post-pleistocene sediments in a 35 foot core from Little Miller's Bay of Lake Okoboji, Iowa. During this time the core samples were obtained and determination of organic matter percentages at one foot intervals was completed. Also, preparation of materials for diatom and pollen analyses was begun. Completion of this investigation is a long time undertaking being supported by other funds and is scheduled for completion in 1968.

A-009-IA.
Landers, R. Q. and D. R. Sanders.
1968. Preimpoundment survey of vegetation of Saylorville Dam inpoundment area. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 2 p.

Four sites were selected in the area of the Saylorville Reservoir to describe the vegetation prior to impoundment. The complex forest pattern prevented a suitable analysis in the time allotted; therefore, the data were used in obtaining other funds to continue this study. (Keywords: vegetation, Saylorville, preimpoundment, forest, survey.) (See project B-006-IA)

A-010-IA.
Campbell, Charles, N. William Hines and Marshall Harris.
1965. Legal aspects of the small watershed program in Iowa. The University of Iowa, College of Law, Monograph No. 6. 45p.

The Watershed Protection and Flood Prevention Act P.L. 566, passed by the 83rd Congress in 1954, provides for a "partnership" among the federal government, state government, local communities, and individuals to deal with local water resource problems. The original purpose of the Act was to carry out works of improvement pertaining to soil and water conservation and flood prevention. However, the scope of the Act has been greatly expanded and now includes provisions dealing with nearly the total spectrum of water resource problems; for example, creation of new sources for municipal water supplies and development of recreational areas are now within the purview of the Act.

In view of the scope of the problems covered by the Act, and the importance of these problems to both rural and urban Iowans, Iowa attorneys and others who guide community decisions in these matters should have some awareness of the provisions of the Act and the ways in which it may be utilized. It is the purpose of this monograph to create such an awareness and in addition to provide sufficient detail concerning the operation of the small Watershed Program to reasonably inform the interested reader.

A-011-IA.
Oulman, Charles S. and Lyle V.A. Sendlein.
1968. The movement of radionuclides through soil formations. Iowa State University, Engineering Research Institute, Final Report. 26 p.

A study was made on the site of the Ames Laboratory Research Reactor to gather basic information needed in planning future field studies concerned with the movement of radionuclides through the soil. The soil and bed rock in the area were mapped by outcrop studies and by electroresistivity and seismic measurements. Six bore holes were drilled to provide control for the indirect geophysical measurements. The physical properties of soils from the B-horizon and from a gully used for waste water disposal were investigated. Tracer studies were made on disturbed soil samples in the laboratory by percolating spiked solutions through soil columns to determine the uptake of strontium and cesium. Batch tests were also made to develop the adsorption isotherms of the soil for strontium and cesium. (Key words: Nuclear facilities, geological mapping, radioactive tracers, cation adsorption).

A-012-IA.
Sendlein, Lyle V.A., Donald E. Henkel and Keith M. Hussey.
1968. Geology of the regolith aquifers of the Nishnabotna Basin. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 29 p.

In the analysis of the water budget of basins the one variable generally assumed to be constant is groundwater inflow and outflow. This study is the first phase of an investigation designed to evaluate the validity of this assumption in a glacial terrain underlain by a bedrock valley system. With the integrated use of geologic and geophysical data a major bedrock valley was mapped. The valley mapped represents the northern extension of a major buried valley system of Missouri. Sand and gravel deposits were not only found in segments of the buried valley but also as a basal drift unit on the bedrock upland surface. The modern West Nishnabotna roughly overlies the major buried valley whereas the East Nishnabotna River only overlies segments of tributaries of the major valley. Bedrock which subcrops in the basin is Pennsylvanian in the southern half both on the upland and in the buried valley. In the northern portion it is Cretaceous on the uplands and Pennsylvanian in the valleys. The application of the seismic refraction electrical resistivity methods proved valuable and economical. (Key Words: Basin study, groundwater geophysics, unconsolidated aquifer, buried valley).

*A-013-IA.
Willrich, T. L.
1969. Properties of tile drainage water. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 39 p. Available from CFSTI as PB 191 064

Water samples from 10 tile drainage outlets were collected and analyzed about twice a month whenever flow occurred. The drainage systems were located on commercial farms in the Clarion-Webster soil association area of north central Iowa. Drainage areas ranged from 6 to 366 acres. Major portions of all areas were intensively cropped. Corn and soybeans were the usual crops.

Median values for properties tested routinely ranged as follows: total N - 12 to 27 mg/l, P - 0.1 to 0.3 mg/l, K - 0.2 to 0.8 mg/l, hardness - 350 to 440 mg/l as $CaCO_3$, alkalinity - 260 to 330 mg/l as $CaCO_3$, specific conductance - 350 to 460 micromhos/cm, and pH - 7.4 to 7.8.

Practically all of the total N was in the nitrate form. Usual values for the other N fractions were: org. N - <0.05 mg/l, NH_4-4 - <0.10 mg/l, and NO_2-N - <0.01 mg/l.

*A-014-IA.
Ruhe, R. V. and W. J. Vreeken.
1969. Hydrologic system related to geology and soils, Four Mile Creek Area, Tama County, Iowa. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 81 p. Available from CFSTI as PB 190 166

Topography in the Four Mile Creek area consists of stepped levels that rise along interfluves from the main valley to divides. The drainage net is incised along tributary and side streams. Maximum relief in the area is 135 feet.

Wisconsin loess covers 54 percent of the area and buries paleosols and glacial till. The loess varies in thickness from 4 to 35 feet. Alluvium is confined to the main, tributary, and side valleys. The main valley alluvium occupies 22 percent of the area.

The hydrologic system in the area is exceedingly complex, and its budget is difficult to determine. Within an original design of four rain gages and analysis of gage data, one gage adequately measured rainfall amounts and distribution. Rainfall in the research area also correlates well with the amount and distribution at Traer, a permanent weather station. Evapotranspiration can only be roughly estimated from open-pan data at Ames and Iowa City.

Stream discharge was measured at two inflow gages and one outflow gage. Correlation of discharges through all gages for 4 years shows that the outflow gage can be used to characterize runoff in the research area. Inflow discharge can be deducted by using an equation developed from all gage data. In relatively drier years, runoff in acre-feet is only 4 to 6 percent of rainfall volume in the area. In relatively wetter years, volume of runoff may be 11 to 17 percent of the volume of rainfall in the area.

Groundwater regimen was characterized at recording wells in the valley alluvium and upland loess. One well adequately represents the system of the main-valley alluvium. One well in the loess on the upland illustrates the changes in the nature of the perched zone of saturation in the lower part of the loess above paleosols.

The geometry of Four Mile Creek channel was measured repeatedly at 10 cross-section stations for several years. Physical changes were recorded. Bed and suspended load samples were collected and analyzed at alternate stations.

Interactions between rainfall, stream discharge, stream stage, and water table levels in the alluvial valley are complex. Precedence, contemporaneity, or delay in response from one part of the system to another are describable qualitatively through inspection of hydrographs, but quantification is difficult. An over-all picture may be developed through methods of time-trend analysis. The effect of amount and distribution of rainfall on stream discharge and groundwater storage in the loess are striking. In-phase and out-of-phase cause and effects are quantifiable. Contributions of one part of the system to another are traceable through time.

In the stream channel, changes in discharge, stage, and hydraulic energy caused changes in the geometry of the channel that are recognizable as scour and fill. The channel changes are cyclic through time. Interactions between stream energy and movement of bed load are also determinable through time-trend analysis.

Bank widening of the stream channel is a process of bank slumping, undercutting of the slump mass during lateral migration of the thalweg or rise in stage, and flushing of the debris by high water.

The hydrologic regimen within small first-order watersheds in loess is related to stratigraphic zoning in the loess reservoir and to topography inherited from paleogeomorphic surfaces. These surfaces have associated clayey paleosols that are more impermeable than the loess. Parts of the buried surfaces are cut in till, also more impermeable than the loess. Subsurface water transmits downward and laterally through the permeable loess reservoir above the buried surfaces to alluvium along the first-order drainage. The subsurface water subsequently flows to alluvium of higher order valleys in the drainage net and ultimately to the main alluvial body along Four Mile Creek.

A-015-IA.
Squarer, David.
1968. An analysis of relationships between flow conditions and statistical measures of bed configurations in straight and curved alluvial channels. Iowa State University, Iowa State Water Resources Research Institute, Final Report. 173 p.

The reliability of predictors for friction factors and rates of sediment transport in alluvial channels is open to question when they are applied to sinuous channels. Bed-form geometry in a curved channel and a straight flume which are subject to the same nominal flow conditions is investigated by statistical analysis of records of streambed profiles. Autocorrelation,

spectral density and probability density functions of a process defined by the bed elevation as a function of the distance along the channel, or as a function of elapsed time at a fixed point of the channel are computed by digital computer. Comparison of the statistical descriptors obtained from the curved channel and from the straight flume permits a quantitative evaluation of the marked differences between bed geometry in curved and straight channels.

The total rate of sediment transport in the curved channel is approximately 15 times as much as that of a straight flume which is subject to nominally identical flow conditions. This difference increases with increase in Froude number. At the same time the overall mean water surface slope in the curved channel is comparable to the water surface slope in the straight flume.

It is shown that bed-friction factors in alluvial beds can be determined either in terms of flow conditions or in terms of the size of the bed forms. The statistical approach described in the text permits practical and relatively simple methods to be used for obtaining characteristic heights and lengths of the bed forms in terms of the moments of the spectral density function. These characteristic bed form dimensions are used in turn to evaluate bed friction factors in a straight flume.

It is demonstrated that characteristic dimensions of the bed forms can be obtained from stationary as well as from non-stationary sample records.

Comparison between time and space spectra permits evaluation of ripple celerity. The resulting relationship shows that small ripples move faster than large ones and that the celerity of ripples increases with increasing flow velocity. These results are confirmed by results obtained from time-lapse photography and are suggested for use in relating time and space domains.

It is shown that the theoretical second order linear Markov model used by other investigators, as well as other simple exponential, sine or cosine spectral density functions do not fit the observed phenomenon. Suggestions for future study are listed.

A-016-IA.
McDonald, D. B., W. L. Paulson and C. A. Merritt.
1968. The effect of photosynthesis on the oxygen balance in a mid-western stream. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 27 p.

The following conclusions were made:

(1) Photosynthesis is a contributing factor to the oxygen resource in the Iowa River. This is evidenced by the relationship between plankton counts vs dissolved oxygen levels in the river, by the observed diurnal oxygen curves and by the light and dark bottle test results. (2) Its relative importance in this basin appears significant since photosynthetic oxygen production exceeds total respiration by almost two times. The photosynthetic production and respiration values presented when compared to those of the other studies appear relatively low. This is probably due to the low respiration levels and the small photosynthetic base of the Iowa River. Other streams researched had high respiration levels due to heavy organic loadings and high photosynthetic rates due to rooted aquatic plants and attached and benthic algae. However, the relative significance of the oxygen factors are comparable to other studies. (3) When evaluating the oxygen resource of a stream, photosynthesis must be considered although its reliability may be variable. This is especially true in a stream such as the Iowa River where the bulk of the photosynthesis is due to planktonic algae whose numbers may show a wide variation. In the present study plankton counts were less than 500 organisms/ml 23% of the time in the river above the impoundment and 13% of the time below the reservoir. However, whether or not the photosynthetic effect can be relied upon quantitatively, it remains am important factor of the oxygen balance in streams.

*A-017-IA.
Huggins, Thomas G. and Roger W. Bachmann.
1969. Production of channel catfish (Ictalurus punctatus) in tertiary treatment ponds. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 119 p.
Available from CFSTI as PB 190 165

The effluent of the Ames Water Pollution Control Plant is emptied into the Skunk River. Because of the seasonal low flow of Skunk River the plant effluent has to be of a high quality to prevent severely polluting the river. This, together with the need for expansion of the Ames treatment plant, influenced the construction of a tertiary treatment pond in the spring of 1966.

During the fall of 1966 the pond had tremendous algal blooms and aquatic insect populations. Introduction of fish was considered in tertiary ponds to utilize the aquatic insects as food. If a desirable species of fish could live and grow in the ponds, an economic return could be attained by using these fish for restocking in other waters.

A series of four tertiary treatment ponds were constructed and data were collected on these ponds from June 1967 to September 1968. The objectives of the study were: 1) To see if fish could live and grow in these ponds, 2) To determine the potential production of fish in these ponds, 3) To describe the physical, chemical and biological features of these ponds.

A-019-IA.
N. William Hines.
1968. Model flood plain zoning ordinance. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 2 p.

Flood plain regulation appears to be an increasingly sensible alternative or supplementary measure to extensive engineering works designed to avoid large-scale loss of property and lives in areas historically subject to periods of high surface waters. The purpose of this study was to explore state and local legislative efforts to restrict land use within flood plains. Through the examination of experience with flood plain regulations existing in various parts of the country, it was hoped the investigation could gain an understanding and appreciation of the essential strengths and weaknesses of present regulatory schemes. Armed with this knowledge, the end product of the study was projected to be the drafting of a Model Flood Plain Zoning Ordinance.

* A-022-IA.
Dague, Richard R. and Kenneth J. Kline.
1969. Management of cattle feedlot wastes. University of Iowa, College of Engineering, Report No. 69-4. 195 p.
Available from CFSTI as PB 190 830

General conclusions of the study or hydrologic aspects of feedlot waste control are (1) The hydrologic aspects, rainfall, runoff, and stream flow, are the primary factors to consider in managing cattle feedlot runoff. This is evidenced by the fact that the nature, volume, and rate of delivery of runoff is directly related to rainfall. Storage requirements for retention facilities depend upon the volume of runoff. In considering disposal by controlled release to a stream, the retention pond discharge rate is proportional to the flow in the stream. (2) Terrace and retention ponds will reduce the pollution from cattle feedlot runoff. Evidence of this is shown by the reduction in suspended solids, BOD, and COD as a result of settling. Terraces will reduce the transport of solids from the lot and to some degree the volume of runoff. Retention ponds will reduce the suspended solids which in turn will result in BOD and COD reductions. (3) Application to land appears to be the most practical method of disposal for both the solids and the liquid. When applied

to agricultural land, the waste has some economic value. The value may exceed the cost of application if the operation is carried on where land is available. To be economical, sufficient area must be available for crops to recover the plant nutrients from the waste. (4) Retention ponds may not remove sufficient amounts of suspended solids, BOD, COD, and nutrients to provide safe effluents for disposal to streams. It may be necessary to provide additional treatment and nutrient removal to protect water quality. The profit potential and the degree of concern of the feedlot owner for adequate waste treatment will dictate the type of treatment system that is practical and economical.

*A-022-IA.
Dague, Richard R., Wayne L. Paulson and Kenneth J. Kline.
1969. Hydrologic aspects of feedlot waste control. University of Iowa, College of Engineering, Report No. 69-2. 37 p.
Available from CFSTI as PB 191 248

Several segments of the agricultural industry contribute large quantities of pollutants to the environment. Cattle feedlots are major contributors. Feedlot wastes have been entering waters for many years, but only in the past five years has the need for controls become apparent. This need has led to a search for acceptable waste control operations.

This paper is concerned with the hydrologic factors that require consideration when designing systems for the control of cattle feedlot runoff. In addition, a discussion of several methods of controlling feedlot wastes is presented.

*A-024-IA.
DeBoer, D. W. and H. P. Johnson.
1969. Development of a mathematical model for the simulation of flatland watershed hydraulics. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 255 p.
Available from CFSTI as PB 188 793.

Many acres of midwestern agricultural lands have artificial drainage. The primary reason for artificial drainage is to accelerate the removal of excess water from the soil surface (surface drainage) and the crop root zone (subsurface drainage). The hydraulics and hydrology of excess water removal from agricultural lands by artificial means is not well understood. The primary objective of the study was to develop and test a mathematical watershed model which could reflect the effect of artificial drainage and hydrologic parameter variations on watershed hydrographs.

A hydrologic mathematical watershed model was developed for the most recently glaciated region of Iowa. The region is characterized by a flat topography, numerous shallow depressional areas

commonly called "potholes", and surface and subsurface drainage systems. The research effort was based on a previously developed hydraulic mathematical watershed model which simulated the movement of excess water from the depressional areas to the watershed outlet. The hydraulic model used excess water as input to simulate watershed hydrographs. The developed hydrologic model uses precipitation as input and simulates the hydrologic watershed processes of infiltration, surface runoff to depressional areas, soil moisture profile storage, evapotranspiration and percolation of water to the water table. The model simulates the hydrology of a watershed from precipitation input to a watershed outflow hydrograph on an individual storm basis.

The model was used to simulate five individual hydrologic events for the 24 square mile East Fork Hardin Creek Watershed, Green County, Iowa. The model simulated hydrographs corresponded in shape with field measured outflow hydrographs. The peak discharge deviation between simulated and actual hydrographs varied from -8 to 29 percent with an 8 percent mean deviation.

B-001-IA.
N. William Hines.
1966. A decade of experience under the Iowa Water Permit System. The University of Iowa, Agricultural Law Center, Monograph No. 9. 99 p.

Ten years have elapsed since the Iowa Study Committee on Water Rights and Drainage Laws drafted and submitted to the Iowa Legislature the Water Rights Bill that revolutionized the allocation of Iowa's water resources. The Iowa permit system is a unique experiment in regulating a natural resource where scarcity is as yet chiefly a potential threat. Now that the administration of the permit system created by this legislation is completing its first decade of operation, the occasion seems ripe for surveying the Iowa experience.

The workings of the Iowa system are of interest to several audiences. All Iowans are affected by the means chosen for allocation of the state's water resources; but to those who must comply with the system to satisfy their water requirements, the details of its operation are of most importance. As the demand for water increases in this country, it is likely that many of the nearly thirty eastern states currently allocating their water resources on the basis of riparian rules will have occasion to reconsider their allocation systems. An awareness of the Iowa experience in water use regulation should provide valuable insight to any state contemplating abandonment of the riparian system in favor of a more modern and efficient water allocation mechanism.

*B-002-IA.
Kirkham, Don.
1969. Groundwater seepage patterns to wells for unconfined flow. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 9 p.
Available from CFSTI as PB 189 525

Dupuit-Forchheimer theory for free surfaces of semi-confined flow has been theoretically investigated as to why the theory fails to predict free surfaces near an outflow sink. It is shown that the theory does indeed give correct free surfaces if the flow medium is of infinite conductivity in the vertical seepage direction as compared with the horizontal. The theory gives non-orthogonal flow nets and examples have been worked out. In another aspect of the research, analytical theory has been developed and digitally computerized to give the free surface for dam seepage; the theory can be modified for well seepage. The present analytical theory needs further development. Gram-Schmidt theory has been developed to provide polynomials to satisfy boundary conditions in a number of seepage problems. Problems on seepage to a piezometer cavity and from one drainage ditch to another have been solved by the polynomials; also the seepage to a well in an

ellipse shaped aquifer. The polynomials permit flow nets to be calculated and drawn by an I.B.M. digital computer. (Key Words: ground water, free surfaces, seepage, Dupuit-Forchheimer theory, flow nets, wells, piezometry, theoretical analysis, computer programs).

*B-005-IA.
Hines, N. William and Frank W. Pechacek.
1969. Physical, legal and economic aspects of assessment of costs among drainage districts: legal phase. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 77 p. Available from CFSTI as PB 189 767

This study discusses the related problems of multipurpose versus single purpose districts, and the allocation of costs and benefits. An introductory background on allocation of costs reviews judicial development of the common law, common enemy rule, the civil law rule of natural drainage, the reasonable use rule, and state statutes creating drainage districts. A more specific analysis of Iowa districts observes the piece-meal development of too many districts, often at cross-purposes or duplicative, and laboring under an inherently inequitable system of cost allocation based on the theoretically appealing economic benefit concept. The current legal apparatus is defined as archaic in terms of present population and technological demands. The study recommends "multi-purpose" approach to drainage management, which is joint participation by both upper-land and bottom-land owners with special emphasis upon use of soil-conservation and water-retention structures by the upper-land owners.

*B-005-IA.
Kumar, S. and H. P. Johnson.
1969. Effect of channel straightening on the movement of flood waves on Boyer River. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 107 p. Available from CFSTI as PB 190 355

Many Iowa rivers have been straightened and leveed with the objective of achieving drainage and flood control on the riparian land. Although these methods have proved beneficial to the land along the reach straightened, they have often resulted in damage to the downstream land owner's property by increasing the discharge, thus forcing the downstream owners to repair or improve their part of the channel. Litigation among drainage districts often results with downstream districts claiming partial reimbursement of the construction and maintenance costs from the districts upstream.

This study was conducted to evaluate the physical effects of river straightening on the movement of flood waves with the objective of arriving at a method for the equitable apportionment of construction and maintenance costs among beneficiaries.

Factors consisting of three spacial patterns of rainfall, three conditions of rainfall timing, two runoff amounts and three values of Manning's roughness coefficient were utilized to investigate their effect on the flood wave characteristics. Two conditions of partial straightening of the river were also investigated. The convex method of flood routing was employed. Hydrograph characteristics studied were (1) attenuation of the flood wave as it moves down the river, (2) change of discharge after straightening, (3) duration of flooding along the river, (4) time to peak, and (5) time of arrival of flood wave at a station.

A method based upon these wave characteristics is proposed whereby the apportionment of costs may be determined. (Key words: mathematical model, watershed hydraulics, drainage, Iowa).

B-006-IA.
Landers, Roger Q. and Dana R. Sanders.
1967. Structure of forest vegetation bodering the Saylorville Impoundment. Iowa State University, Iowa State Water Resources Research Institute, Completion Report. 29 p.

Sites chosen in the area of the Saylorville Reservoir were studied from the standpoints of classification, composition of slope forests, and pre-impoundment watershed description. It was found that discrete communities could not be shown to exist and that the continuum approach is most plausible as a classification tool.

Canopy species with high importance values in the majority of stands include elms, ironwood, and ash. On drier sites white oak and shagbark hickory are dominants, with important understory species of Ribes spp., Parthenocissus quinquefolia, and Xanthoxylum americanum. Red oak, black maple, and basswood are more abundant on mesic sites. Characteristic understory species on these sites include Anemonella thalictroides, Parthenocissus quinquefolia, Hepatica acutiloba, Carex albursina, and Asarum canadense. The majority of sites seem to fall somewhere between the above two categories. Any of a number of tree spacies may be dominant in the canopy from site to site, and the understory dominants also show this site to site variation.

In considering the management of these slope forests, it is our hypothesis that the great majority of slope forest species will not be capable of withstanding periods of flooding. Changes in structure and composition of vegetation will occur. This results in a disturbance situation in which there will be a predominance of opportunistic species capable of withstanding the stresses of flooding but undesirable in other aspects of recreational use or watershed protection. (Key words: vegetation, structure, slope forest, watershed, preimpoundment survey, Saylorville, Des Moines River, continuum-index, oak, maple).

B-013-IA.
Toksoz, Sadik and M. Y. Khan.
1970. Flow of water into tile drains in stratified soils. Iowa State University, Iowa State Water Rssources Research Institute, Completion Report. 7 p.

The project objectives were (1) to set up and solve appropriate differential equations for water flow into tile drains and drainage wells in a two-layered soil (2) to put the resulting drain spacing and well spacing formulas into graphical or some other convenient form so that these formulas can be used easily by drainage engineers and (3) to infer the effects of soil stratification on drain spacing and well spacing and, if proved possible, to extend or adapt the solutions of two-layered problems to many layered soils.

All the three objectives have been achieved. One Ph.D. thesis and one M.S. thesis have emerged from this project. Four articles, emerging from this project, have been submitted for publication. Abstracts of the articles are included in the report.

Ph.D. THESES

Asseed, Mohamed Shaban.
1966. Horzontal advance of flooding irrigation water in relation to infiltration rate of soil. Ph.D. Thesis. Iowa State University. 240 p. Univ. Microfilms, Ann Arbor, Mich. (Diss. Abstr. 27:2962B) (A-003-IA)

Mathematical equations describing the horizontal advance of the irrigation stream on the surface of soil were derived and discussed for different types of infiltration equations corresponding to different known field conditions. Complex variable theory was applied to transform certain complicated forms of solutions, not usable in practical work, to solutions in algebraic form that could easily be used in irrigation design.

An irrigation model having a visible photographic front was constructed and operated to test the theory. The model was made of plexiglas with glass beads or soil aggregates as the porous medium and water as the fluid. Potassium dichromate dye was injected in the porous medium to trace the direction and velocity of the stream lines when the water moved within the body of the porous medium.

A series of experimental runs was made in which different porous mediums with different infiltration equations were used. For each porous medium different rates of simulated irrigation water were used, and different conditions of surface slope and roughness were applied.

A comparison between experimental data obtained with the model and the calculated position of the water on the surface and below the surface by theory shows a good agreement between theory and experiment. Dimensionless functions were used to present the model data. These dimensionless functions are useful for irrigation design under field conditions when the infiltration equation in the field is given by

$$Y = Et^a$$

where

y = the cumulative infiltration in ft^3/ft^2

t = the time in hours

E and a are coefficients

Field determined infiltration equations of the type

$$y = At^{1/2} + Bt$$

where

y = the cumulative infiltration in ft^3/ft^2

t = the time in hours

A and B are coefficients

were used to develop theoretical curves for the horizontal advance of the flooding irrigation water for different soil types, for different antecedent moisture content, and for different depths of surface water storage. Numerical examples of the use of both the dimensionless functions and the developed theoretical curves are included for clarity.

Powers, W. L.
1966. Solution of some theoretical soil drainage problems by generalized orthonormal functions. Ph.D. Thesis. Iowa State University. 252 p. Univ. Microfilms, Ann Arbor, Mich. (Diss. Abstr. 27:2961B) (A-003-IA)

In this theoretical investigation generalized orthonormal functions were used to solve mathematically the problem of surface water moving into and through water-saturated soil bedding and the problem of steady rainfall seeping through soil into drainage ditches of unequal water levels. The generation process for forming the orthonormal functions and the expressions for the potential function and the stream function were programmed for the IBM 360 computer located at Iowa State University.

In the first problem theoretical solutions for several different geometries of the soil bedding were obtained. The minimum rainfall rate necessary to keep the soil bedding saturated and the percent of the total water falling on the soil surface at the minimum rainfall rate which actually moves through the soil were computed for the several different geometries investigated. As an example we found that for homogeneous soil bedding with a hydraulic conductivity of 25.40 cm. per day, a 3.33 percent slope of the surface of the soil bedding, a depth to an impermeable barrier at the drainage furrow of 60.96 cm., and a width of 9.14 meters that the minimum rainfall rate necessary to keep the soil saturated was 1.27 cm. per day and about 10 percent of the water that fell on the soil surface from the minimum rainfall rate moved through the soil bedding.

In the second problem, theoretical solutions for several geometries of the flow region between the two drainage ditches were obtained. The maximum height of the water table and its location between the two ditches were found. The percent of

the total rain water that reached each ditch and the percent of the water that reached the lower water level ditch which seeped from the higher water level ditch were computed for the nine geometries investigated. As an example, we found that for a homogeneous soil between two ditches with water levels of 0.6 meters and 1.1 meter, a ratio of rainfall to hydraulic conductivity of 0.025, and a ditch spacing of 10 meters that the maximum height of the water table from the impermeable barrier was 1.29 meters at a distance of 6.1 meters from the ditch with the lower water level. We also found that 61 percent of the water that fell as rain seeped into the ditch with the lower water level while the remaining 39 percent seeped into the ditch with the higher water level. For this example, no water seeped from one ditch to the other.

It was found that the solution to the second problem was in very good agreement with a previous solution for the special case when both ditches had equal water levels.

Bakr. H. M. A.
1967. Comparison of six methods of leaching salts from soil columns. Ph.D. Thesis, Iowa State University. 279 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 28:3560B) (A-003-IA)

Six methods of water applications were used in the laboratory for leaching NaCl, $NaHCO_3$ and Na_2SO_4 from Ida loess, 28 glass beads and Clayton sand, presalinized to a five percent level and packed in columns to 25 and 50 cm depths. Electrical conductivity measurements of the water were used as a measure of the leaching effectiveness. Surface evaporation was prevented.

In Method I there was standing surface water followed by gravity drainage. The conductivity was measured just above and at a fixed distance above the soil surface and in stirred standing surface water. It was found that salts mixed very slowly with water depending on: the type of the porous medium, the type of salt, location of measurements and the lengths of soil columns. When the gravity drainage was permitted, no water moved through the columns apparently due to a sealing effect.

In Method II Clayton sand was salinized with the sodium salts and packed in 25 cm long columns. There was surface leaching a) with single water height increments of 132 cm or more depending on the salt, and b through g) with multiple height increments of 88, 44, 22, 11, 4.4 and 1.1 cm. For multiple water height increments only one salt, $NaHCO_3$, was used to salinize the soil. During and following each increment, gravity drainage was allowed. The drainage water was collected and the electrical conductivity of the drainage water and combine drainage water was measured. The results indicated that the amount of water needed for removing the salts was in order: NaCl $NaHCO_3$ Na_2SO_4. The results indicated that more water was saved when the amount of each increment was decreased and the number of surface water applications increased.

In Method III sodium bicarbonate, Clayton sand, 25 cm. long columns and increments of 11 cm. height were used. There was leaching of water upward through the soil columns by subirrigation applied under a pressure of 35 cm. Only surface drainage as runoff was allowed. Collection and electrical conductivity measurements of the surface runoff were taken. Method IV was the same as III except that gravity drainage was allowed after each application of 11 cm. height water increment. For Methods III and IV it was found that with surface drainage less leaching water was required to remove essentially all the salt from the soil than was required when gravity drainage was allowed. Therefore, Method IV was preferred over Method III.

In Method V, there was leaching of water upward through the 25 cm., $NaHCO_3$ presalinized sand columns by subirrigation with the water table height at 12.5 cm. from the bottom of the soil columns. The water which reached the surface by capillarity was then allowed to stand for at least 36 hours after which gravity drainage was permitted. Drainage water samples were collected and electrical conductivity measurements were made. Method VI was the same as V except that the water table was kept at 2 cm. above the bottom of the columns for at least five days. Results showed that Methods V and VI were more efficient than Methods IIa, III and IV but were less efficient than Method IIg where 1.1 cm. height increments were used.

Method IIg, where 1.1 cm. height increments were used, appears to be the best leaching method. This may not be true in the field where evaporation prevention is difficult or imporsible.

Sprinilta, Sam.
1967. Flow of water through columns of layered soil. Ph.D. Thesis. Iowa State University. 366 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 28: 3559B) (A-003-IA)

Three experiments were conducted to study the effects of depth of ponding head, kind and thickness of upper layer soil, kind and thickness of lower layer soil, and magnitude of outflow pressure on flow rate and water pressure profile during steady vertically downward flow of water through soil columns containing a layer of lower saturated hydraulic conductivity overlying a layer of higher saturated hydraulic conductivity. A method for determining unsaturated hydraulic conductivity was developed.

In the first two (sorption) experiments, water was allowed to move downward from a constant positive ponding head maintained at the upper surface into each air-dry soil column and

to leave the column at the lower surface at atmospheric pressure. Negative pressure occurred in every column; water pressure was smallest at the interface. Flow rate and water pressure at each location increased with increasing depth of ponding head, decreasing upper layer thickness, or increasing saturated hydraulic conductivity of upper layer soil. Flow rate and water pressure profile in the upper layer did not vary with kind of lower layer soil. Increasing lower layer thickness tended to increase flow rate and to decrease slopes of water pressure in a zone immediately below the interface. The water pressure profile in a given layer depended upon the kind of soil in the layer. No zone of strictly constant negative water pressure occurred in any water pressure profile.

In the third (desorption) experiment, each soil column was brought to saturation and then downward flow was initiated while maintaining a constant positive ponding head at the upper surface of the column. Non-negative outflow pressures were used in succession in a decreasing order. The occurrence of negative pressure in the initially saturated soil columns resulted in increased flow rate. Each decrease in outflow pressure decreased water pressure at each depth. Water content data obtained when the outflow pressure was 0 cm of water showed that unsaturation was present at each depth except near the two ends of each soil column and that the water content attained entirely by desorption was not necessarily a unique function of water pressure. No zone of strictly constant negative water pressure occurred in any water pressure profile.

Comparisons of water pressure profiles of the sorption experiments with the corresponding profiles of the desorption experiment revealed little difference in water pressures in the upper layer and in the lower part of the lower layer. At each depth in the upper part of the lower layer, the water pressure attained via sorption was larger than that attained via desorption; the reverse tended to hold for flow rate.

The method developed, using a two-layer soil column, for determining unsaturated hydraulic conductivity appeared to be satisfactory. At a given water pressure or water content, large variations in unsaturated hydraulic conductivity both within and between columns of the same soil existed despite similarity in bulk density. None of the semi-log curves of unsaturated hydraulic conductivity versus water pressure was linear despite the narrow range (0 to -61 cm of water) of water pressures.

Yen, C. L.
1967. Bed configuration and characteristic of flow in a meandering channel. Ph.D. Thesis. The University of Iowa. 136 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 27: 1172B) (A-015-IA)

The flow of water and configuration of channel bed in a stream with movable boundaries are complicated, firstly, by the nonlinear alignment of the channel; secondly, by the presence of movable boundaries. The flow and the bed configuration are interdependent because the flow which erodes the channel depends on the shape of the channel and vice versa. The bed configurations in a meandering channel with fixed walls have been studied for cases of different width-depth ratios and Froude numbers. An approximate analytical solution for bed configuration in the case of fully developed flow in a bend with fixed walls indicates that the transverse bed slope at a given point is directly proportional to the maximum radial velocity above that point; this solution is in good agreement with the actual measurements. The flow characteristics -- mean flow velocity, flow direction, bed shear, water-surface elevation, and turbulence intensity -- were measured in a fixed-bed model, of which the bed topography conformed to a representative alluvial-channel configuration determined from experiments with a movable-bed meandering channel. It has been found that the bed shear is highest in the area where deposition occurs, and that the point bar creates a resistance which may be in excess of that of a meander with uniform cross section.

Fritton, D. D.
1968. Soil water redistribution during evaporation. Ph.D. Thesis, Iowa State University. 152 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 29: 4474B) (A-026-IA)

Temperature and moisture distribution data were taken for a 9 by 11 by 19.5 cm soil column where wind was the evaporation agent and for a similar soil column where radiation was the evaporation agent. A Webster silty clay loam soil characterized by a soil-water retention curve and an inflow diffusivity versus moisture content curve was used in the experiments. The experimental results were compared with results calculated from a solution of the diffusion equation normally used to describe isothermal movement of soil water and a heat and mass transfer solution which accounted for temperature effects. It was found that the isothermal diffusion equation would describe the cumulative evaporation for the wind treatment where the diffusivity had to be divided by a resistance factor and for the radiation treatment where the same diffusivity used for the wind treatment was corrected for an increased temperature. The isothermal diffusion equation, even when an adjusted diffusion coefficient was used with it, would also describe the moisture distributions in the wind case for all times less than 200 hrs. The isothermal diffusion equation, even when an adjusted diffusion coefficient was used with it, would not predict the formation of a surface layer of dry soil and, thus, did not describe the moisture distributions for the radiation treatment for times greater than 20 hr. or for the wind treatment for times greater than 200 hrs. It was found that the heat and mass transfer equation would predict

the development of a dry surface layer and with additional experimental knowledge of the soil-water retention curve as a function of temperature would describe the moisture distribution where temperature gradients were important.

Squarer, D.
1968. An analysis of relationships between flow conditions and statistical measures of bed configurations in straight and curved alluvial channels. Ph.D. Thesis. The University of Iowa. 188 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 129: 2048B) (A-029-IA)

The reliability of predictors for friction factors and rates of sediment transport in alluvial channels is open to question when they are applied to sinuous channels. Bed-form geometry in a curved channel and a straight flume which are subject to the same nominal flow conditions is investigated by statistical analysis of records of stream bed profiles. Auto-correlation, spectral density and probability density functions of a process defined by the bed elevation as a function of the distance along the channel, or as a function of elapsed time at a fixed point of the channel are computed by digital computer. Comparison of the statistical descriptors obtained from the curved channel and from the straight flume permits a quantitative evaluation of the marked differences between bed geometry in curved and straight channels.

The total rate of sediment transport in the curved channel is approximately 15 times as much as that of a straight flume which is subject to nominally identical flow conditions. This difference increases with increase in Froude number. At the same time the overall mean water surface slope in the curved channel is comparable to the water surface slope in the straight flume.

It is shown that bed-friction factors in alluvial beds can be determined either in terms of flow conditions or in terms of the size of the bed forms. The statistical approach described in the text permits practical and relatively simple methods to be used for obtaining characteristic heights and lengths of the bed forms in terms of the moments of the spectral density function. These characteristic bed form dimensions are used in turn to evaluate bed friction factors in a straight flume.

It is demonstrated that characteristic dimensions of the bed forms can be obtained from stationary as well as from non-stationary sample records.

Comparison between time and space spectra permits evaluation of ripple celerity. The resulting relationship shows that small ripples move faster than large ones and that the celerity of ripples increases with increasing flow velocity. These results are confirmed by results obtained from time-lapse photography and are suggested for use in relating time and space domains.

It is shown that the theoretical second order linear Markov model used by other investigators, as well as other simple exponential, sine or cosine spectral density functions do not fit the observed phenomenon. Suggestions for future study are listed.

Annambhotla, V.S.S.
1969. Statistical properties of bed forms in alluvial channels in relation to flow resistance. Ph.D. Thesis. The University of Iowa. 137 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 30: 4147B) (A-029-IA)

The objective of this study was to investigate the statistical properties of dune bed forms in alluvial channels and relate them to the hydraulic friction factor. Emphasis was placed on doing this for large rivers because very little is known about the relationship between resistance to flow and bed configuration in rivers.

Bed profile records were acquired from a straight 3-feet wide laboratory flume and from the Missouri river at Omaha, Nebraska. The bed material in both cases was fine sand. Discrete digital data of the sand bed profiles were obtained from continuous records. Statistical computations were performed on a digital computer.

The river data were seen to be nonstationary both in the mean and in the mean square. A suitable filter, designed to attenuate the low frequency trends in the data, was selected, on the basis of some exploratory studies, to render the data stationary in the mean. Pilot studies, made by analyzing selected river data by spectral analysis and zero-crossing distances and amplitudes analysis, suggested that the latter of the two methods is preferable, mainly because spectral analysis of data that is nonstationary in the mean square is more apt to give misleading results.

Statistical properties of the wave lengths, amplitudes and heights were evaluated by the zero-crossing distances and amplitudes analysis for selected flume data and all river data. A study of the frequency distributions of the bed form characteristics showed that the bed elevations were approximately normally distributed and that the wave lengths, amplitudes and heights were approximately exponentially distributed.

The bed form friction factor was plotted against a modified relative roughness parameter defined in terms of the bed form dimensions and the hydraulic mean radius of the flow. This showed reasonably promising results. A more definitive resistance relationship could not be formulated, however, because of the limited number of observations and also because of the suspected effects of the variations in the shape and arrangement of dune forms, concerning which adequate information is lacking.

Effects of water temperature on bed form roughness were observed to be significant. The tendency in the Missouri river was that the bed forms became rougher with increasing temperatures and vice versa. However, there seem to be some other undetermined factors also influencing the bed forms. Variations in sediment size with respect to time is suggested as one possible factor.

The study indicates that reasonably good measures of bed form characteristics can be obtained by statistical analyses.

Cramer, W. D.
1969. Engineering parameters of an induced draft aerator with foam recycle. Ph.D. Thesis. Iowa State University. 116 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. Order No. 70-13576) (A-032-IA)

This thesis reports on the basic mechanisms of an induced draft aerator with foam recycle. The aerator consists of two vertical concentric tubes mounted above a shrouded turbine impeller. As the impeller rotates, a vortex is formed in the inner tube. By increasing the impeller speed to a "critical impeller speed," N_c, the vortex deepens until it hits the impeller starting to cause gas dispersion. Further increase in impleller speed increases the induced gas flow rate. Foam forms when the rising dispersed gas bubbles reach the surface of the broth. The top of the outer tube is located near the surface of the liquid permitting foam spillage and recycle through the annular space between the vertical tubes. By adjusting the physical parameters foam formation can be totally controlled within the system.

A laboratory aerator of 18 inches in diameter and 4 feet in depth was constructed. Experimental results were obtained to correlate the important variables of the system. These variables include oxygen absorption rate, air pumping rate, foam recycle rate, impeller speed, power requirement, liquid viscosity, liquid density, and many geometric parameters such as the agitator diameter, agitator blade height, impeller submergence, and so on.

DeBoer, D. W.
1969. Flood hydrology of watersheds with depressional storage. Ph.D. Thesis. Iowa State University. 255 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. Order No. 70-13580) (A-024-IA)

Many acres of midwestern agricultural lands have artificial drainage. The primary reason for artificial drainage is to accelerate the removal of excess water from the soil surface (surface drainage) and the crop root zone (subsurface drainage). The hydraulics and hydrology of excess water removal from agricultural lands by artificial means is not well understood. The primary objective of the study was to develop and test a mathematical watershed model which could reflect the effect of artificial drainage and hydrologic parameter variations on watershed hydrographs.

A hydrologic mathematical watershed model was developed for the most recently glaciated region of Iowa. The region is characterized by a flat topography, numerous shallow depressional areas commonly called "potholes", and surface and subsurface drainage systems. The research effort was based on a previously developed hydraulic mathematical watershed model which simulated the movement of excess water from the depressional areas to the watershed outlet. The hydraulic model used excess water as input to simulate watershed hydrographs. The developed hydrologic Model uses precipitation as input and simulates the hydrologic watershed processes of infiltration, surface runoff to depressional areas, soil moisture profile storage, evapotranspiration and percolation of water to the water table. The model simulates the hydrology of a watershed from precipitation input to a watershed outflow hydrograph on an individual storm basis.

The model was used to simulate five individual hydrologic events for the 24 square mile East Fork Hardin Creek Watershed, Green County, Iowa. The model simulated hydrographs corresponded in shape with field measured outflow hydrographs. The peak discharge deviation between simulated and actual hydrographs varied from -8 to 29 percent with an 8 percent mean deviation.

Dougal, Merwin D.
1969. Physical and economic factors associated with the establishment of stream water quality standards. Ph.D. Thesis. Iowa State University. 1531 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. Order No. 70-13581) (A-001-IA)

A comprehensive study is reported of water pollution control and stream water quality as they relate to the establishment of stream and effluent standards. The ability of Iowa Streams to assimilate organic wastes was determined on a state-wide basis, with three hydrologic-water quality regions being identified: Ideal, Good, and Poor. Quantitative values were assigned for low flow discharges in each region. The preliminary results indicate that the BOD loading in the streams must be limited to 10 - 15 mg/l to maintain the established dissolved oxygen standard of 4 mg/l. The physical characteristics of effluents from typical waste treatment processes were determined and related to mathematical models for BOD progression. A more refined BOD model was developed.

A case study of the Skunk River at Ames revealed the nature of the response of an Iowa stream to discharge of effluents from a water pollution control plant. A digital computer model was developed for simulating, verifying and forecasting stream water quality. The results indicate three major factors influence stream quality: oxidation of the carbonaceous organic wastes contained in effluents, nitrification of nitrogenous compounds, and the effect of nutrient levels in causing a substantial algal response. The economic value of water pollution control was evaluated for the City of Ames. Present annual expenditures will double or triple in the future depending on the desired level of stream water quality.

Key Words: Economics, mathematical models path of pullutants, waste assimilative capacity, water quality, water pollution biochemical oxygen demand, computers, dissolved oxygen, quality standards, rivers, sewage treatment, simulation, streams.

Hanson, T. P.
1969. Steady state and transient behavior of a continuous fermentor. Ph.D. Thesis. Iowa State University. 201 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. Order No. 70-13589) (A-032-IA)

The fermentation kinetics of the homofermentative organism Lactobacillus delbrueckii in a glucose-yeast extract medium is studied in both batch and continuous culture under conditions of controlled pH. From a graphical analysis of the experimental data, a mathematical model of the batch process is derived which relates bacterial growth, glucose utilization and lactic acid formation. The parameters in the model represent the activity of the organism and are a function of pH having a maximum value at about pH 5.90.

The batch growth curves of L. delbrueckii exhibit several exponential phases. The position of the slope changes and the overall bacterial yield is related to the initial amount of yeast extract in the medium. It is postulated that this behavior is due to several stimulatory substances in the yeast extract that accelerate growth and are consumed by the bacteria during the course of the fermentation. Using a Monod-type expression to represent the effect of the essential and stimulatory components, the following growth equation is proposed to represent the observed behavior.

$$\frac{dC_V}{dt} = \left(k_o + \frac{k_1 C_{S1}}{K_{S_1} + C_{S1}} + \cdots + \frac{k_n C_{Sn}}{K_{Sn} + C_{Sn}}\right)\left(\frac{C_{El}}{K_{El} + C_{El}}\right)\cdots\left(\frac{C_{Em}}{K_{Em} + C_{Em}}\right)$$

C_v = bacterial density,

k_i = specific growth rate constants,

C_{Si} = concentration of stimulatory component,

C_{Ei} = concentration of essential component,

K_{Ei} = Michaelis constants.

An experimental program based on a three dimensional, statistical design is carried out to observe the effect of pH, feed concentration and dilution rate on the steady state behavior of a continuous stirred tank fermentor (CSTF). The feed medium has a constant ratio of two parts glucose to one part yeast extract plus added mineral salts. An approximate prediction of the steady state bacterial density, glucose concentration and lactate concentration in the CSTF could be made from the batch fermentation data using either a graphical technique or a method based on the kinetic model derived for the batch case.

In moving from one point on the statistical design to another, step changes are made in the operating conditions and the transient behavior of the CSTF is observed in terms of acid production rate, glucose concentration and bacterial density. Using the batch kinetic model, this transient behavior is simulated on the analog computer. The response time for the glucose concentration is much faster for the simulated runs than is observed, but the response time of the bacterial density is about the same for both cases.

Johnson, R. L.
1969. Treatment of waste waters by pulsed adsorption beds. Ph.D. Thesis. Iowa State University. 201 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. Order No. 70-13596) (A-025-IA)

A new process for tertiary treatment of waste waters was developed in this laboratory and pilot plant investigation. The Pulsed Adsorption Bed (PAB) process incorporates the physical-chemical adsorption of organic material onto the surface of granular media. This adsorption of the organic material effectively creates a much higher concentration in the micro-environment of the media-waste water interface so that further, rapid biological oxidation and assimilation of the organic material proceeds at the interface. The organic material which was adsorbed onto the media of the laboratory units was significant enough to be easily measured. It was shown that adsorption of the organic material would produce a 4 to 40 fold concentration effect over the bulk concentration of the synthetic waste water used in the laboratory portion of the study.

Incorporation of a solids-separation unit with the newly developed PAB process units would result in a tertiary waste water

treatment system capable of 70 to 90 percent removal of the organic material in the final effluent from conventional complete treatment facilities. The combined PAB and solids-separation tertiary treatment system could be designed, constructed and operated at a total annual cost of approximately 3.5¢/1000 gallons, about one half the cost of other tertiary treatment processes of comparable efficiency.

Toksöz, Sadik.
1969. Drain spacing formulas and nomographs for stratified soils. Ph.D. Thesis. Iowa State University. 103 p. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 30: 2654B) (B-013-IA)

Under this theoretical study, the problems of steady drainage of two and three-layered soils have been solved. It has been deduced that solutions for soils with more than three layers can be obtained by following the same methods and procedures developed for the two and three-layered soils.

Five flow nets have been prepared for a two-layered soil. These flow nets show the effect of the hydraulic conductivity of the lower soil layer on the flow lines and equipotentials and on the maximum water table height above the drain centers. An additional flow net has been given for a three-layered soil.

Drain spacing formulas for the two and three-layered soils have been given. A set of 16 nomographs have been prepared for easy calculation of drain spacings in two-layered soils. In stratified soils, if the effect of a soil layer on the drain spacing is neglected, the resulting spacing would be in error. Expressions for calculating such errors have been developed and discussed for the two and three-layered soils. It has been shown that, for the two-layered soils, statements like "when the hydraulic conductivity of the upper layer is five to 10 times greater than that of the lower layer, the lower layer can be assumed to be impermeable" are misleading. Drain spacings calculated on the basis of the above statement may be as much as 25 to 40 percent smaller than the correct spacings, depending on the geometry of the flow system. Such errors will be larger if the hydraulic conductivity of the lower layer is higher than that of the upper layer. The errors will decrease as the thickness of the upper layer increases.

M. S. THESES

Le Blanc, Adrian D.
1967. Movement of radionuclides through soil. M. S. Thesis. Iowa State University. 87 p. (A-011-IA)

Three methods for determining hydraulic breakthrough were investigated using chloride and fluorescein as tracers. A titrimetric method using chloride as the tracer gave reproducible results for 50 gm and 100 gm soil columns. Fluorescein breakthrough curves obtained by using a calibration curve for fluorescein filtered through soil were reproducible and, when contact with air and glassware was minimized, were practically identical to these obtained using chloride as a hydraulic tracer. The breakthrough curves were practically the same for flowrates between 1 and 5 ml/min.

Tests were made to determine the effect of calcium concentration on cesium and strontium breakthrough. These tests showed that the strontium breakthrough to influenced by the calcium ion concentration and that reproducible breakthrough curves could not be obtained without strictly controlling the calcium concentration. Cesium breakthrough was affected less by calcium than was strontium, but the concentration of calcium was also controlled in the work that was done with cesium.

Breakthrough curves were obtained for various concentrations of cesium and strontium using calcium as a competing ion in a concentration of 50 mg/l. From these breakthrough curves adsorption isotherms were developed. From these same breakthrough curves the ratio (meq adsorbed/total meg passed) was obtained. This ratio was constant for a given percent breakthrough regardless of the cation concentration. Using these constants an equation was developed which describes the percent cation retained as a function of percent breakthrough. This together with the Langmuir isotherm provide a means of predicting any strontium or cesium breakthrough curve.

The effect of flowrate on the strontium breakthrough curves for 50 and 100 gm soil columns was determined using flowrates from 1 ml/min to 5 ml/min. The breakthrough curves obtained using the lower flowrate were displaced 1.5 sample volumes to the right of the curves obtained using the higher flowrate.

Using the hydraulic breakthrough curves, strontium and cesium breakthrough curves for 100 gm soil columns were predicted and compared with the actual curves. The predicted cesium breakthrough curve was almost identical to the actual curve. The predicted strontium breakthrough curve was to the left of the actual curve resulting in an error from 3 percent at 50 percent breakthrough to 25 percent at initial breakthrough.

Fifty gm and 100 gm soil colums equilibrated with cesium and with strontium solutions of given concentrations, were eluted with 50 mg/l calcium solutions to indicate their leaching characteristics. Strontium was found to reach an equilibrium plateau and as a result the leaching rate for strontium was less than the leaching rate of cesium.

Sanders, Dana Roy.
1967. Structure of Slope forests along the Des Moines River in central Iowa prior to impoundment. M.S. Thesis. Iowa State University. 106 p. (B-006-IA)

Transects down the slopes yielded data from which correlation matrices were prepared. However, the values obtained have limited significance because sample points were not randomly selected. Constellation diagrams of species interrelationships were also presented. From these the overall relationships which existed were shown.

In the random-point study, the vegetation was considered at three levels - the canopy, the tree reproduction, and the herbaceous layer. Each was sampled separately on 11 sites using appropriate sampling procedure.

The data obtained from each layer were summerized and compared by use of the continuum index. Stands occupying a low position along the index (1500-1800) were found to have a group of associated species.

Data made available by this study will be important in comparing the results obtained after flooding has occurred with composition prior to flooding. Hopefully, this comparison will lead to some predictions as to which species can be successfully grown along the periodically flooded slopes of the reservoir.

Tarman, D. W.
1967. Analysis of electrical resistivity measurements of shallow deposits. M. S. Thesis. Iowa State University. 75 p. (A-011-IA)

This study was designed to determine the most valid and economical method of interpretation of electrical resistivity data.

The Gish-Rooney method gave results in the drift-bed-rock area which were within 10 percent of the control depth approximately 75 percent of the time, with 70 percent of the remaining values falling within 15 percent of control. The method worked well in the shallow alluvial setting.

The cumulative method, in 53 percent of the cases, gave results which were within 10 percent of actual values with about half of the other 47 percent falling within 15 percent of control depths.

Fifty percent of the analyses using the Mooney-Wetzel method agreed with the control depths within 10 percent. The maximum electrode spread used in the study was considered near optimum for use with the Mooney-Wetzel method since longer spreads would have caused deeper penetration of the current into various layers of the bedrock. Any additional layers added to the system would cause a greater departure from the number of layers assumed in the use of the method.

Tagg's method did not give definite results for the data analyzed.

Although geologic control was very good there is still the possibility that some of the resistivity depths which did not correlate favorably with the control depths may reflect actual conditions. A relatively flat bedrock surface was assumed when interpolating between control points. If this assumption is not valid, the results of the study may have been much better than reported here.

When the small expense and ease of obtaining the data are considered, depth values within 10 or 15 percent can be considered quite good. Considerably better results may be expected when the method is applied to areas where the resistivity contrasts between the constituent layers are larger.

Nissen, Michael C.
1968. A study of variables which influence flood damage evaluation. M. S. Thesis. Iowa State University. 86 p. (A-001-IA)

Numerous physical and economic variables which influence flood damage evaluation have been studied. Various combinations and treatments of these variables are employed by the several methods for estimating average annual flood damage. The variables as used in the frequency method were found to be most consistent with the type of data available. That method was also considered to be the most generally applicable and flexible of the methods reviewed. A 3.3-mile reach of the Skunk River flood plain near Ames, Iowa was selected for crop and pasture flood damage evaluation using the frequency method. Not all variables involved in flood damage analysis by that method were varied. The value of average annual crop and pasture flood damage was not refined beyond the value associated with the series of annual peak discharges.

Ritter, W. F.
1968. Yield reduction of corn resulting from variable durations of inundation at different fertility levels. M.S. Thesis. Iowa State University. 71 p. (A-002-IA)

A flooding experiment has been carried out in which corn was inundated at various stages of growth for different durations of time. Two different levels of nitrogen fertilizer were used in the experiment to determine the effect flooding has on yield reduction at different nitrogen levels. In 1966, the corn plots were flooded for 24, 48, and 72 hours, respectively; at the 6 inch height, 30 inch height, and silking growth stages. In 1967, the corn plots were flooded at the same stages of growth, but for 48, 72, and 96 hours, respectively.

The results showed that corn was affected most when it was inundated at the early stages of growth. Flooding caused more damage to corn plants where 50 pounds of actual nitrogen per acre was used than corn plants that had nitrogen levels of 350 pounds per acre of actual nitrogen. The high nitrogen application rates, in some cases, had a greater effect than the excess water.

The artificial flooding of corn plots did not cause as much damage as natural flooding of potholes. Observations of potholes that were flooded by June rains revealed that corn plants were completely killed after four to five days inundation.

Soil samples taken after floodings showed that there was no accumulation of nitrogen in the top four feet of the soil profile. A large amount of nitrogen was lost during the inundation period. From the characteristics of the soil profile, this nitrogen would be leached through the soil profile entirely and enter the groundwater flow.

Selim, H. M.
1968. Temperature and moisture changes under evaporation in laboratory soil profiles as influenced by cracks. M. S. Thesis. Iowa State University. 158 p. (A-026-IA)

A two-dimensional model consisting of three identical compartments was used to study the influence of soil shrinkage cracks on heat and water redistribution during wind or radiative drying. The results showed that for soils with cracks the moisture content is lower compared to soils with no cracks. This decrease was as much as 5 to 10% moisture content but varied for the different soils and the evaporation treatment. The results also showed that, under wind, soil temperatures were lower at all depths for soils with cracks than with no cracks, whereas, under radiation, soil temperatures were higher near the surface for soil with cracks compared to soils with no cracks.

Because soil water movement in the unsaturated condition depends on the soil water diffusivity, two methods were used to determine this important parameter. In the study the two methods were used concurrently to determine the soil water diffusivity from horizontal infiltration of water into a soil column. The diffusivity results obtained showed satisfactory agreement between the two methods, which is an evidence of the validity of the unsaturated flow equation.

Sohn, Arnold J.
1968. Competitive recreational uses of selected Iowa lakes. M.S. Thesis. Iowa State University. 173 p. (A-005-IA)

A study to determine cycles and fluctuations in recreational activity was conducted during 1966 and 1967 on Clear, Spirit, Okoboji, and Little Wall lakes. Major emphasis was placed on summer activities, with checks of waterfowl hunting intensities on Eagle Lake and Ventura Marsh conducted during the fall hunting seasons. In addition to describing activity cycles, an attempt was made to analyze areas of present or future conflict between users. Primary sources of data included: Time-lapse movie camera records as indices to activity cycles; questionnaires to short-term visitors and permanent residents on the lakes; pneumatic car-counter records at park entrances and boat-launching ramps; line intercept counts of boat traffic; counts and location plottings of boats on the lakes; and interviews with lake personnel including Water Safety Patrol Officials, resort operators, and other businessmen located near the lakes.

Boast, Charles W.
1969. Potential flow to a piezometer or a well partially penetrating a porous medium. M. S. Thesis. Iowa State University. 71 p. (B-002-IA)

This thesis contains a solution to the boundary value problem of flow of water from a saturated flow medium into a well which only partially penetrates the flow medium. The well can be empty or partially full of water and can be unlined or partially or fully lined with an impermeable sheath. The flow medium can be bounded below by either on impermeable barrier or a constant head water source. Similarly the flow medium can be bounded laterally by either a barrier or a source, or it can be unbounded laterally. The upper boundary of the flow medium can be either impermeable, a constant head source, or a water table.

The solution is in the form of a function, which gives the hydraulic head at any point in the flow medium. The flow pattern is easily calculated from this hydraulic head function. If the upper boundary is a water table then the solution gives only the initial flow pattern, before the water table begins to fall and become curved.

In the solution the flow medium is divided into two regions, one below the well and one in the remainder of the flow medium. The method involves use of the Gram-Schmidt orthonormalization method. Results calculated by the method are compared to results obtained by others with electric analogs, with a relaxation technique, and with two other analytical techniques.

Carlson, Richard E.
1969. Measurement and analysis of the radiation characteristics of plants as a means of evaluating drought. M. S. Thesis. Iowa State University. 101 p. (A-031-IA)

Experiments were conducted during the summer of 1968 to examine the optical properties of individual corn, soybean and sorghum leaves with respect to relative leaf water content. In addition, the differences between dorsal and ventral reflectance were measured from crop leaves representing both monocotyledonous and dicotyledonous type leaves in order to evaluate the effectiveness of the palisade layer in the dicotyledonous type leaves as a source of scattering or absorption. Certain environmental factors (e.g. moisutre stress and nutrient stress) may cause quite marked effects on crop canopies. The initial step in this study was to determine the magnitude of these effects on the spectral properties of individual leaves. Reflectance difference between normal soybean leaves and soybean leaves from plants which had been subjected to an extended period of suboptimal moisture availability were compared. The spectral components of normal and nitrogen deficient corn leaves were also measured and compared. Soil reflectance is an important component of the total energy sensed from a crop canopy, therefore, soil reflectance was measured from vertically oriented soil samples for two soil types at various levels of soil moisture content.

Huggins, T. G.
1969. Production of channel catfish (Ictalurus punctatus) in tertiary treatment ponds. M.S. Thesis. Iowa State University. 120 p. (A-017-IA)

The effluent of the Ames Water Pollution Control Plant is emptied into the Skunk River. Because of the seasonal low flow of Skunk River the plant effluent has to be of a high quality to prevent severely polluting the river. This, together with the need for expansion of the Ames treatment plant, influenced the construction of a tertiary treatment pond in the spring of 1966.

During the fall of 1966 the pond had tremendous algal blooms and aquatic insect populations. Introduction of fish was considered in tertiary ponds to utilize the aquatic insects as food. If a desirable species of fish could live and grow in the ponds, an economic return could be attained by using these fish for restocking in other waters.

A series of four tertiary treatment ponds were constructed and data were collected on these ponds from June 1967 to September 1968. The objectives of the study were: 1) To see if fish could live and grow in these ponds, 2) To determine the potential production of fish in these ponds, 3) To describe the physical, chemical and biological features of these ponds.

Kline, K. J.
1969. Management of cattle feedlot wastes. M.S. Thesis. The University of Iowa. 195 p. (A-022-IA)

General conclusions of the study of hydrologic aspects of feedlot waste control are (1) The hydrologic aspects, rainfall, runoff, and stream flow, are the primary factors to consider in managing cattle feedlot runoff. This is evidenced by the fact that the nature, volume, and rate of delivery of runoff is directly related to rainfall. Storage requirements for retention facilities depend upon the volume of runoff. In considering disposal by controlled release to a stream, the retention pond discharge rate is proportional to the flow in the stream. (2) Terraces and retention ponds will reduce the pollution from cattle feedlot runoff. Evidence of this is shown by the reduction in suspended solids, BOD, and COD as a result of settling. Terraces will reduce the transport of solids from the lot and to some degree the volume of runoff. Retention ponds will reduce the suspended solids which in turn will result in BOD and COD reductions. (3) Application to land appears to be the most practical method of disposal for both the solids and the liquid. When applied to agricultural land, the waste has some economic value. The value may exceed the cost of application if the operation is carried on where land is available. To be economical, sufficient area must be available for crops to recover the plant nutrients from the waste. (4) Retention ponds may not remove sufficient amounts of suspended solids, BOD, COD, and nutrients to provide safe effluents for disposal to streams. It may be necessary to provide additional treatment and nutrient removal to protect water quality. The profit potential and the degree of concern of the feedlot owner for adequate waste treatment will dictate the type of treatment system that is practical and economical.

Koelliker, J. K.
1969. Soil percolation as a renovation means for livestock lagoon effluent. M.S. Thesis. Iowa State University. 111 p. (A-021-IA)

A field experiment was operated from June-September 1968 in central Iowa to study the use of a grass-covered, Clarion-Webster silty clay loam soil profile as a treatment media for anaerobic manure lagoon effluent applied by sprinkler irrigation equipment. The experimental plots were underdrained at 4-ft. depth to provide soil drainage.

Effluent was applied at four loading rates -- 1.5 and 3.0 inches at 70 percent available soil moisture and 1.5 and 3.0 inches at 95 percent available soil moisture, as measured at 6-12 inches deep. The amount of liquid applied ranged from 13.9-30.5 inches. These rates provided a rest period between applications, which allowed the profile to drain and reaerate, so that the integrity of the system was maintained.

Specific characteristics of the applied lagoon effluent studied as it percolated through the soil profile included COD (chemical oxygen demand), nitrogen, phosphorus, chloride, and pH. Samples were collected on the surface, 3, 6, 12, and 30 inches deep in the soil profile, as well as from water flowing from the tile drains in each plot.

All four loading rates gave similar results in renovation for the substances studied.

Mehta, S. C.
1969. Limnological factors affecting pesticide residues in the Iowa River and Coralville Reservoir. M.S. Thesis. University of Iowa. 70 p. (A-027-IA)

The pesticides P, P'DDT, O,P'DDT, P,P'DDE, P,P'DDD, aldrin, dieldrin, heptachlor, heptachlor epoxide, 1-hydroxy chlordene, alpha BHC, beta BHC and gamma BHC were all detected in one or the other of the water, algae, mud or fish samples. The concentrations of pesticides found in different samples varied from parts per trillion to parts per million range. The parts per trillion concentration of pesticides was detected in surface waters. Algae and fish contained pesticides in the range of parts per billion to parts per million.

The presence of pesticides in algae samples was not confirmed by thin-layer chromatography or microcoulometric gas chromatography. This leaves an area of further research. More algae samples should be analyzed to detect the presence of pesticides. The results obtained on gas-liquid chromatography should be further identified and confirmed by the methods mentioned above. Infra-red spectroscopic examination can also be employed to identify the different pesticides. Microscopic examination of algae samples to be analyzed for pesticides detection should be performed in order to determine the major forms of algae-storing pesticides.

The effect of Coralville Reservoir on concentrations of pesticides is many fold. The detention of water in the reservoir helps to precipitate and degrade some pesticides. Muds in the reservoir enhance precipitation and degradation. Increases in algae and other planktonic forms due to inundation of littorial areas by an

an increase in reservoir level help to reduce the concentrations of pesticide. Increase in storage area can sometimes increase the concentrations of pesticides due to increased flooding of terrestrial areas containing pesticides in the soil. There appears to be an improvement in the water quality at the downstream station below the dam as regards to pesticide concentrations.

Water samples at the conjunction of the Iowa River and Clear Creek should be analyzed to determine the effects of Clear Creek on the water quality of the Iowa River at the University Water Treatment plant. More water samples should be analyzed from Lake Station 2 to determine overall effects of the reservoir on the types and concentrations of pesticides released into the Iowa River.

Fish were found to contain a minimum of 0.034 ppm of dieldrin, which is sufficient to kill 50 percent of fathead minnows in a 96 hour period. Though nothing could be said about the adverse effects of dieldrin on the different activities of the fish, it is certain that the concentrations of pesticides detected in fish were not sufficient to kill the fish. Primarily channel catfish and carp were collected in this study.

Usinowica, Paul J.
1969. Limnological factors affecting odors and odor control at the University of Iowa Water Treatment Plant. M.S. Thesis. University of Iowa. 90 p. (A-028-IA)

Odors and odor control in the Iowa River are influenced by varying factors throughout the year. The three major odor problem periods each seem to be related to separate factors and cause different effects on the quality of the product water from the University Water Treatment Plant. Because the water plant cannot effectively control all odor problems by use of breakpoint chlorination and activiated carbon application, the applications of other treatment methods should be carefully studied and evaluated for the water plant. Furthermore, if the quality of the river water continues to decline and effective treatment methods are not found, the development and use of the well at the water plant as the raw water source must be seriously considered.

Vanderholm, D. H.
1969. Field treatment and disposal of livestock effluent by soil percolation. M.S. Thesis. Iowa State University. 65 p. (A-021-IA)

The results of this study indicate that spray irrigation of livestock lagoon effluent on agricultural land is a feasible solution to the problem of disposal. The soil profile provides an excellent medium for treatment of the effluent, thereby greatly decreasing the potential pollution hazards to ground and surface

waters created by livestock wastes. Under proper management, it is possible to prevent any general nuisance problems from occurring. Selection of criteria to evaluate renovation performance is difficult. A comparison with common treatment systems used for municipal and industrial wastes can be made, but since these usually discharge only to surface waters, the long-term effects may differ. In most instances, addition to the ground water will be the ultimate disposal route using a soil system. Since ground water movement rates are normally slow, a buildup of the treated waste may occur in the vicinity of the disposal area over long-term operation. Because of this, it may be necessary to specify a different set of standards for successful use of the soil profile for livestock waste treatment and disposal.

Khan, Muhammad Y.
1970. Steady state flow around a well in unconfined stratified aquifer. M.S. Thesis. Iowa State University. 82 p. (B-013-IA)

This thesis presents an analysis, by setting up a boundary value problem with 8 boundary conditions, of a three-dimensional steady flow around a well penetrating an entire two-layered aquifer with an outer boundary of constant hydraulic head. Expressions for the hydraulic head distribution and the stream function for steady flow in the region have been developed and used effectively to obtain the following relation between the well discharge and the drawdown at the face of the well.

$$\frac{H}{r_w} = \left\{\left(\frac{a_1}{r_w} + \frac{a_2 k_2}{k_1}\right)^2 + \frac{\ln k}{k_1}\left[\frac{Q}{\pi r_w^2} - 2RF(k)\right]\right\}^{1/2} - \left(\frac{a_1}{r_w} + \frac{a_2 k_2}{r_w k_1}\right)$$

where H is the well drawdown induced by the constant discharge Q; r_w is the radius of the well; k_1 and k_2 are the hydraulic conductivities of the upper and the lower strata, respectively; a_1 and a_2 are the thickness of the upper and the lower strata respectively; R is the steady vertical recharge; F(k) is a dimensionless function of $k = r_e/r_w$ (that is, the ratio between the radii of the outer boundary and the well).

A set of three computer programs are given to determine the water table height at any radius r, maximum value of the water table, the critical radius where the height of the water table is maximum, and coordinates of equipotentials and stream lines.

Two sets of flow nets, for $r_e/r_w = 100$ and $r_e/r_w = 500$, have been prepared to show three different flow situations and the effect of the hydraulic conductivity of the lower stratum on equipotential lines, stream lines and the water table height.

Kumar, S.
1970. Effect of channel straightening on the movement of flood waves on Boyer River. M.S. Thesis. Iowa State University. 101 p. (B-005-IA)

Many Iowa rivers have been straightened and leveed with the objective of achieving drainage and flood control on the riparian land. Although these methods have proved beneficial to the land along the reach straightened, they have often resulted in damage to the downstream land owner's property by increasing the discharge, thus forcing the downstream owners to repair or improve their part of the channel. Litigation among drainage districts often results with downstream districts claiming partial reimbursement of the construction and maintenance costs from the districts upstream.

This study was conducted to evaluate the physical effects of river straightening on the movement of flood waves with the objective of arriving at a method for the equitable apportionment of construction and maintenance costs among beneficiaries.

Factors consisting of three spacial patterns of rainfall, three conditions of rainfall timing, two runoff amounts and three values of Manning's roughness coefficient were utilized to investigate their effect on the flood wave characteristics. Two conditions of partial straightening of the river were also investigated. The convex method of flood routing was employed. Hydrograph characteristics studied were (1) attenuation of the flood wave as it moves down the river, (2) change of discharge after straightening, (3) duration of flooding along the river, (4) time to peak, and (5) time of arrival of flood wave at a station.

A method based upon these wave characteristics is proposed whereby the apportionment of costs may be determined.

Keywords: Mathematical model, watershed hydraulics, drainage, and Iowa.

ANNUAL REPORTS

Kirkham, Don and A. W. Warrick.
1967. Annual Report of the Iowa State Water Resources Research Institute for FY 1967. Iowa State University, Iowa State Water Resources Research Institute. 102 p.

Kirkham, Don and Sadik Toksöz.
1968. Annual Report of the Iowa State Water Resources Research Institute for FY 1968. Iowa State University, Iowa State Water Resources Research Institute. 108 p.

Kirkham, Don and Sadik Toksöz.
1969. Annual Report of the Iowa State Water Resources Research Institute for FY 1969. Iowa State University, Iowa State Water Resources Research Institute. 105 p.

Kirkham, Don and Norris L. Powell.
1970. Annual Report of the Iowa State Water Resources Research Institute for FY 1970. Iowa State University, Iowa State Water Resources Research Institute. 174 p.

LIST OF PROJECTS FUNDED BY ISWRRI

A-001-IA.
Economic factors in the establishment of water quality stream standards.
Principal investigator: Merwin D. Dougal

A-002-IA.
Evaluation of flood damage to corn from controlled depth and frequency of flooding.
Principal investigator: Craig E. Beer

A-003-IA.
Moisture movement to vertical sinks in water-unsaturated soil.
Principal investigator: Don Kirkham

A-004-IA.
Recession characteristics of Iowa streams.
Principal investigator: J. W. Howe

A-005-IA.
Competitive recreational uses of selected Iowa lakes.
Principal investigator: Arnold O. Haugen

A-006-IA.
Discharge -- valley form relationships of selected Iowa streams.
Principal investigator: Neil E. Salisbury

A-007-IA.
To collect, characterize, and study the biodegradability and the chemical oxidation of carbon-adsorbed materials from effluents from sewage plants.
Principal investigator: Owen Sletten

A-008-IA.
Diatoms and pollen in sediments of an Iowa lake
Principal investigator: John D. Dodd

A-009-IA.
Preimpoundment survey of vegetation of Saylorville Dam impoundment area.
Principal investigator: Roger Q. Landers

A-010-IA.
Legal aspects of the small watershed program in Iowa.
Principal investigator: N. William Hines

A-011-IA.
The movement of radionuclides through soil formations.
Principal investigators: Charles Oulman
Lyle V. A. Sendlein

A-012-IA.
Geology of the regalith aquifers of the Nishnabotna Basin.
Principal investigators: Keith M. Hussey
Lyle V. A. Sendlein

A-013-IA.
Properties of tile drainage water.
Principal investigator: T. L. Willrich

A-014-IA.
Influence of geohydrology on landscape and soil formation.
Principal investigator: Robert V. Ruhe

A-015-IA.
Laboratory investigation of flow in river bends.
Principal investigators: Hunter Rouse
Emmett M. O'Loughlin
Chin-Lien Yen

A-016-IA.
Reoxygenation of Iowa streams.
Principal investigators: H. Sidwell Smith
Donald B. McDonald

A-017-IA.
Feasibility of fish production in tertiary waste treatment ponds.
Principal investigator: Roger W. Bachmann

A-018-IA.
Economic analysis of alternative water pollution control measures.
Principal investigator: Jerald R. Barnard

A-019-IA.
Model flood plain zoning ordinance.
Principal investigator: N. William Hines

A-020-IA.
The energy loss of flow around alluvial-channel bends.
Principal investigator: Emmett M. O'Loughlin

A-021-IA.
Soil filtration to reduce pollution potential of lagoon effluent entering the groundwater system.
Principal investigators: Craig E. Beer
J. Ronald Miner

A-022-IA.
Management of Cattle feedlot wastes.
Principal investigator: Richard R. Dague

A-023-IA.
Waterfowl populations and recreational use patterns in the Saylorville Reservoir area as related to pre-impoundment conditions.
Principal investigator: Arnold O. Haugen

A-024-IA.
Development of a mathematical model for the simulation of flat-land watershed hydraulics.
Principal investigator: Howard P. Johnson

A-025-IA.
Development of pulsating adsorption filter for tertiary treatment of waste waters.
Principal investigator: Robert L. Johnson

A-026-IA.
Simultaneous flow of water and heat in water-unsaturated Iowa soils during evaporation.
Principal investigator: Don Kirkham

A-027-IA.
Limnological factors affecting pesticide residues in surface waters.
Principal investigators: Donald B. McDonald
David Mick

A-028-IA.
Effects of limnological factors on water treatment.
Principal investigators: Donald B. McDonald
Neil B. Fisher

A-029-IA.
Effects of river curvature on resistance to flow.
Principal investigators: John F. Kennedy
John R. Glover

A-030-IA.
Interrelationship of surface and subsurface flow in the Nishnabotna Drainage Basin.
Principal investigators: Lyle V. A. Sendlein
Keith M. Hussey

A-031-IA.
Measurement and analysis of the radiation characteristics of plants as a means of evaluating drought.
Principal investigators: Robert H. Shaw
Douglas N. Yarger

A-032-IA.
Treatment of aqueous agricultural wastes for clean water and for microbial protein production.
Principal investigator: George T. Tsao

A-033-IA.
Rational institutional arrangements for water resource management.
Principal investigator: N. William Hines

A-034-IA.
Relationship of hydrology and soils to gully growth.
Principal investigator: Howard P. Johnson

A-035-IA.
Effects of stream channelization on fishes and bottom fauna in the Little Sioux River, Iowa.
Principal investigator: Robert J. Muncy

A-036-IA.
Development of model for pricing water in providing a basis for allocating water among competing uses.
Principal investigators: John F. Timmons
James Prescott

A-037-IA.
Sociological aspects of water-based recreation in Iowa.
Principal investigator: Dean R. Yoesting

A-038-IA.
Economic factors affecting change in the intensity of flood plain use.
Principal investigator: Jerald R. Barnard

A-039-IA.
Plant species as wildlife cover and erosion control on "mudflats" in Iowa's large reservoir systems.
Principal investigator: Roger Q. Landers

A-040-IA.
Natural mixing and transfer processes for thermal loads in streams.
Principal investigator: William W. Sayre

B-001-IA.
Iowa water permit study.
Principal investigator: N. William Hines

B-002-IA.
Groundwater seepage patterns to wells for unconfined flow.
Principal investigator: Don Kirkham

B-005-IA.
Physical, legal and economic aspects of assessment of costs among drainage districts.
Principal investigators: N. William Hines
H. P. Johnson

B-006-IA.
Structure of forest vegetation bordering the Saylorville Impoundment.
Principal investigator: Roger Q. Landers

B-009-IA.
An analysis of the economic implications of the permit system of water allocation.
Principal investigator: Neil E. Harl

B-011-IA.
An economic analysis of organizations of water users.
Principal investigators: Charles W. Meyer
J. Ronnie Davis

B-013-IA.
Flow of water into tile drains in stratified soils.
Principal investigator: Sadik Toksoz

B-015-IA.
Development of models for analyzing water resources development and use within a regional framework.
Principal investigators: John F. Timmons
James Prescott

B-017-IA.
Determining the demand and economic values of water recreation resources at MacBride State Park, Iowa.
Principal investigators: Martha M. Glascock
Jerald Barnard

B-018-IA.
Hydrologic response of ice-covered streams.
Principal investigator: John F. Kennedy

B-019-IA.
Groundwater seepage patterns to wells for unconfined flow-phase II.
Principal investigator: Don Kirkham