1990

35th Annual Midwest Groundwater Conference Program with Abstracts

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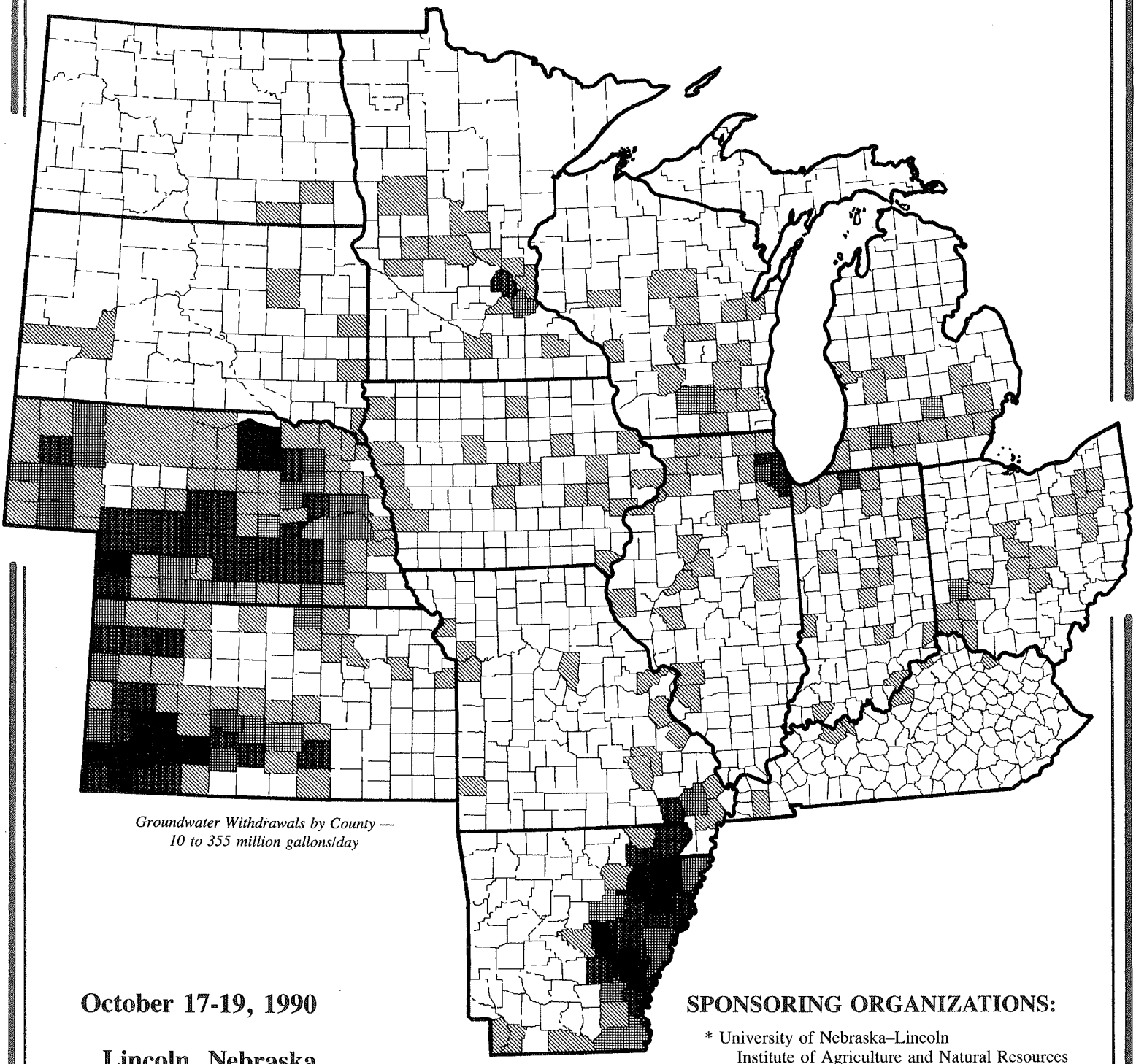
35TH ANNUAL

MIDWEST GROUNDWATER CONFERENCE

PROGRAM WITH ABSTRACTS



Groundwater Withdrawals by County — 10 to 355 million gallons/day

October 17-19, 1990

Lincoln, Nebraska

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* Nebraska Groundwater Foundation
* Water Resources Division, U. S. Geological Survey

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35th ANNUAL MIDWEST GROUNDWATER CONFERENCE

The Midwest Groundwater Conference began in 1956 in Urbana, Illinois, to promote the exchange of ideas and perspectives between state-supported groundwater professionals working in the midwestern states. Over the years, the meeting has continued to provide an informal setting for discussion and presentation of groundwater issues and research. Papers are not published in order to encourage presentation of new ideas and on-going research. Recent years have brought increasing problems in managing and protecting our groundwater resources. Therefore, it is more important than ever to encourage communication among groundwater specialists to meet the challenges of the future.

We at the University of Nebraska are happy to host the 1990 conference. We hope your visit to Nebraska will be productive and enjoyable.

Sponsoring Organizations

* Conservation and Survey Division, Institute of Agriculture and Natural Resources (IANR), University of Nebraska-Lincoln
* Water Center, IANR, University of Nebraska-Lincoln
* Agriculture Research Division, IANR, University of Nebraska-Lincoln
* Department of Geology, University of Nebraska-Lincoln
* Nebraska Groundwater Foundation
* Water Resources Division, U. S. Geological Survey, Lincoln, NE

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In addition, we gratefully acknowledge the staff of the Conservation and Survey Division for their help in program development, registration, and many other areas which made this conference possible.

PROGRAM

WEDNESDAY, OCTOBER 17

4:00 - 8:00 p.m. Registration and Cash Bar, Hilton Hotel Lobby

THURSDAY, OCTOBER 18

7:45 - 10:00 a.m. Registration in Hotel Lobby. All conference sessions in Hotel Ballroom.

8:10 - 8:15 INTRODUCTIONS: Bob Kuzelka, Conservation and Survey Division and Water Center, UNL

8:15 - 8:20 WELCOME: Irvin T. Omtvedt, Vice Chancellor, Institute of Agriculture and Natural Resources, UNL

8:20 - 9:00 KEYNOTE ADDRESS: Is There a Federal Groundwater Policy?: Jeffrey A. Zinn, Specialist in Natural Resources Policy, Congressional Research Service, Washington, D.C.

GENERAL SESSION: Governmental Roles in Groundwater

Moderator: Bob G. Volk, Director, University of Nebraska Water Center

9:00 - 9:20 Federal Agencies' Roles in Groundwater: B. Fenemore, Office of Groundwater Protection, U. S. Environmental Protection Agency, Kansas City, KS

9:20 - 9:40 State and Local Government Agencies' Roles in Groundwater: G. Hutton, Nebraska Department of Environmental Control

9:40 - 10:00 Indiana's Water Rights Statute - Does the Law Really Work?: M. E. Basch and R. K. Reynolds, Department of Natural Resources, Indianapolis, IN

10:00 - 10:20 COFFEE BREAK

10:20 - 10:40 Midwestern and Western State Regulation of Agricultural Chemical Use: J. D. Aiken, Department of Agricultural Economics, UNL

10:40 - 11:00 Nebraska's Special Protection Area Program - Progress and Prospects: D. Ehrman, Nebraska Department of Environmental Control

11:00 - 11:20 Statewide Pesticide Monitoring in Minnesota: J. W. Hines, Minnesota Department of Agriculture

11:20 - 11:40	Five-Year Study Looking at Factors Influencing Groundwater Contamination in Rural Nebraska: J. Daniel, Nebraska Department of Health
11:40 - 1:00	LUNCH (on your own)

CONCURRENT SESSIONS

Session #1 - Geophysical Applications to Groundwater

Moderator: Eric M. Durrance, Chair, Department of Geology, UNL

1:10 - 1:30 p.m.	Conjunctive Use of Geophysical and Geological Data in the Construction of a Groundwater-Flow Model: J. F. Ayers, Conservation & Survey Division, UNL
1:30 - 1:50	Geoelectrics for Defining Transport Properties for Groundwater Pollution Studies: W. E. Kelly, Dept. of Civil Engineering, UNL, and O. Mazac and S. Mares, Prague, Czechoslovakia
1:50 - 2:10	Geoelectrics and Geostatistics for Characterizing Groundwater Protection Zones: W. E. Kelly and I. Bogardi, Department of Civil Engineering, UNL, and A. Bardossy, University of Karlsruhe, West Germany
2:10 - 2:30	Use of Seismic Refraction to Determine the Depth to Water and Saturated Thickness of an Alluvial Aquifer Along Rapid Creek, Rapid City, SD: E. A. Greene, U. S. Geological Survey, Rapid City, SD

Session #2 - Computer Applications to Groundwater

Moderator: You-Kuan Zhang, Conservation and Survey Division, UNL

1:10 - 1:30	Use of Multiple Regression to Relate Environmental Factors to the Concentrations of Nitrate and Atrazine in Groundwater in Nebraska: A. H. Chen and A. D. Druliner, U. S. Geological Survey, Lincoln, NE
1:30 - 1:50	Simulation of Groundwater Movement in a Shallow Unconfined Aquifer with Agricultural Contamination: V. Zlotnik, Department of Geology, UNL

1:50 - 2:10 Optimizing Water-Use in Nonlinear Aquifer Systems by Using a Coupled Optimal Management Model and a Ground-water Simulation Model: J. M. Peckenpaugh, U. S. Geological Survey, Lincoln, NE, and D. T. Pederson, Conservation and Survey Division and Department of Geology, UNL

2:10 - 2:30 Modeled and Actual Patterns of Groundwater Level Declines in Nebraska: R. K. Davis, Department of Geology and D. T. Pederson, Conservation and Survey Division and Department of Geology, UNL

2:30 - 3:00 COFFEE BREAK

Session #3 - Impacts of Climatic Change on Groundwater

Moderator: Blaine L. Blad, Chair, Department of Agricultural Meteorology, UNL

3:00 - 3:20 Nebraska's Drought Assessment Response Team: George Beattie, Nebraska Department of Agriculture

3:20 - 3:40 ***WITHDRAWN*** Climate Change and the Seasonal and Annual Ground-Water Balance: J. A. Bowman, K. P. Bowman and C. Ray, Illinois State Water Survey, Champaign, IL

3:40 - 4:00 Impact of Climatic Changes on Groundwater Remediation Projects: J. K. Powers, Leggette, Brashears and Graham, St. Paul, MN

4:00 - 4:20 Climatic Variability and the Coupling of Surface Water and Groundwater: R. W. Buddemeier and T. J. McClain, Kansas Geological Survey, Lawrence, KS

4:20 - 4:40 Use of Short-term Climatic/Ground-Water Relations to Estimate the Effects of Long-term Climatic Variations on Groundwater Conditions in the High Plains: J. T. Dugan, U. S. Geological Survey, Lincoln, NE

Session #4 - GIS/Remote Sensing Applications to Groundwater

Moderator: Mike Shulters, District Chief, Water Resources Division, U. S. Geological Survey, Lincoln, NE

3:00 - 3:20 Groundwater Resources for Expanded Subirrigation in the Saginaw Bay Valley, MI: B. E. Vieux and C. He, Department of Resource Development, Michigan State University, East Lansing, MI

3:20 - 3:40 Use of ARC/INFO Geographic Information System for Regional Aquifer Studies at the Kansas Geological Survey: D. O. Whittemore, S. Shamsnia and T-M. Chu, Kansas Geological Survey

3:40 - 4:00 Application of GIS Procedures to a Groundwater Model in Southwest Nebraska: J. M. Peckenpaugh, U. S. Geological Survey, Lincoln, NE

4:00 - 4:20 Multiple Cell Solute Transport Model, Cell Size Error Analysis Using a Geographic Information System: D. Adelman and S. Soberski, Nebraska Natural Resources Commission

4:20 - 4:40 Using GIS to Evaluate Performance of the DRASTIC Model: J. W. Merchant, Conservation and Survey Division, UNL

BANQUET, Hilton Hotel Lower Level

5:30 - 6:30 Cash Bar

6:30 Dinner

Moderator: Perry Wigley, Director, Conservation and Survey Division, UNL

Introductions: Gordon Kissel, Executive Director, Nebraska Association of Resources Districts, Lincoln, NE

Invited Speaker: Senator Bob Kerrey, D-NE, "The Natural Resources District Experience in Nebraska"

FRIDAY, OCTOBER 19

7:30 - 8:15 a.m. Continental Breakfast, Hilton Ballroom

GENERAL SESSION: Chemical Aspects of Groundwater

Moderator: David C. Gosselin, Conservation and Survey Division, UNL

8:20 - 8:40 Plans for the Artificial Recharge of a Glacial Aquifer in Eastern South Dakota: P. J. Emmons, U. S. Geological Survey, Huron, SD, V. R. Schaefer, and D. E. DeBoer, Department of Civil Engineering, South Dakota State University, Brookings, SD

8:40 - 9:00	Ground-Water Quality Investigation of the Lake Calumet Area of Southeast Chicago: S. J. Cravens, Illinois State Water Survey
9:00 - 9:20	Ground-Water Quality in the Nemaha Natural Resources District, Southeastern Nebraska: D. Q. Tanner and G. V. Steele, U. S. Geological Survey, Lincoln, NE
9:20 - 9:40	Summary of the Iowa State-wide Rural Well-Water Survey: D. R. Bruner, R. D. Libra, G. R. Hallberg, Iowa Dept. of Natural Resources and B. C. Kross, Department of Preventative Medicine, University of Iowa, Iowa City, IA
9:40 - 10:15	COFFEE BREAK
10:20 - 10:40	Occurrence of Herbicides and Nitrate in the Missouri River Alluvial Aquifer from the Iowa Border to Miami, MO: D. W. Blevins, A. C. Ziegler, U. S. Geological Survey, Independence, MO and G. M. Carlson, Missouri Department of Health, Jefferson City, MO
10:40 - 11:00	Determination of Atrazine, Alachlor and Selected Degradation Products in Contaminated Groundwater: D. B. DeLuca, Department of Land Resources, and W. Sonzogni, Department of Civil Engineering, University of Wisconsin, Madison, WI
11:00 - 11:20	Analysis of Chemigation Risk: D. E. Eisenhauer, Department of Biological Systems Engineering, UNL
11:20 - 11:40	A Critical Evaluation of Agricultural Chemical Policy Performance on Groundwater Protection: E. P. Ditschman, Institute of Water Research, J. R. Black and J. P. Hoehn, Department of Agricultural Economics, Michigan State University, East Lansing, MI
11:40 - 12:00	Wrap-Up and Adjourn

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ABSTRACTS

35th Annual Midwest Groundwater Conference

KEYNOTE ADDRESS

Is There a Federal Groundwater Policy?

THURSDAY, OCTOBER 18

8:20 - 9:00 am

IS THERE A FEDERAL GROUNDWATER POLICY?

Jeffrey Zinn
Specialist in Natural Resources Policy
Environment and Natural Resources Policy Division
Congressional Research Service
Washington, D.C.

In the past, federal groundwater policies and initiatives have emerged somewhat haphazardly from agency to agency. Congress has generally fostered this situation by providing relatively little direction. The situation is changing now, however, and numerous congressional committees are considering legislation that would clarify federal policy, make federal programs more consistent, and support enhanced federal efforts to address groundwater concerns.

The presentation will review and comment on congressional considerations of groundwater legislation during the 101st Congress. The ideas and approaches making their way through the legislative process will be emphasized (farm bill provisions are an example), as will changing congressional perspectives on the appropriate federal role in groundwater policy as new information becomes available and as states continue to move ahead with their own programs.

GENERAL SESSION

Governmental Roles in Groundwater

THURSDAY, OCTOBER 18

9:00 - 11:40 am

FEDERAL AGENCIES' ROLES IN GROUNDWATER

Bob Fenemore, Acting Director
Office of Groundwater Protection
U.S. Environmental Protection Agency - Region VII
Kansas City, Kansas

EPA is generally acknowledged to be the dominant federal agency addressing groundwater issues. Its regulatory responsibilities and programs, in partnership with state environmental agencies, focus on preventing groundwater contamination and ensuring the continued use of the resource as a drinking-water supply. Other federal agencies--principally USDA, USGS, U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation--are becoming more involved in groundwater issues by providing technical support to federal and state regulatory agencies.

Federal agencies also have a major role in cleanup of groundwater contamination caused either as the result of their own past activities, or by the actions of others. These cleanup efforts usually are resource intensive and require large expenditures by the federal government over many years and reinforce the need to prevent groundwater contamination rather than to focus on after-the-fact cleanup efforts.

STATE AND LOCAL GOVERNMENT AGENCIES' ROLES IN GROUNDWATER

U. Gale Hutton, Chief
Water Quality Division
Nebraska Department of Environmental Control
Lincoln, Nebraska

The importance of an abundant supply of high quality ground water to the past, present and future of this nation is widely recognized. However, in many areas of the United States, ground waters have been degraded beyond acceptable quality as the result of human activities.

In order to accomplish comprehensive ground-water quality management, a well-coordinated division of responsibility at all levels of government is needed. The federal roles must include research on health-based risk levels for contaminants and remediation technologies, technology transfer, maintenance of a national clearing house for information, and responsible coordination of all existing ground-water related programs within the multiple federal offices.

Ground water is so widely variable with regard to quality, uses, occurrence, and hydrogeologic settings that it must be managed through state and local programs tailored to protect against specific threats. States must take the lead role in the development and implementation of comprehensive ground-water programs. This should involve the development of management strategies, standard setting, monitoring, assessment, development of source control measures, education, remediation oversight, close coordination with local governments, and funding.

Implementation on the grass roots level has been and will continue to be the most effective method for implementing many programs, particularly for nonpoint-source ground-water issues. Clearly, the success of any comprehensive ground-water program will hinge on the aggressive participation of local governments in protecting highly vulnerable ground waters against sources and contaminants within their jurisdiction.

INDIANA'S WATER RIGHTS STATUTE: DOES THE LAW REALLY WORK?

Mark E. Basch and Robert K. Reynolds
Indiana Department of Natural Resources
Division of Water
Indianapolis, Indiana

Indiana's Water Rights--Emergency Regulation Statute (Indiana Code 13-2-2.5) provides protection for domestic well owners against the impacts of nearby high-capacity ground-water withdrawal facilities. The law became effective statewide on September 1, 1985. Since then, the Department of Natural Resources Division of Water has investigated nearly 350 complaints from domestic well owners who believed their water supplies were being affected by high-capacity pumpage. In order to demonstrate how the Water Rights statute is implemented, two specific water-use conflicts will be presented as "case studies."

The first case study involves domestic well failures resulting from high-capacity pumpage by the towns of Berne and Decatur, located in Adams County in northeastern Indiana. Results from the Division of Water's investigation indicated that only those wells completed in the unconsolidated aquifer present in the area were believed to have been affected by the pumpage. The cost of providing the affected domestic well owners with an alternate water supply was distributed between the towns of Berne and Decatur.

The second case outlines the impacts on domestic wells caused by a dewatering operation occurring on the northeast side of Indianapolis. Ground-water pumpage was necessary for the construction of a lake in a new subdivision being developed in the area, and several adjacent domestic wells failed as a result of the water-level declines. Under the provision of the Water Rights Statute, the development corporation was required to provide compensation to the affected homeowners.

MIDWESTERN AND WESTERN STATE REGULATION OF AGRICULTURAL CHEMICAL USE

J. David Aiken, Assoc. Professor
Department of Agricultural Economics
University of Nebraska-Lincoln

A major environmental and agricultural issue is pollution of ground water from field application of agricultural pesticides and fertilizers. Current EPA pesticide regulations do not reduce the likelihood of drinking-water contamination from field application, although EPA's pending Pesticides in Ground Water Strategy will change this when implemented. In addition, EPA cannot regulate fertilizer use. Thus, there are no current federal regulatory programs designed to limit ground-water contamination from field application of agrichemicals.

To fill this regulatory void, several midwestern and western states have established programs regulating agrichemical use to prevent ground-water contamination. These include:

-- Chemigation regulations in several states, including Nebraska, Kansas and Colorado;

-- Pesticide use regulations in Wisconsin, where pesticide use restrictions are triggered when 20-50 percent of the drinking water limit for that pesticide has been reached;

-- Arizona pesticide- and fertilizer-use regulations, which include mandatory statewide fertilizer-use best management practices (BMPs);

-- Nebraska and Montana agrichemical-use regulation, where fertilizer or pesticide contamination has been detected in critical areas;

-- Kansas pesticide management areas;

-- Iowa pesticide-use regulations and agrichemical checkoffs; and;

-- California pesticide-use regulations, including Proposition 65.

These programs illustrate the range of current state policies for controlling ground-water contamination from agrichemical application.

NEBRASKA'S SPECIAL PROTECTION AREAS: PROGRESS AND PROSPECTS

Dick Ehrman, Unit Supervisor
Planning/Assessment Unit
Ground Water Section
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Lincoln, Nebraska

Since its creation in 1986, Nebraska's Special Protection Area (SPA) program has provided the state with additional options in management of nonpoint-source (NPS) ground-water contamination. Acting upon requests from local governmental agencies, the Nebraska Department of Environmental Control (NDEC) studies areas for evidence of NPS contamination. If NPS pollution exists or is likely, NDEC can then declare an SPA. At that time, the local Natural Resources District (NRD) must prepare an action plan, utilizing education, best management practices, and other means to deal with the problem. Progress is evaluated by an NRD monitoring network and by annual reports.

After three years of studies, and declaration of the first SPA in south-central Nebraska around Superior, several observations have become evident:

1. The SPA program has been very successful in forging stronger state-NRD relationships, improving knowledge of Nebraska's ground-water quality, and increasing visibility of the NPS program.

2. Current levels of funding for NDEC's program efforts are barely adequate for current activities and are inadequate for any more sophisticated study or evaluation techniques.

3. In small or largely rural SPAs, the NRDs' additional taxing authority of two mills (2/10 of a cent) for program administration is inadequate.

4. The one-year time frame for SPA studies is inadequate, especially in large areas.

5. Most NRDs require financial and/or technical assistance to establish reliable monitoring networks.

The SPA program is still largely in its adolescence. With implementation of the first and subsequent SPAs, the program can continue to grow in activity and effect.

STATEWIDE PESTICIDE MONITORING IN MINNESOTA

John W. Hines, Supervisor
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St. Paul, Minnesota

The Minnesota Department of Agriculture (MDA) monitors for pesticides in ground water throughout the state. The department's efforts are based around the central philosophy that a well-designed monitoring program will provide information on changes in water quality with time and on the spatial characteristics of state water quality. This information is necessary in order to understand how current and revised pesticide-use practices affect water quality; such an understanding is crucial to the successful formulation and implementation of effective policy regarding pesticide use and groundwater quality.

To date there is up to five years of quarterly data on 25 wells in surficial sand aquifers of the state. An additional 100 wells in various aquifers have been sampled on varying frequencies over the past three to five years. Atrazine is the most frequently detected pesticide, usually occurring at sub part-per-billion concentrations. Atrazine is the only pesticide occurring frequently enough for trend analysis as other pesticides occur infrequently. Generally, atrazine concentration has tended to decrease during the recent 41-month drought, although this decrease is not statistically significant.

The information generated during monitoring activities is an integral part of the state's pesticide-management plan program. Special monitoring projects designed to answer specific questions or monitor certain conditions are also undertaken.

FIVE-YEAR STUDY LOOKING AT FACTORS INFLUENCING GROUNDWATER CONTAMINATION IN RURAL NEBRASKA

Jack Daniel, Division Director
Environmental Safety
Nebraska Department of Health
Lincoln, Nebraska

The Nebraska Department of Health (NDOH), through a cooperative agreement with the Centers for Disease Control, investigated approximately 2,000 private rural wells in Nebraska from 1985-1989. The objective was to characterize the drinking-water quality and to increase the NDOH's capability to monitor occupational safety and health. Water samples were analyzed for coliform bacteria, nitrate-nitrogen, 13 pesticides, and gross alpha, a measure of naturally occurring radiation. Comparison of the various contaminants with well construction type, well depth, soil types and land use, and distance of the well from a feedlot or barnyard were conducted to determine the factors that contribute to the contamination of these wells.

The study showed that the highest level of nitrate contamination was found in the northeastern part of the state, as well as through the Central Platte Valley. This type of contamination was correlated mainly with shallow wells terminating in a pit or depression. High nitrate levels frequently were found to occur with coliform contamination, as well as detectable levels of pesticides. Coliform contamination was mostly detected in old wells. High alpha radioactivity occurred mainly in the western part of the state and was attributed to uranium and associated with shallow wells. Numbers of rural domestic wells contaminated with pesticides were much less than expected.

CONCURRENT SESSION #1

Geophysical Applications to Groundwater

THURSDAY, OCTOBER 18

1:10 - 2:30 pm

CONJUNCTIVE USE OF GEOPHYSICAL AND GEOLOGICAL DATA IN THE CONSTRUCTION OF A GROUNDWATER-FLOW MODEL

Jerry F. Ayers, Assoc. Professor
Conservation and Survey Division
and Department of Geology
University of Nebraska-Lincoln

Geophysical survey information combined with test-hole logs were used as the data base for the construction of a numerical model to simulate groundwater flow and the impact of pumping on part of the lower Platte River alluvial aquifer located in eastern Nebraska. The hydrogeologic framework of the study area was determined from the interpretation of seismic-refraction data, shallow seismic-reflection profiles, and vertical electrical soundings. Seismic-survey results calibrated to test-hole logs provided the basis to map the areal extent of the complex bedrock surface beneath the study area. Results of the geoelectric survey were used to map the areal extent and thickness of a near-surface, low-permeability unit along the western margin of the Platte Valley floodplain. Geophysical data was also used to estimate the bulk density and porosity of the aquifer. Utilizing all of the field data available, a groundwater-flow model was designed to simulate a two-layer system in which part of the aquifer is under confined flow conditions. The model was then applied to the study area to evaluate the impact of pumping from a well field that provides municipal water to the City of Lincoln.

GEOELECTRICS FOR DEFINING TRANSPORT PROPERTIES FOR GROUND-WATER POLLUTION STUDIES

William E. Kelly, Chair
Department of Civil Engineering
University of Nebraska-Lincoln

O. Mazac and S. Mares
Prague, Czechoslovakia

Surface geoelectrical methods have been successfully applied to a number of practical problems in hydrogeology. Success in defining aquifer geometry (i.e., thicknesses, and depths) was gradually followed by efforts to determine the hydraulic properties (permeability, transmissivity, and leakance) of aquifers. In recent years, the attention of hydrogeologists, and subsequently of geophysicists, has turned to problems involving ground-water pollution; first detection and mapping of ground-water pollution and more recently, defining transport properties.

Electrical charges induced by pollutant plumes or injected tracers can be used to define transport properties. Ultimately, electrical measurements substitute for monitoring wells. Two general approaches are possible: the modified mise-a-la-masse method, and surface measurements involving profiling and sounding. It is also possible to use borehole measurements in combination with these approaches.

The purpose of this paper is to review both approaches and illustrate the mise-a-la-masse method using data from a research project in Moravia, Czechoslovakia.

GEOELECTRICS AND GEOSTATISTICS FOR CHARACTERIZING GROUND WATER PROTECTION ZONES

William E. Kelly and Istvan Bogardi
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The paper is directed at developing and testing methodological tools for quantitatively defining aquifer protective layers using surface geophysical methods, primarily geoelectrics. Groundwater pollution is a crucial environmental issue; as a consequence stringent specifications are enforced to assure reliable aquifer protection. However, a great amount of observation is needed to guarantee reliable aquifer protection layers in view of the spatial variability of aquifer parameters controlling aquifer protection. Traditional measurements for aquifer protection are expensive, time-consuming, and often destructive relative to the soil material.

Surface geophysical methods are relatively inexpensive, fast and non-destructive. Though these methods have been around for a century, their use to define protection properties of aquifers has been limited. A methodology is described to combine all information in a way that provides a cost-effective measure of protection for the target layer to perform. Modern instrumentation and advanced interpretation techniques for surface geophysics are used with system techniques such as geostatistics, fuzzy-set theory and network-design methods. For an aquifer, the target layer would be the aquifer layer itself and the property to be defined would be transmissivity. Thus if measurements of, say, electrical resistivity of an aquifer can be expressed (even imprecisely) in terms of transmissivity, they can be combined with estimates from other sources such as specific capacity, borehole logs, and pumping tests to develop the "best" map of transmissivity.

Protection of a well field will depend strongly on the characteristics of the zone(s) above an aquifer. For an unconfined aquifer the pollution potential, which would be inversely proportional to the protection provided, depends strongly on the depth to the water table and the attenuation properties of the vadose zone. Generally, the attenuation properties of the vadose zone would be expected to increase with decreasing electrical resistivity.

For a leaky aquifer, protection can be provided by an overlying aquitard alone or in combination with a vadose zone above the aquitard. It has become fairly common to site solid-waste disposal facilities so as to use aquitards as natural liners. The methodology can be applied to characterize natural clay layers either for well-field protection or for waste disposal and compacted soil liners. An example illustrates the methodology.

USE OF SEISMIC REFRACTION TO DETERMINE THE DEPTH TO WATER AND SATURATED THICKNESS OF AN ALLUVIAL AQUIFER ALONG RAPID CREEK, RAPID CITY, SOUTH DAKOTA

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Seismic refraction was used to determine the depth to the water table and to bedrock at three sites in an unconsolidated alluvial aquifer along Rapid Creek in Rapid City, South Dakota. A 12-channel, signal-enhancing seismograph and a shotgun energy sound source were used. The shotgun energy source used 21-millimeter (8-gauge) shells, which were fired into the ground to produce a compressional sound wave of sufficient energy to travel to bedrock and back to the land surface. The shotgun was used instead of explosives because the investigation was conducted inside the city limits. Compared to a hammer and plate, the shotgun required fewer repetitions (stacks) to produce sharper first-arrival times on the record.

The seismic-refraction data were analyzed using intercept-time formulas and time-distance plots for a three-layer problem. Computer analysis of the data was conducted using a seismic-refraction inverse modeling program (SIPT), which is based on delay-time and ray-trace modeling. From the analysis, time-distance plots were produced, velocities in each geologic layer were determined, and maps displaying depth to each geologic layer (geologic cross sections) were constructed. Based on preliminary data, the average compressional velocities of the refracted waves were 1,200 ft/s in the unsaturated alluvium and 5,200 ft/s in the saturated alluvium. Average velocities in bedrock were 6,800 ft/s for sandstone and 9,200 ft/s for shale.

CONCURRENT SESSION #2

Computer Applications to Groundwater

THURSDAY, OCTOBER 18

1:10 - 2:30 pm

USE OF MULTIPLE REGRESSION TO RELATE ENVIRONMENTAL FACTORS TO THE CONCENTRATIONS OF NITRATE AND ATRAZINE IN GROUND WATER IN NEBRASKA

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Multiple regression techniques were used to determine the relative significance of environmental factors to concentrations of nitrate, as nitrogen, and atrazine in ground water of the High Plains aquifer in Nebraska. Fifty-six environmental factors, which were classified as hydrogeologic, hydrochemical, climatic, soil, and land-use characteristics, were examined at one well in each of 271 sites in 12 counties throughout Nebraska during the 1984-87 irrigation season. Of the 56 environmental factors, average hydraulic conductivity of the unsaturated zone, clay content of the soil, irrigation-well density, average screened well depth, and depth to water accounted for the largest variation in nitrate and atrazine concentrations in ground water. This functional relation between these environmental factors and nitrate and atrazine concentrations in ground water may be useful in predicting areas susceptible to ground-water contamination by agricultural chemicals for irrigated land of the High Plains aquifer in Nebraska. Based on these statistical relations, maps showing various degrees of susceptibility to agricultural-chemical contamination of ground water in the High Plains aquifer in Nebraska have been developed.

SIMULATION OF GROUNDWATER MOVEMENT IN A SHALLOW UNCONFINED AQUIFER WITH AGRICULTURAL CONTAMINATION

Vitaly Zlotnik
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University of Nebraska-Lincoln

Nebraska is one of the leading Midwestern states participating in the U.S. Department of Agriculture Water Quality Research Initiative (1990-1994). The project is directed toward advancement of crop-production systems which economically minimize the contamination of water resources, particularly ground water, by fertilizers and pesticides.

As part of this research, a model is being developed which simulates ground-water contaminant transport for selected sites in Nebraska's Platte Valley. The model will be used as the basis for monitoring net design, and for the prediction of environmental changes under different management practices. A novel approach has been necessary to describe extremely non-steady, non-uniform, three-dimensional flow and contaminant movement in the unconfined aquifer. Its originality is based on superposition of single-well and irrigation lot analytical geohydraulic descriptions in an integrated model of unconfined aquifer.

The new model will serve as a tool to determine sensitivity of an aquifer to multifactor irrigation practices, to help minimize monitoring-site operation expenses, and to design technologies capable of transfer to other sites.

OPTIMIZING WATER-USE IN NONLINEAR AQUIFER SYSTEMS USING A COUPLED OPTIMAL MANAGEMENT MODEL AND A GROUND-WATER SIMULATION MODEL

Jon M. Peckenpaugh
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Darryll T. Pederson, Professor
Conservation and Survey Division
and Department of Geology
University of Nebraska-Lincoln

A methodology is developed to determine the optimal irrigation water-usage for confined or unconfined aquifers under steady-state or transient conditions. This method is applicable to the nonlinearity of an unconfined aquifer where significant changes in saturated thickness are occurring. An additional procedure has been developed for the flow model that computes hydraulic conductivity and storage of the aquifer as its saturated thickness changes.

The methodology, referred to as SIMOPT, entails the coupling of two models, GRG2, an optimization model, and MODFLOW, a ground-water flow model, through programming developed in this research. Hydraulic heads and pumpage represent the state and control variables, respectively. To reduce the size of the management problem, the ground-water flow equations are computed only at the control variable cells by expressing the hydraulic heads as an implicit function of pumpage. The partial derivatives of the reduced problem are solved analytically. The optimizing procedures include reduced gradient procedures in GRG2 combined with an augmented Lagrangian procedure. The final management problem contains linear constraints with a nonlinear objective function.

SIMOPT was tested against a dewatering problem and two small hypothetical problems. SIMOPT was applied to a hypothetical medium-sized, unconfined aquifer system, representing hydrogeological conditions in southwestern Nebraska. SIMOPT was used to evaluate a variety of management scenarios. One scenario was to optimize the maximum pumpage using constraints that prevented excessive water-level declines within the aquifer by allowing only predetermined declines in its saturated thickness.

MODELED AND ACTUAL PATTERNS OF GROUNDWATER LEVEL DECLINES IN NEBRASKA

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Groundwater-level decline patterns in Nebraska conform to the circular island concept of Bredehoeft and others (1982). This concept can be modified by elongation so the center of the island is a regional groundwater divide and the shoreline is a regional river. Groundwater table elevation is a function of recharge rate and transmissivity. An equilibrium exists such that the gradient of the water table will convey all recharge to discharge areas. An adjustment of the water table occurs with groundwater withdrawals until a new equilibrium is attained when pumping equals capture.

The decline pattern observed in many areas of Nebraska shows the greatest groundwater level declines in the divide areas. The steepest gradient is near the regional rivers. This pattern is independent of the location of wells within the basin. A similar pattern occurs adjacent to the Arkansas River in south-central Kansas.

A hypothetical basin was modeled. Initial groundwater levels were calculated based on steady state with uniform recharge and with discharge to constant head boundaries. Uniform and non-uniform stress was applied and groundwater levels compared to steady state. The decline patterns were similar to each other and to to the measured declines.

This study shows that a groundwater basin functions as a unit when stressed and management programs must address the entire basin and not just one part.

CONCURRENT SESSION #3

Impacts of Climatic Change on Groundwater

THURSDAY, OCTOBER 18

3:00 - 4:40 pm

DROUGHT ASSESSMENT RESPONSE TEAM

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The purpose of the Drought Assessment Response Team (DART) is to provide the state of Nebraska an effective and systematic means of assessing and responding to drought conditions. The objective of the response team is to provide for a timely and systematic flow of information from data collection through analysis, to dissemination of the information. Another objective is to prepare and keep current an inventory of state and federal agency responsibilities that can be used in responding to drought situations.

In the past, various state and federal agencies, as well as interested private organizations, have come together to participate in discussions on the drought situation in the state of Nebraska. Various programs have been offered and implemented by the Drought Assessment Response Team to help mitigate the effects of drought in Nebraska. Programs include development of a drought tabloid, dissemination of information which was very useful to residents in counties across the state, and the development of a drought hotline which enabled the Department to refer individuals with difficulties to the appropriate agency that might be able to respond to them. Also, a haying and grazing referral system was developed to provide additional service to the hotline whereby individuals could seek feed or grazing opportunities for livestock.

Probably the most important accomplishment of DART in the past few years has been to establish a working relationship with the various state and federal agencies and private organizations and to provide for a free flow of information between the various agencies and organizations represented. While the most satisfactory way of dealing with drought is to in some manner provide for more rainfall, in the practical sense anything that can be done to mitigate losses and hardship due to drought is an important objective. The dissemination of information and support during the times of drought goes a long way to assist people in adjusting to drought conditions.

CLIMATE CHANGE AND THE SEASONAL AND ANNUAL GROUND-WATER BALANCE

WITHDRAWN *WITHDRAWN*

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The consequences of global climate change resulting from increasing atmospheric carbon dioxide (CO_2) could include alterations in regional terrestrial hydrology, including soil moisture and shallow ground-water systems. Such changes would have important economic, social, and environmental effects by disrupting water availability.

One of the most profound yet least understood impacts of climate change is so-called "summer drying" in the Midwest. Some global climate models predict that Midwest summers will turn significantly hotter, if not both hotter and drier, in a "CO_2 climate." Higher temperatures anticipated from CO_2-induced warming are expected to cause higher evapotranspiration and more soil-moisture depletion. Summers will begin earlier, more moisture will evaporate from the soil, and less rain will fall. This means that the Midwest, one of the most productive centers of agriculture in the world, could acquire a climate that is less than ideal for sustaining maximum crop yields, and one where water resources are transformed from a surplus to a scarcity.

To study one possible impact of climate change on hydrology, simulated ground-water levels are compared for present and increased-CO_2 climates for two representative hydrologic environments (sandy and clay-rich), with varied vegetation. Ground-water levels are simulated with DRAINMOD, a time-dependent, one-dimensional, vertical, subsurface moisture-flux model. Climatic input from DRAINMOD (temperature, precipitation, and evaporation) are derived from the Princeton University global-climate model experiments with present and increased atmospheric CO_2. The prescribed evaporation rates from the GCM are compared with others computed from semi-empirical formulas and with observed evaporation quantities.

DRAINMOD is coupled with the GCM output and verified for both hydrogeologic environments by simulating soil moisture and shallow ground-water levels assuming present concentrations of CO_2. Output from GCMs with doubled CO_2 are then coupled with DRAINMOD, again for both hydrogeologic environments, to determine the impact of climate change on soil moisture and shallow ground-water levels.

IMPACT OF CLIMATIC CHANGES ON GROUND-WATER REMEDIATION PROJECTS

J. Kevin Powers
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It has long been recognized that climatic changes, particularly precipitation surplus and deficit cycles, have a marked effect on ground-water levels and flow patterns. These effects need to be considered when designing ground-water remediation systems.

This paper addresses the impact of drought cycles on ground-water remediation projects in several hydrogeologic environments. Case studies are presented for each of these environments. The first environment considered is a glacial outwash aquifer overlying a glacial till. In this case the water level in the outwash aquifer dropped below the highest points of the till surface, in effect forming islands in the outwash aquifer and altering ground-water flow patterns.

The second environment considered is a site in a glacial outwash aquifer in close proximity to a river. When this site was initially investigated, the ground-water flow was toward the river, which was an aquifer-discharge point. Ground-water elevations in the aquifer have dropped as a result of several years of drought, while the head in the river has remained constant due to the presence of a dam a short distance downstream of the site. The result has been a complete reversal of ground-water flow direction.

The third environment considered is a glacial outwash aquifer overlying a bedrock aquifer. As water levels dropped through several years of drought, the water table surface dropped from the outwash into the bedrock.

Methods of avoiding problems due to climatic changes are discussed. Decision criteria for determining when to modify a recovery system and when to wait for a return to "normal" conditions are also explored.

CLIMATIC VARIABILITY AND THE COUPLING OF SURFACE WATER AND GROUNDWATER

Robert W. Buddemeier and Thomas J. McClain
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Lawrence, Kansas

The current debate about the precise nature of the Greenhouse Effect and the predictive validity of climate models tends to distract attention from some basic physical realities: atmospheric concentrations of radiatively active trace gases are increasing, and the resulting change in the earth's energy budget will drive some form of climate change. Local and regional changes cannot at present be predicted with reliability, resulting in an environment of uncertainty for both researchers and policy makers.

The hydrologic cycle is an integral part of the climate system, and has components interacting over a wide range of time and space scales. Groundwater and surface-water resources exhibit climate sensitivity and complex interactions on a variety of scales. The Kansas Geological Survey, in cooperation with the U.S. Geological Survey, the Kansas Water Office, and other agencies, has developed a research plan for systems-level studies of stream-aquifer interactions. The objective is to identify critical uncertainties and system sensitivities to environmental variation and human impacts so that research and management efforts may be effectively targeted.

Studies already in progress indicate that reduced streamflows in parts of western and central Kansas may be significantly related to runoff reduction by agricultural conservation practices, although traditional explanations have focussed on discharge reductions by irrigation-induced lowering of the water table. This example will be used to illustrate: 1) that single-parameter studies or management plans are not an adequate approach to changes in the hydrologic system; and 2) how existing data and situations may be used as proxies for future responses to environmental change.

USE OF SHORT-TERM CLIMATIC/GROUND-WATER RELATIONS TO ESTIMATE THE EFFECTS OF LONG-TERM CLIMATIC VARIATIONS ON GROUND-WATER CONDITIONS IN THE HIGH PLAINS

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Short-term variability in ground-water recharge and consumptive irrigation requirements in the High Plains derived from simulation of soil-water conditions indicate a useful method of predicting hydrologic conditions resulting from long-term climatic variability. The principal investigative tool used in this study is a model of soil-water balance that integrates the hydrologic characteristics of soils, vegetation, and climate to simulate the water available for plant growth and for recharge to underlying ground-water supplies. In addition to soil-water-simulation results, the study examines the effects of short-term climatic deviations upon readily observable ground-water conditions, including: changing irrigation demands (pumpage), water-table fluctuations, and variations in stream baseflows.

Results of the analyses of annual computed potential recharge and net consumptive irrigation requirements during 1951-80 in selected areas of the eastern High Plains indicate, statistically, that typical or median conditions tend to be definitely skewed toward significantly drier hydrologic regimes. Conditions represented by a statistical mean, however, tend to reflect the significance of a few wet years to the present long-term ground-water balance. If such wet periods are absent from a normal climatic sequence, the resultant relationship of recharge to consumptive-water requirements would cause much greater stress upon available ground-water resources.

Simulation of previous climatic sequences, excluding these relatively wet periods, indicates significant increases in consumptive irrigation requirements and declines in potential recharge. Slight to moderate shifts toward drier average climatic conditions would have significant effects upon observable hydrologic conditions, including severe declines in water tables and stream baseflows.

CONCURRENT SESSION #4

GIS/Remote Sensing Applications to Groundwater

THURSDAY, OCTOBER 18

3:00 - 4:40 pm

GROUNDWATER RESOURCES FOR EXPANDED SUBIRRIGATION IN THE SAGINAW BAY VALLEY, MICHIGAN

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Groundwater withdrawn for subirrigation has caused some concerns about its impact on well-water quality and supply in the Saginaw Bay Area of Michigan. This study used a hydrologic budget and geographic information systems (GIS) approach to estimate groundwater recharge rate and map the availability of groundwater for subirrigation. Groundwater recharge rate estimated by the hydrologic budget equation, based on a 30-year data set of weather and streamflow, ranges from 1 to 1.5 inches per year in the Saginaw Bay Area. Baseflow resulting from discharges from the groundwater storage varies between 4.3 to 6.02 inches per year. Negative values of recharge less baseflow indicate depletion of regional groundwater storage. It may also indicate upward movement of groundwater from bedrock aquifers.

Well-log records were used to derive potentiometric surfaces of water in drift and bedrock aquifers to locate the recharging area. The results indicate that central Huron County, western Sanilac County, and eastern Tuscola County may be recharging areas. Salinity, indicated by chloride and sodium concentrations, are lower in these areas. Groundwater yield in 28 percent of the recharging area ranges between 100 and 500 gpm. Potential subirrigation expansion lies in the southwest of Huron and Sanilac, and central and northeastern parts of Tuscola counties, totaling 278,248 acres.

USE OF ARC/INFO GEOGRAPHIC INFORMATION SYSTEM FOR REGIONAL AQUIFER STUDIES AT THE KANSAS GEOLOGICAL SURVEY

Donald O. Whittemore, Saeed Shamsnia, Tyan-Ming Chu
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We used the geographic information system ARC/INFO on a Data General minicomputer to develop a water-chemistry data base and an interface for interactive mapping and query of hydrologic-related data as a part of Dakota aquifer studies. The data base, called KWATCHEM, was constructed using the INFO relational data-base management system. KWATCHEM comprises two types of files: 1) a master file containing information on sample-site characteristics and 2) a series of analytical files containing site identification, sample-collection information, and chemical measurements. The data-base structure is based on a compromise between storage space and relation efficiency because INFO cannot handle variable-length, but only fixed-length, records. The user-friendly interface, called KHARCINS, was programmed using the ARC macro language. KHARCINS involves menus which are pulled down for selection and screen display of geographically referenced data, such as state, county, township, range, and section boundaries, geologic contacts, rivers, and well locations. Other menus allow selection of line character, point symbols, and color. Hard copies of terminal displays can be made on a color screen printer attached to the display terminal, or sent to a laser printer or a color plotter. Each point for a water-chemistry record from KWATCHEM that is displayed can be individually selected on the terminal screen, and, via menus, the information from the master file and the analytical files for that site can be displayed in a screen window. Data contours are generated using the Survey's Surface III software, which is better for contouring than ARC routines, then converted into and edited as an ARC/INFO file.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) PROCEDURES TO A GROUND-WATER MODEL IN SOUTHWEST NEBRASKA

Jon M. Peckenpaugh
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Lincoln, Nebraska

A geographic information system (GIS) is being used as a research tool in a ground-water study in southwest Nebraska. The GIS processes input and output data for a ground-water flow model. The GIS input procedures are more efficient and accurate than manual methods. The software packages being used in this study are ARC/INFO* for the GIS and MODFLOW for the ground-water flow model.

The GIS software is used to present the data in a variety of scales and projections that would be time-consuming and expensive to develop with non-GIS procedures. In addition to the GIS routines, additional programs or macros written by U.S. Geological Survey personnel are used to read input data directly into model formats from GIS polygon, line, and point coverages.

GIS procedures were used in developing the study-area map and the model-grid map. The grid map was developed so that both point and polygon data could be assigned to the model nodes.

The following data were assigned to node locations using the GIS procedures: water levels, base of aquifer, altitude of the land surface, soils, climatic data, irrigation and observation-well sites, and irrigation-well and test-hole-log sites.

Model-generated water levels and streamflows are displayed and analyzed using GIS procedures, which allow maps of these items to be constructed with a variety of scales, projections, and annotations.

* Use of trade name is for identification only and does not constitute endorsement by the U.S. Geological Survey.

MULTIPLE-CELL SOLUTE TRANSPORT MODEL, CELL-SIZE ERROR ANALYSIS USING A GEOGRAPHIC INFORMATION SYSTEM

Don Adelman and Steve Soberski
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An important assumption in multiple-cell, solute-transport models is that there is uniform mixing of solute in an aquifer cell even though the solute source is present in a small part of the cell. A Geographic Information System (GIS) was used in conjunction with the multiple cell model to investigate the error introduced when assuming uniform solute mixing. The GIS was used to divide a hypothetical 49-square-mile area first into 2.5-acre cells, then cells of 10, 40, 160, and 640 acres. Using the GIS, the advance of solute for the smallest cells, which should advance the solute the least due to the mixing assumption, was compared to the advance of solute for the larger cell sizes. Two criteria, multiple-cell model computation time and solute concentration compared to 2.5-acre cell concentrations, were used to determine optimum cell size. The 10-acre cell size proved to be the optimum for these criteria.

The accuracy of the multiple-cell model and the 2.5-acre cells used as the standard were also checked. The distance the model advanced solute using 2.5-acre cells was found to compare reasonably well with the distance calculated manually using a tracer-velocity computation.

USING GIS TO EVALUATE PERFORMANCE OF THE DRASTIC MODEL

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DRASTIC is a spatial model designed for evaluation of groundwater-pollution potential. The model was developed by the National Water Well Association via the Delphi method, a procedure used to assist experts in reaching a consensus, rather than through experimentation. DRASTIC employs seven differentially weighted and rated variables (depth to groundwater, recharge, aquifer characteristics, soils, topography, influence of the vadose zone and hydraulic conductivity of the aquifer) to compute an index value that is presumed indicative of an area's susceptibility to groundwater contamination.

Although now widely used, and often implemented in GIS, no rigorous examination of the model's performance has been conducted. A preliminary attempt to verify DRASTIC performance has been conducted for Nebraska and Kansas sites where GIS-based implementations of DRASTIC have been carried out. Shortcomings in spatial-data quality are shown to have an impact on model results, and the need to use all seven variables is shown to be questionable in some circumstances. Comparison of DRASTIC-index values with actual pollution occurrences shows general agreement. Problems in verifying DRASTIC performance are identified and suggestions for use of the model are made.

GENERAL SESSION

Chemical Aspects of Groundwater

FRIDAY, OCTOBER 19

8:20 - 11:40 am

PLANS FOR THE ARTIFICIAL RECHARGE OF A GLACIAL AQUIFER IN EASTERN SOUTH DAKOTA

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Brookings, South Dakota

Glacial aquifer systems provide 70 percent of all water used in eastern South Dakota. Periods of drought during the 1970s and 1980s have resulted in increased demand on ground-water resources by municipal, industrial, and irrigation users. Such demands create a need for systematic water-management programs, including the use of artificial recharge. The Huron Project of the U.S. Bureau of Reclamation's High Plains States Groundwater Demonstration Program was developed to demonstrate, at a specific site, the potential for artificial recharge of glacial aquifers in eastern South Dakota.

The objectives of the Huron Project are to: 1) use excess flows from the James River during spring runoff as a source of water; 2) treat the water in the City of Huron's water-treatment plant; 3) move the water to a site west of Huron in an existing pipeline; and 4) inject the water into a buried glacial aquifer. The use of treated water will minimize potential degradation of aquifer water quality and may, in fact, improve aquifer water quality.

The site-selection phase of the project was completed during December 1987. The design, construction, operation, and evaluation phase of the project began during April 1990. The first two years of this phase will include test drilling and installation of observation wells to better define the hydrogeology of the aquifer and to extensively monitor the aquifer and injectate to determine water-quality characteristics and potential mixing effects. Artificial recharge is scheduled during the third and fourth years of this phase.

GROUND-WATER QUALITY INVESTIGATION OF THE LAKE CALUMET AREA OF SOUTHEAST CHICAGO

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Champaign, Illinois

The Lake Calumet area of Chicago's southeast side has been exposed to a wide range of industrial contaminants since the 1860s. For the past several decades the area has also been increasingly used for waste disposal. Dozens of operating or retired waste-handling facilities are present throughout the area. The 31 square miles surrounding Lake Calumet probably contain more hazardous substances than any other area of equivalent size in the state of Illinois. Over 200 monitoring wells have been constructed in the unconsolidated deposits and shallow bedrock by both regulated and non-regulated facilities within the area. Unfortunately, no regional study of ground-water quality has been performed, leaving in question the degree to which the unconsolidated deposits and shallow bedrock of the area have been contaminated by waste disposal and other potentially contaminating activities.

In order to assess ground-water quality in this area, all of the available groundwater quality information was compiled and evaluated. Because most of the existing information is from monitoring wells at waste-disposal sites, 16 private and public water-supply wells in the shallow bedrock were sampled for major inorganics, trace metals, and organic compounds. Four new bedrock-monitoring wells were also constructed and sampled in areas where no other wells could be found. Significant inorganic and organic contamination is present in the unconsolidated deposits near waste-disposal facilities. No widespread regional contamination has been found within the shallow dolomite aquifer, although several wells have been found to have significant concentrations of trace metals and organic compounds.

GROUND-WATER QUALITY IN THE NEMAHA NATURAL RESOURCES DISTRICT, SOUTHEASTERN NEBRASKA

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United States Geological Survey
Lincoln, Nebraska

In the summer of 1989, water samples were collected from 80 wells in southeastern Nebraska to characterize ground-water quality. The wells were selected to represent the four major aquifer groups: bedrock aquifers in carbonates of Paleozoic age or sandstones of Mesozoic age, paleovalley aquifers and shallow aquifers in deposits of Pleistocene age, and the Missouri River alluvial aquifer in deposits of Quaternary age.

Water samples from 20 of the 80 wells had nitrate concentrations greater than 5 milligrams per liter (mg/L), indicating probable agricultural contamination. Water from four wells exceeded the U.S. Environmental Protection Agency drinking water standard for nitrate. Median nitrate concentrations were significantly larger in the paleovalley and shallow aquifers than in the other aquifers.

Enzyme-assay tests, a relatively new method for screening the triazine herbicides, were used to determine which water samples were analyzed by the more costly method of gas chromatography. Trace levels of atrazine were detected in samples from seven wells using gas chromatography. Most detections were from samples from the shallow aquifer.

The concentrations of several other water-quality constituents were related to aquifer group in a statistically significant manner. Water samples from the bedrock aquifers had the largest median concentrations of sulfate (250 mg/L) and dissolved solids (708 mg/L). Water samples from the Missouri River alluvial aquifer had the largest median concentrations of iron (7.9 mg/L) and manganese (1 mg/L).

SUMMARY OF THE IOWA STATE-WIDE RURAL WELL-WATER SURVEY

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Geological Survey Bureau
Iowa City, Iowa

Burton C. Kross
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The State-Wide Rural Well-Water Survey (SWRL) was carried out as part of the implementation of the Iowa Groundwater Protection Act of 1987. This survey of domestic wells was conducted from April 1988 to June 1989. It was designed to address two primary questions: 1) what proportion of private rural wells in Iowa are affected by various environmental contaminants?; and 2) what proportion of rural Iowa residents are using contaminated water? A stratified systematic sample design was developed in order to provide statistically valid estimates for state and multi-county regions. The concentration of nitrogen species, 27 pesticides, 8 pesticide metabolites, major inorganic ions, and total coliform bacteria were determined at 686 wells.

Results show that 18.3 percent of rural domestic wells are contaminated with nitrate-nitrogen (NO_3-N), exceeding the 10 mg/L health advisory. This is proportional to 130,000 rural residents. One or more pesticide residues were detected in 13.6 percent of rural wells (94,000 rural residents). Depth of the wells is an important factor relating to contamination. 28 percent of rural wells are less than 50 feet deep and show increased incidents of contamination; 35.1 percent had NO_3-N above the health advisory and 17.9 percent had one or more pesticides detected.

These results need to be assessed in light of the two-year drought that occurred concurrent with this study. However, SWRL will lend valuable insight into the quality of water used in Iowa, and will provide a baseline with which to measure future trends in groundwater quality.

OCCURRENCE OF HERBICIDES AND NITRATE IN THE MISSOURI RIVER ALLUVIAL AQUIFER FROM THE IOWA BORDER TO MIAMI, MISSOURI

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Independence, Missouri

Gale M. Carlson
Missouri Department of Health
Jefferson City, Missouri

In July 1989, herbicides were detected in water from 14 percent of 81 farmstead wells located along two reaches of the Missouri River alluvium. Samples from the northwestern reach located between Iowa and St. Joseph, Missouri (48 wells) had almost twice the percentage of herbicide detections as the southern reach located between Kansas City and Miami, Missouri (33 wells).

Atrazine and alachlor were the most frequently detected of seven herbicides analyzed. Atrazine was detected in 10 percent of the wells, but only one sample exceeded the U.S. Environmental Protection Agency's proposed maximum contaminant level (MCL) of 3 micrograms per liter. Alachlor was detected in 4 percent of the wells. Cyanazine, metolachlor, metribuzin, and trifluralin were detected in less than 3 percent of the wells. Butylate was not detected in any well. Detection of one herbicide increased the probability of detecting other herbicides.

Fifty-nine wells in the northwestern reach were previously sampled in July 1988. Alachlor was detected in 7 percent of the wells, and two samples exceeded the MCL of 2 micrograms per liter.

Nitrate exceeded 0.2 milligrams per liter in 48 percent of the wells sampled in 1988 and 1989. Nitrate exceeded the Missouri drinking-water standard of 44 milligrams per liter in 14 percent of the wells.

These data do not confirm nonpoint sources of herbicides. Farmstead wells may be contaminated by herbicide mixing and loading near well heads and the Missouri River, where atrazine concentrations were 4 micrograms per liter during high stages in June 1989.

DETERMINATION OF ATRAZINE, ALACHLOR, AND SELECTED DEGRADATION PRODUCTS IN CONTAMINATED GROUNDWATER

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Atrazine and alachlor are the most popular corn herbicides in Wisconsin. Analytical methods were developed for the analysis of degradation products of atrazine and alachlor in water. Two degradation products of alachlor (2,6-diethylaniline [DEA] and 2-Cl-2',6'-diethylacetanilide) and two of atrazine (deethylatrazine and deisopropylatrazine) were targeted for study. These were selected based upon their likelihood to occur in groundwater as determined by literature review, the existing toxicological information on the products, and the availability of analytical standards.

Samples were collected from four sites in Wisconsin characterized by atrazine- and/or alachlor-contaminated groundwater. These samples were analyzed for atrazine, alachlor, and their targeted degradation products. Neither DEA or 2-Cl-2',6'-diethylacetanilide appear to contribute significantly to alachlor contamination of groundwater. Deethylatrazine was detected in all 32 of the study wells where atrazine was detected, and in three wells where atrazine was not detected. Deisopropylatrazine was detected in 19 of the wells with atrazine detections and in two wells where atrazine was not detected.

The data were used to develop a model predicting degradation product levels as a function of the concentration of atrazine in groundwater. When this model is used (for illustrative purposes only) to adjust the Wisconsin atrazine Enforcement Standard (ES) to account for the presence of degradation products in atrazine-contaminated groundwater, the ES decreases from 3.5 ug/l to 1.1 ug/l.

ANALYSIS OF CHEMIGATION RISK

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Chemigation is increasing. (Chemigation is the application of chemicals--fertilizers, herbicides, insecticides, fungicides, etc.--via an irrigation system.) To protect the water source, several states, including Nebraska, have enacted chemigation laws. Such laws require that safety equipment be installed on each irrigation system where chemicals are injected. Still, a chemical backflow event is possible.

A mathematical model was developed to estimate the risk of contaminating a water source when chemigating with a typical center-pivot equipped with a chemigation backflow prevention assembly (CBPA) in Nebraska. Available chemigation data were used with an event tree to develop a listing of equipment failure scenarios. The frequency for each scenario was determined by defining the probability of failure for each component in each scenario and multiplying them by the frequency of the initiating event. The consequences were determined by a mathematical representation of the system hydraulics.

Based upon a total of 18,376 chemigation events, the frequency of chemical backflow for chlorpyrifos, Bacillus thuringiensis, atrazine, and ammonium nitrate was 4.2×10^{-1} 8.9×10^{-2}, 2.2×10^{-2}, and 2.4 events per year, respectively. The greatest mass flows resulted from broken chemical-injection line check valves, while the most frequent scenario was the combination of a plugged low pressure drain, a fouled mainline check valve, and a leaky riser. Risk of backflow could be reduced by improving the reliability of the chemical-injection line check valve and the mainline check valve, and increasing the capacity of the low-pressure drain.

A CRITICAL EVALUATION OF AGRICULTURAL CHEMICAL POLICY PERFORMANCE ON GROUNDWATER PROTECTION

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Due to the prevalent use of agricultural chemicals to enhance crop production, and their potential for contaminating vulnerable aquifers, Michigan, along with other states, has come under Environmental Protection Agency (EPA) review for the development of agricultural chemicals in groundwater management plans (MPs). A wide variance exists in state approaches to protecting groundwater from agricultural chemicals.

California, Wisconsin, Iowa, and Minnesota represent states with different approaches at various stages of implementation. Each state program is the result of a unique set of circumstances. However, there has yet to be an extensive evaluation of the structure, conduct, and performance of programs designed to protect groundwater used for drinking water.

This research critically evaluates agricultural-chemical policy performance in four states and develops a decision-making framework for the development of MPs in Michigan and other states. Using the traditional Structure-Conduct-Performance framework (S-C-P), the circumstances, interactions among policy community members and decisions leading up to current structures, and the conduct of affected entities are identified and evaluated. Appropriate models which satisfactorily evaluate the performance of these programs on groundwater quality and farmer safety are then identified.

The S-C-P is applied to each of the four states. The efficacy of each state's program is then scored. Regulatory-transaction costs in relation to groundwater-damage costs is one scoring technique that is explored. The cost-effective components of each state are then input into an adaptive decision-making framework which enables state, local, and on-farm decision makers to choose better tools and methods for the development of MPs designed specifically to meet state physical, socio-demographic, and economic circumstances.

The decision-making framework is evaluated, and policy recommendations concerning EPA, state interactions, and local implementation of agricultural management plans are presented.