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# Kansas Geological Survey

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## 21<sup>st</sup> Annual Water and the Future of Kansas Conference

### Competing Priorities: Resolving Conflicts

Coordinated By:  
Al Macfarlane and Margaret Townsend

Sponsored By:  
Kansas Water Resources Research Institute (KWRI)  
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*GEOHYDROLOGY*



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## ACKNOWLEDGMENTS

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# 21st Annual Water and the Future of Kansas Conference

March 11, 2004

Lawrence, Kansas

## Competing Priorities: Resolving Conflicts

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Kansas Geological Survey (KGS)



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# Program and Abstracts

**7:30-8:00 am Poster/Display Setup**

**8:00-8:30 am Registration, Continental Breakfast/View Posters/Displays**

**8:30-10:10 am Plenary Session (Regency C)**

**8:30-8:40 Welcome and Opening Remarks**—*Bill Hargrove*, Director, Kansas Water Resources Institute

**8:40-9:10 The Waters of Kansas, Past and Present**—*Donald Worster*, Hall Distinguished Professor of American History, University of Kansas, Lawrence, KS

**9:10-9:40 The Role of Litigation to Protect Drinking-water Sources from Agricultural Impacts**—*Brent Blackstock*, Environmental Lawyer, McKinney & Stringer, Tulsa, OK

**9:40-10:10 Streams in Transition: Ecological Responses to Increasing Urbanization**—*Dr. Anne Spacie*, Professor of Fisheries, Purdue University, West Lafayette, IN

**10:10-10:30 am Break**

**10:30-11:45 am Issue Forums / Panel Discussions (concurrent)**

**Ogallala—Managing the Aquifer: Subunit Protocols (Regency C)**  
*Tom Huntzinger*, Kansas Div. of Water Resources, Topeka, KS, Moderator

**Public Water Supply Water-quality Issues (Brazilian B)**

*Andy Ziegler*, USGS, Lawrence, KS, Moderator

**Urban—Rural Water Issues (Brazilian C)**

*Don Sneath*, Kansas Dept. of Health and Environ., Topeka, KS, Moderator

**Protection of Critical Habitat (Brazilian A)**

*Chris Mammoliti*, Tetra Tech EM, Inc., Topeka, KS, Moderator

**11:45 am Luncheon (Regency A–B)**

*Roger Welsch*, Author

**12:45-1:30 pm View Posters/Displays**

**CONCURRENT SESSIONS 1–4 (run simultaneously)**

**1:30-2:50 pm Session 1—Urban—Rural Water Issues**

**(Brazilian A)**

**1:30 Some Legal Aspects of Changing from Agricultural to Urban Water Use in Kansas**—*John Peck*, Univ. of Kansas, Lawrence, KS

**1:50 Well Pumping Curtailment in Colorado: Conflict Between Surface- and Ground-water Users**—*Tom Cech*, Central Colorado Water Conservancy District and Groundwater Management Subdistrict, Greeley, CO

**2:10 Watersheds: the Amphitheater for Conflict Management and Public Participation**—*James Triplett*, Pittsburg State Univ., Pittsburg, KS

**2:30 Environmental Consequences of Ground-water Overexploitation**—*Marios Sophocleous*, Kansas Geological Survey, Lawrence, KS

**1:30–2:50 pm Session 2 – Impacts of Agriculture on Water Quality (Brazilian C)**

**1:30 Occurrence of Antibiotics in Hog-waste Lagoons From Confined-animal Feeding Operations from 1998 to 2002**—*Michael T. Meyer*, USGS, Lawrence, KS

**1:50 Pesticide and Nutrient Management: Kansas Agriculture vs. the Challenge**—*Dale Lambley*, Kansas Dept. of Agri., Topeka, KS

**2:10 Water Quality and Quantity Issues Associated with Irrigated Alfalfa Production in Southwest Kansas**—*Tom Willson*, Kansas State Univ., SWREC, Garden City, KS

**2:30 Watershed Water-quality Classification in Kansas**—*J. M. Shawn Hutchinson*, Dept. of Geog., Kansas State Univ., Manhattan, KS

**1:30-2:50 pm Session 3 – Ogallala Management Issues (Regency C)**

**1:30 A Coupled Hydrologic–Economic Modeling Tool to Support Ground-water Management Decisions**—*Dave Steward*, Dept. of Civil Eng., Kansas State Univ., Manhattan, KS

**1:50 HIPLAIN—The High Plains Aquifer Information Network—www.hiplain.org**—*Margaret Townsend*, Kansas Geological Survey, Lawrence, KS

**2:10 Crop Water Allocation Program**—*Norman Klocke*, Kansas State Univ., SWREC, Garden City, KS

**2:30 Depletion Predictions for the High Plains (Ogallala) Aquifer in Northwest Kansas**—*Gary Hecox*, Shaw Env. & Infrastructure, Inc., Knoxville, TN

**1:30-2:50 pm Session 4 – Recreation and Public Water Supply Issues (Brazilian B)**

**1:30 Marion Reservoir Blue-green Algae Bloom – Summer 2003**—*Mike Tate*, Kans. Dept. of Health and Environ., Topeka, KS

**1:50 Sediment Quantity and Quality Issues for Kansas Reservoirs**—*Kyle Juracek*, USGS, Lawrence, KS

**2:10 Watershed Restoration and Protection Strategy for the Upper Wakarusa River Watershed**—*Paul Liechti*, Kansas Biological Survey, Lawrence, KS

**2:30 Assessing the Impact of Maneuver Training on NPS Pollution and Water Quality**—*Stacy Hutchinson*, Dept. of Bio. and Agri. Engineering, Kansas State Univ., Manhattan, KS

**2:50-3:10 pm Break**

**CONCURRENT SESSIONS 5-8 (run simultaneously)**

**3:10-4:30 pm Session 5 – Water Use Issues (Regency C)**

**3:10 Population Growth and Water Resources: Case Study and Forecast for Phoenix, Arizona, USA (40 minutes)**—*Alan Christopher*, M-Dac.com, Phoenix, AZ

**3:50 Walnut Creek Intensive Ground-water Use Control Area (WCIGUCA): The First Ten Years**—*Cory Curran*, Kansas Dept. of Agri./DWR, Stafford, KS

**4:10 A Field Assessment of a Method for Estimation of Ground-water Consumption by Phreatophytes – Year One**—*Jim Butler*, Kansas Geological Survey, Lawrence, KS

**3:10-4:30 pm Session 6 – Water Quality in Surface Water (Brazilian A)**

**3:10 Occurrence and Fate of Antibiotics in Kansas Wastewater Treatment Facilities**—*Alok Bhandari*, Dept. of Env. Engineering, Kansas State Univ., Manhattan, KS

**3:30 Continuous Real-time Water-quality Monitoring of Kansas Streams**—*Andy Ziegler*, USGS, Lawrence, KS

**3:50 Temporal and Spatial Occurrence and Persistence of Pharmaceuticals, Pathogens, and Other Wastewater Compounds in an Effluent-dependent Stream, Tucson, AZ**—*Gail Cordy*, USGS, Tucson, AZ

**4:10 Small Artificial Water Bodies: a Neglected but Important Factor in Water Supply and Environmental Quality**—*R. W. Buddemeier*, Kansas Geological Survey, Lawrence, KS

**3:10-4:30 pm Session 7 – Water-use Impacts on Critical Habitat (Brazilian C)**

**3:10 Spatial and Temporal Changes in Flow and Water Quality in the Cimarron River, Southwestern Kansas**—*Don Whittemore*, Kansas Geological Survey, Lawrence, KS

**3:30 Critical Habitats: Designation and Protection in Kansas**—*Chris Hase*, Kansas Dept. of Wildlife and Parks, Pratt, KS

**3:50 Protecting and Enhancing Instream Flow**—*Susan Lee*, Kansas Water Office, Topeka, KS

**4:10 Water-use Impacts to Endangered Species in Kansas: the Case of the Least Tern**—*Bill Busby*, Kansas Biological Survey, Lawrence, KS

**3:10-4:30 pm Session 8 – Covering Water Issues (Brazilian B)**

**Reporters Involved in Reporting Water Issues in Kansas**—

*Rex Buchanan*, Kansas Geological Survey, Lawrence, KS, Moderator  
Panelists: *Dave Ranney*, Lawrence Journal World; *Amy Bickel*, Hutchinson News; *Kelly Lenz*, Agriculture Director, WIBW Radio; *Jean Hays*, Wichita Eagle; *Mike Corn*, Hays Daily News

# Posters

## High Plains Aquifer

1. **Modeling Ground-water Flow and Economics in Sheridan County, Kansas**—*Mauricio Herrera*, Kansas State Univ., Manhattan, KS
2. **Understanding GIS Ground-water Elevation Data Trends Using Transient Ground-water Models**—*Wei Jin*, Kansas State Univ., Manhattan, KS
3. **High Plains Aquifer Analysis based on Water Usage per Square Mile**—*John Huslig*, Alexandria, VA
4. **The Kansas Water Congress**—*David A. Brenn*, Topeka, KS
5. **High Plains Aquifer Information Network (HIPLAIN) – Year 2**—*David Young*, Kansas Geological Survey, Lawrence, KS
6. **A Preliminary Updated Bedrock Surface-elevation Map for the Ogallala Region of Western Kansas**—*P. Allen Macfarlane*, Kansas Geological Survey, Lawrence, KS
7. **Ground-water Levels and Storage-Volume Changes in the Equus Beds near Wichita, Kansas, 1940–2003**—*Cristi V. Hansen*, USGS, Lawrence, KS
8. **Ground-water Depletion and Agricultural Land-use Change in Wichita County, Kansas**—*Lisa M.B. Harrington*, Kansas State Univ., Manhattan, KS
9. **Estimating Resilience of Ground-water Resources in Western Kansas**—*Robert W. Buddemeier*, Kansas Geological Survey, Lawrence, KS
10. **Ogallala Management Issues**—*Tina Alder*, Kansas Dept. of Agri., Topeka, KS

## Education

11. **KGS Geohydrologic Information on the Internet**—*Daniel R. Suchy*, Kansas Geological Survey, Lawrence, KS
12. **Kansas Environmental Leadership Program (KELP)**—*Judy Willingham*, Kansas State University, Manhattan, KS
13. **The Prototype Interactive Ground-water Tutor: a New Tool for Computer Assisted Instruction in Secondary- and Undergraduate-level Earth and Environmental Science Education**—*P. Allen Macfarlane*, Kansas Geological Survey, Lawrence, KS
14. **StreamLink**—*Alison Reber*, Kansas StreamLink, Lawrence, KS

## Ponds

15. **Assessing Temporal Changes in Ponds and Pond Numbers Using Historical Air Photos: a Comparison Between the Midland and Allen SE Quadrangles**—*R. O. Sleezer*, Emporia State Univ., Emporia, KS

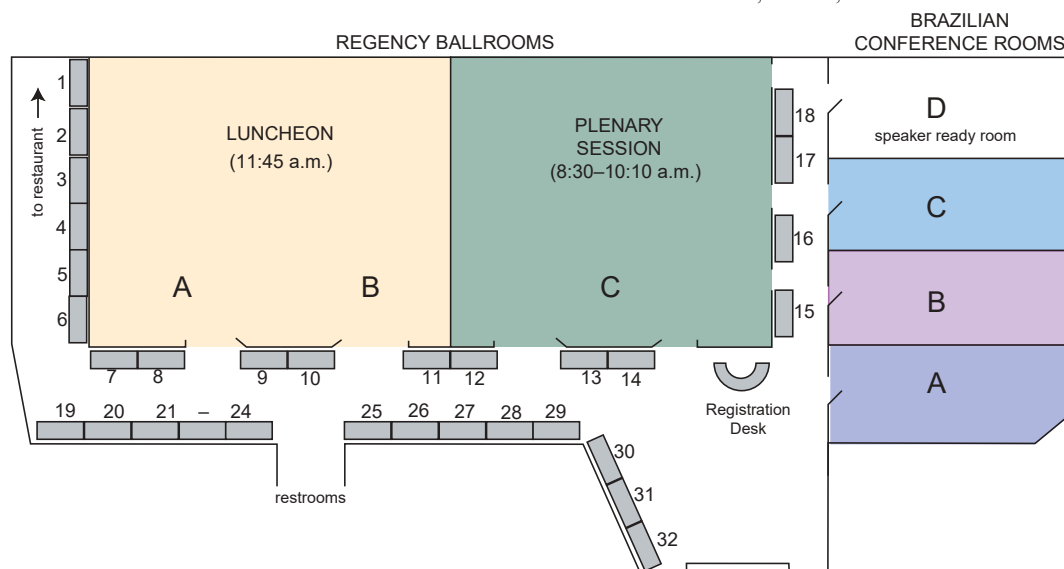
16. **Watershed Parameterization Using Geospatial Modeling and Preliminary Assessment of the Effects of Small Impoundments (Ponds)**—*D. P. Young*, Kansas Geological Survey, Lawrence, KS
17. **A Comparison of Pond Inventories Using Satellite and Airborne Sensors**—*S. L. Egbert*, Kansas Biological Survey, Lawrence, KS
18. **Using Multispectral Airborne Imagery to Inventory and Assess Rural Water Bodies**—*Michael Houts*, Kansas Biological Survey, Lawrence, KS

## Water Use Issues

19. **Water Use in Kansas, 1990–2000**—*Joan F. Kenny*, USGS, Lawrence, KS
20. **Estimates of Flow Duration and Peak-discharge Frequency for Kansas Stream Locations**—*Charles A. Perry*, USGS, Lawrence, KS
21. **Mobile Irrigation Lab (MIL) Project Overview**—*Dan Rogers*, Kansas State Univ., Manhattan, KS
22. **KanSched—An Irrigation Scheduling Tool**—*Dan Rogers*, Kansas State Univ., Manhattan, KS
23. **SDI—An Irrigation System Option for Kansas**—*Dan Rogers*, Kansas State Univ., Manhattan, KS
24. **Center-pivot Nozzle Package Performance Testing**—*Dan Rogers*, Kansas State Univ., Manhattan, KS
25. **Water-right Development in Kansas**—*Brownie Wilson*, Kansas Geological Survey, Lawrence, KS
26. **Republican River Compact Settlement and Ground-water Model**—*David Barfield*, Kansas Dept. of Agri., Topeka, KS

## Water Quality

27. **TMDL Implementation to Improve Water Quality**—*Will Boyer*, KSU/KCARE, Lawrence, KS
28. **Occurrence of Antibiotics in Water from Fish Hatcheries**—*Elisabeth A. Scribner*, USGS, Lawrence, KS
29. **Identifying Sources of Fecal Bacteria in the Upper Arkansas River**—*Thomas C. Willson*, KSU/SWREC, Garden City, KS
30. **Attitudes and Behavior: Exploring the Relationship Between Water Quality Attitudes and Best Management Practices**—*Mary Dobbs*, Kansas State Univ., Manhattan, KS
31. **Performance Characteristics of a Magnetic Particle-based Immunoassay (ELISA) for the Analysis of Atrazine Metabolites in Water Samples**—*Gary D. Hinshaw*, Abraxis LLC, Warminster, PA
32. **Water Quality Prior to Implementation of Best Management Practices on Two Urban Golf Courses**—*Amanda Reed*, Wichita State Univ., Wichita, KS



## Luncheon Speaker — Roger Welsch

Roger Welsch taught most of his life at universities and colleges in Nebraska. In 1988, he walked away from a full professorship in English and anthropology at the University of Nebraska to live and write on his small tree farm near Dannebrog. A short time later, Roger's old friend Charles Kuralt invited him to become part of CBS's award-winning show "Sunday Morning." When asked if he misses teaching, Welsch replies, "I'm still teaching, but now my class has five million students—and I don't have to grade the papers!"



Welsch is author of the best-selling *It's Not the End of the Earth But You Can See It From Here*, *Busted Tractors and Rusty Knuckles*, and numerous other books, including *Diggin' In and Piggin' Out*, named one of the ten best cookbooks of 1997 by *Bon Appetit* magazine. His writings have appeared in *Natural History Magazine*, *Reader's Digest*, *Esquire Gentleman*, and *Successful Farming*, where he is now a contributing editor.

The University of Nebraska named Welsch "Outstanding Speaker of the Year" in 1990. Other honors include the Nebraskaland Foundation's Trailblazer Award, Washington DC Press Club's Distinguished Nebraskan Award, the Ruth Etting Award for contributions to live performance, AK-SAR-BEN's coveted Contributions to Agriculture Award, the Governor's Award for contributions to the traditional arts, Progressive Farmer's Ag Leader of the Year Award, and the Nebraska Library Association's Sandoz Award for contributions to plains folklore, history, and literature. Welsch says his most significant honor was his adoption into the Omaha Tribe in 1967, and his official designation as Tribal Friend by the Pawnee in 1995. In his spare time, Welsch enjoys walking the banks of the Middle Loup River near his home and working on antique Allis Chalmers tractors.

## Plenary Sessions

### “The Waters of Kansas, Past and Present”

*Donald Worster*, Hall Distinguished Professor of American History, University of Kansas, Lawrence, Kansas

Major Stephen Long’s early 19<sup>th</sup> century expedition of the Great Plains found rivers of little water, with blowing sand, and he labeled the region “the great american desert.” Later generations would challenge and revise this label, unlearn and relearn that perception. But in general, experience taught that water is indeed scarce much of the time and over much of the state, with important exceptions: a few very wet years, and a significant difference between eastern and western parts of the state. Kansas lies on the cusp separating arid and humid America. Its situation is therefore one of great complexity and uncertainty. And its history has been one of trying to fashion a permanent way of life on that cusp.

John Wesley Powell’s model of “cooperative commonwealths” proposed a radical new set of political boundaries based on watersheds. Unfortunately, it was never adopted in Kansas or other western states. The consequences for water perception and management have been serious.

A key challenge from the beginning (and it remains the key challenge today) was how to maintain agriculture in this state. Even when cities began to appear and grow, along with industry, water continued to go mainly to farming. The recurrent failure of that volatile water supply has repeatedly brought agriculture, and the entire state, to its knees, most notably in the 1930’s. Drought and human culture then combined to create one of the world’s greatest environmental disasters. Can Kansas agriculture survive over the long-term, especially in the western part of state, without continual government subsidies or the ongoing depletion of a limited underground water supply? If not, then what policies should we adopt?

# The Role of Litigation to Protect Drinking-water Sources from Agricultural Impacts

*Brent Blackstock, Environmental Lawyer, McKinney & Stringer, P.C., Tulsa, Oklahoma*

Source-water supplies for many municipalities are drawn from water sources that are increasingly at risk due to the environmental impact of nonpoint source pollution from large-scale agricultural operations. In some cases the environmental risk can be managed through regulation, negotiation, and compromise. However, if excessive risk remains after all other alternatives have been exhausted, litigation may become the only viable option to recover past economic loss and prevent future damage.

# Streams in Transition: Ecological Responses to Increasing Urbanization

*Dr. Anne Spacie*, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana

Many watersheds throughout the country are undergoing rapid land-use change in the form of urbanization. Forest, range, or agricultural areas on the periphery of cities are modified, initially, by scattered homes or low-density housing developments that require new roads and utility lines to support. Later these neighborhoods may fill in with more closely spaced houses and commercial districts. In the process, the hydrology of each watershed is profoundly affected. Although it still impacts a small percentage of total land area, urbanization has become the second leading cause of stream degradation, after agriculture. When undisturbed forest is cleared, the hydrologic changes caused by urban runoff include increased total streamflow, increased peak flow, reduced storm lag time, and reduced base flow. Sediment and nutrient runoff usually increase as well. Additional impacts such as construction-site runoff, municipal effluents, storm sewers, and riparian modifications add further stressors to the mix. A variety of studies have shown that imperviousness (roads, roofs etc.) covering approximately 10% of a watershed leads to significant stream impairment. Even low levels of development (150 persons per square mile) may cause measurable changes in water quantity, quality, and stream-community composition.

If these generalizations also apply to the prairie and Plains states, it suggests that regional planners should anticipate a variety of environmental problems. Midwestern urbanization may not follow the typical pattern, however, because the drainage systems of croplands are already highly modified. Runoff may or may not increase after development and downstream water quality might actually improve. At present there is little understanding of the mechanisms relating cropland conversion to stream ecological response. Specific predictions of long-term hydrologic impacts that would assist planners are generally lacking.

We compared physical and ecological characteristics of eight streams in central Indiana, ranging from low to high watershed imperviousness. The watersheds in the Indianapolis area have undergone rapid development and significantly increased streamflow in recent decades. For example, Little Eagle Creek watershed has undergone an 18% increase in impervious area between 1973 and 1991, and almost a doubling of its mean annual discharge. Increased flow should lead to stream-channel enlargement, either by incision or lateral (bank) erosion. The study streams in this project were surveyed for geomorphic stability. Two qualitative and seven quantitative stability measures were tested to distinguish between stable and degrading sites. Quantitative measures including shear stress, bankfull flow, and flow that mobilizes the bed ( $Q_{crit}$ ) were generally more successful predictors of urbanization than the qualitative measures.

Bed mobilization during storm flow is thought to be an important mechanism affecting the composition of stream communities. We sampled fish and macroinvertebrates at three sites in each of the study streams over a two-year period to evaluate biological metrics as possible urbanization indicators. An index of overall fish-habitat quality (QHEI) was negatively correlated to watershed imperviousness. Overall quality of the fish community (as measured by the index of biotic integrity, IBI) also declined with imperviousness. In particular, the proportion of darters and sculpins declined significantly with greater channel instability and imperviousness.

Metrics were also evaluated for the 35 insect families found in the eight watersheds sampled. While most of these metrics showed negative trends with increasing imperviousness, two were most significant: a decrease in the proportion of clinger taxa (insects susceptible to substrate scouring) and an increase in the ratio of *Baetis* to total Ephemeroptera. Both of these metrics showed a clear change at very low levels of urbanizations, levels at which streams still appear unimpacted (having a good riparian buffer, typical riffle-pool development, clean gravel, etc.)

Freshwater mussels are of particular concern because many populations are declining throughout the region. We found that mussel populations were reduced in the urban streams (four species total, mussels present at 28% of urban sites) compared to rural streams of similar size (12 species total, mussels present at 46% of sites). Sites with unstable channels and high shear stress (whether in urban or rural areas) were negatively correlated with the presence of mussels. Because of their slow growth, long life spans, poor dispersal, sensitivity to erosion, and complex reproductive requirements, freshwater mussels are especially vulnerable to physical-habitat degradation.

Such ecological impacts need to be incorporated into hydrologic models if future regional planning is to be successful. We are currently using a long-term hydrologic impact assessment (L-THIA) model to predict annual runoff and NPS pollutant loading. Input requirements include long-term climatic records, soil types, and land-use information. A web-based version is available to the public (see web link below). Using observed land uses within the Little Eagle Creek watershed for 1973–1991, the model predicted an 80% increase in annual average-runoff volume and increases of more than 50% in annual average loads for Pb, Cu, and Zn. In contrast, estimated nutrient (N and P) loads decreased by 15% due to the loss of agricultural land. While the model is not detailed enough for ecological processes, it has great utility for regional planners testing alternative land-use scenarios. It has been adopted by the *Planning with POWER* program, a statewide extension program in support of watershed planning at the local level.

For literature citations, additional project information, and web links, see: [www.purdue.edu/fnr/html/faculty/Spacie](http://www.purdue.edu/fnr/html/faculty/Spacie)

# Urban–Rural Water Issues

## Some Legal Aspects of Changing from Agricultural to Urban Water Use in Kansas

*John Peck, Professor of Water Law, University of Kansas, Lawrence, Kansas*

Like many other Western states, Kansas is going through a transition in its water use. Often, cities needing water cannot obtain new water-rights permits from the Chief Engineer of the Division of Water Resources (DWR), either due to over-appropriation in the vicinity, or the lack of a convenient source of quality water. One method of obtaining a needed municipal water supply is to acquire existing water rights from nearby irrigators or industrial users. Cities that acquire water rights must face the legal requirements for such changes and transfers. (A “change” in Kansas water law is the change in one of three attributes of a water right—type of use, place of use, or point of diversion. A “transfer” means to change ownership of the water right.)

Under the Kansas Water Appropriation Act, K.S.A. §§ 82a-701 *et seq.*, a water right is the right to use a certain annual quantity of water at a given diversion rate on a piece of land in perpetuity. It is a real property right, tied to the land on which it is used, and treated like land for conveyance purposes. Water, in contrast to a water right, is personal property, not treated like land. The Act allows the holder of a water right to make changes in the type of use, place of use, or point of diversion, with prior permission of the Chief Engineer, as long as the change neither impairs existing water rights nor adversely affects the public interest. It is thus possible for a city to purchase an irrigation water right and make necessary changes to turn that right into a municipal right. Moreover, Kansas cities have the right of eminent domain and can theoretically use that power to acquire water rights.

There are potential legal hurdles with any such acquisition of water or water rights. To protect against impairing existing water rights, DWR regulations prohibit increasing the consumptive use of a water right. This rule results in the city, as purchaser, effectively being able to use less water than the original user of the water right. Cities have to drill new wells to divert the water under the water right the city has purchased, necessitating a change in the point of diversion. The city must also change the type of use from its original use to municipal use, which can raise legal issues. A list of water-use preferences exists in the Water Appropriation Act, which can also complicate a transfer. If a city needs to use eminent domain powers to condemn a water right, questions exist on what rights the city can acquire and how far water can be moved. If the city needs to move large quantities of water long distances, the Kansas Water Transfer Act, K.S.A. §§ 82a-1501 *et seq.*, might be relevant.

# Well Pumping Curtailment in Colorado: Conflict Between Surface- and Ground-water Users

*Tom Cech*, Executive Director of the Central Colorado Water Conservancy District and  
the Groundwater Management Subdistrict, Greeley, Colorado

Colorado experienced a most extraordinary water year in 2003. Unprecedented drought in 2002—the driest event in over 300 years—gripped the state and much of the western United States. This natural disaster led to increased scrutiny of tributary ground-water use in Colorado, particularly in the South Platte River basin. Several hundred shallow, junior alluvial wells were shut off in 2003 to protect senior water rights. Prospects for long-term ground-water use are dim.

The year 2002 began with well-below average snow pack in the Rocky Mountains and predictions of severe municipal and agricultural water shortages. The Colorado Supreme Court contributed to the uncertainty by ruling in *Empire Lodge v. Moyers* that alluvial ground-water pumping should be curtailed unless a decreed augmentation plan was obtained from Water Court. The Colorado Legislature responded in 2003 with SB73, and authorized the State Engineer to approve alluvial-well pumping for a three-year interim period. However, this approval could only be given if senior water rights were not injured. Well owners were in a quandary—would they have irrigation water to finish the season, and would they be able to pump their junior wells in the future?

Colorado has operated under the Doctrine of Prior Appropriation—“first in time, first in right”—since the late 1800’s, and developed an extensive surface-water supply based on this management system. However, Colorado’s arid climate severely limits water availability during times of drought. Severe dry periods during the 1930’s and 1950’s led to the drilling of thousands of shallow irrigation wells in the South Platte basin to supplement water from rivers and reservoirs. Well pumping was basically unrestricted until in 1969, when the Colorado Legislature enacted the Water Rights Determination and Administration Act. The 1969 Act incorporated shallow, “junior,” ground-water wells into the priority system with existing “senior” ditch and reservoir companies. It also required all out-of-priority well-pumping depletions to be mitigated, or “augmented,” before pumping was allowed to continue during dry summer months. This law was severely tested in 2002 and 2003.

In 2003, approximately 250 alluvial wells were shut off by the State Engineer due to inadequate augmentation plans. Failure to comply with this order resulted in a \$750 per day fine and court costs. It appears that 700–800 wells, out of a total of 4,500 alluvial irrigation wells in the South Platte basin, will be shut off in 2004. One thousand wells augmented by Central’s Groundwater Management Subdistrict were able to fully operate in 2003 due to the ownership of \$70 million of water rights. A new Well Augmentation Subdistrict was also created to provide an augmentation plan for 460 former members of other augmentation groups that were unable to pump in 2003. Cost to join the new subdistrict was \$5,000 per well, 10 mils of property tax, and an annual fee of approximately \$55 per acre per year on all lands irrigated with well water.

# Watersheds: the Amphitheater for Conflict Management and Public Participation

*James R. Triplett*, Biology Department, Pittsburg State University, Pittsburg, Kansas

Throughout the United States, competing uses from increased public demand are putting a major strain on our resources and the agencies charged with protecting and managing them. The primary stage for all of this action can usually be defined by the limits of the watershed—the larger the watershed, the larger the issues. From land use to water quality, the issues are typically complex and contentious. While a full range of conflict-management techniques are available to those attempting to deal with these issues, few offer the long-term benefits of meaningful public participation. Collaborative learning is one such approach that includes stakeholder participation in all levels of the process, from problem identification to consensus solutions. Initially developed and applied to large-scale forest-management plans, it has found utility in a wide range of resource-management issues, particularly those related to water quality. From site-specific criteria in Kansas to Watershed Coalitions in Oregon, collaboration in one form or another has produced meaningful results.

## Environmental Consequences of Ground-water Overexploitation

*Marios Sophocleous*, Kansas Geological Survey, Lawrence, Kansas

Ground water is a highly vulnerable and important resource for both humans and the environment; therefore, it is essential to understand the environmental implications of ground-water overexploitation. This presentation emphasizes the hydrologic fundamentals for such understanding, which involve ground-water flow-system concepts, factors controlling aquifer responses to development, and surface-water–ground-water interactions. It also highlights the environmental consequences of ground-water overexploitation throughout the world, including Kansas. Expanding irrigated agriculture and increasing world population are having a pronounced effect on global water resources and the environment. Overexploitation and pollution in many regions of the world are threatening ground-water resources, with serious consequences for human welfare and the environment. Ground-water overexploitation not only results in aquifer depletion and water-quality degradation, but also impacts the ecological integrity of streams and wetlands and results in significant losses of habitat and biodiversity. Thus, it is necessary for societies to recognize that the water resources are finite and vulnerable, and find ways to reconcile the demands of human development with the tolerance of nature. The essential first step for making water use sustainable is awareness and knowledge of human impacts on the environment.



# Impacts of Agriculture on Water Quality

## Occurrence of Antibiotics in Hog-waste Lagoons from Confined-animal Feeding Operations from 1998 to 2002

*Michael T. Meyer*, U.S. Geological Survey, Lawrence, Kansas; *Gloria Ferrell*, U.S. Geological Survey, Raleigh, North Carolina; *Joe Bumgarner*, U.S. Environmental Protection Agency, RTP, Cary, North Carolina; *Dana Cole*, University of Georgia, College of Veterinary Medicine, Athens, Georgia; and *Steve Hutchins*, Illinois State Geological Survey, Champaign, Illinois

Antibiotic residues in agricultural waste may help maintain or encourage antibiotic resistance. Knowledge of antibiotic residues in human and animal waste may prove to be important to understand microbial resistance patterns in the environment. Thus it is important to understand the occurrence and distribution of antibiotics in confined-animal feeding operations. Samples of liquid hog lagoon and pit waste were analyzed for antibiotic residues as part of several disparate studies of swine animal-feeding operations. These studies were conducted in six states (North Carolina, Iowa, Oklahoma, Missouri, Nebraska, and Illinois) at different time intervals between 1998 and 2002. The liquid waste samples were analyzed for 22 antibiotics using liquid chromatography/electrospray-mass spectrometry. The most frequently detected antibiotics were chlortetracycline, sulfamethazine, and lincomycin. Samples from Oklahoma contained greater concentrations of sulfathiazole and oxytetracycline than sulfamethazine and chlortetracycline, respectively. In a few samples from Illinois low concentration of virginiamycin, and tylosin were detected. The concentrations of the most frequently detected antibiotics ranged from low 5g/L to low mg/L. The data indicate that the tetracycline and sulfonamide class of antibiotics and lincomycin are widely used in swine animal-feeding operations and that they either revert back to the parent compound after excretion or resist degradation.

# Pesticide and Nutrient Management—Kansas Agriculture vs. the Challenge

*Dale Lambley, Kansas Department of Agriculture, Topeka, Kansas*

Kansas is an agricultural state with the majority of the state's land surface devoted to production of livestock, wheat, corn, grain sorghum, and other field crops. Many crops, particularly in western and south-central Kansas, are grown under irrigation. At present, most of the water used in Kansas each year is directed toward row-crop production and forage for livestock. Kansas also is part of the Great Plains ecoregion, a land blessed with fertile grassland soils and "where the skies are not cloudy all day." Unfortunately, blue skies can mean lack of rainfall. Rainfall can be very erratic in amount and intensity. Ground-water resources in Kansas and other Great Plains states often are limited. When climate is coupled with intensive agricultural uses made of the land, both water quantity and quality become issues important to the state. A challenge important to the farming community is managing pesticides and nutrients used in crop production, as both relate to the quality of the state's surface water and ground water.

Sediment and erosion control have been an important focus of agricultural production methods in Kansas since the dust bowl days. Both continue to be important, with the two most recent highlights being efforts to retain crop residue cover on fields and beginning an even newer initiative to reestablish vegetation and riparian zones along streams to provide filtration and prevent bank erosion.

Efforts to manage pesticide and nutrient inputs to protect water quality are more recent initiatives. Prior to the 1990's, the principal focus of crop fertilizer use was to maximize crop yield. In 1991, a concern developed within the Kansas Department of Agriculture (then called Kansas State Board of Agriculture) over the increased frequency with which certain pesticides, particularly soil-applied herbicides, were being detected in surface waters of northeast Kansas. Following study and public hearings, the agency established in 1992 a pesticide-management area (PMA) for the purpose of decreasing triazine herbicide runoff into the waters of the Delaware River and Perry Reservoir.

The Delaware Basin PMA initiative brought together a group of Federal government, State government, agricultural association, and private sector partners to form a coalition to focus on agricultural issues and water-quality protection throughout the state. That coalition remains active to this day. The PMA initiative taught a number of lessons, many of which continue to guide the approaches used to address agricultural water-quality efforts today.

Since the Delaware PMA, the state has developed its program for establishing Total Daily Maximum Load (TMDL) criteria for various water bodies, and many efforts have been initiated to address water-quality concerns over nonpoint source pollutants arising from farming and ranching operations. Nonetheless, the landscape is vast and challenges remain.

At present, key surface-water quality challenges facing the state appear to be the need to reduce the levels of sediment, bacteria, and nutrients (particularly) phosphorus. A key ground-water challenge is protecting aquifers from nitrate enrichment. Superimposed over all quality issues is the need for water conservation. Although many actions are underway, much remains to be accomplished. Meeting the challenge will require additional research, education, and much practice implementation. Further, we will likely find water-quality protection to be a moving target. As additional research is conducted, new challenges will be identified.

# Water Quality and Quantity Issues Associated with Irrigated Alfalfa Production in Southwest Kansas

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Irrigated alfalfa acreage in southwest Kansas has increased dramatically in the last 10 years due to increasing demand, and consistently high prices. It is currently the most profitable crop produced in southwest Kansas, and one of the few crops that turns a profit without government subsidies. Although alfalfa is a drought-tolerant crop, its long growing season and perennial life cycle result in much greater potential for water use than field crops, for example a total of 1.5× as much water (precipitation plus irrigation) is required for economically optimal production of alfalfa as for corn. Given the historic lack of “teeth” in enforcing these limits, it is not surprising that large-scale hay producers from southwest Kansas are featured in the State’s list of chronic over-pumpers every year. Whatever its impact on water supply, however, it is clear that alfalfa production can have a strong positive impact on water quality. It has the potential to remove more residual nitrogen from deeper in the soil profile than any other crop grown commercially in Kansas, and can be as effective as any crop in recovering nitrogen from the land application of animal waste. We will present data from field experiments in southwest Kansas that demonstrate the yield response of alfalfa given different levels of irrigation, and the effectiveness of alfalfa in removing residual N accumulated below the root zone of traditional field crops. High levels of residual soil nitrate resulted in dramatic reductions in nitrogen fixation, meaning that the maximum effective removal rate for residual N is probably much greater than previously estimated. We will discuss the difference that enforcement or non-enforcement of allocation standards could have on the overall supply of water for irrigation in southwest Kansas given current trends in alfalfa acreage, and compare approaches to nutrient management planning (NMP) regulations that could take full advantage of the unique characteristics of deep rooted perennial forage legumes for the safe disposal of high nitrogen waste products from concentrated animal feeding operations (CAFOs) and other sources.

# Watershed Water-quality Classification in Kansas

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Concerns regarding water quality in the United States have led to the increasing use of watersheds as a natural-resource assessment and environmental-management approach to surface-water quality. A watershed approach allows for the study of a defined, organized system instead of a single stream or water body. By identifying certain factors that may contribute to surface-water impairments, efficient monitoring strategies can be developed, causes of impairments can be determined, and prioritization can begin for restoration of watersheds. This research provides a watershed classification in Kansas at the HUC 11 scale to identify watersheds that have been impaired by factors such as human, environmental, physical, and agricultural impacts. Using a geographical information system (GIS) to aid in the management and storage of data, variables related to surface water were used in this classification. These variables were grouped together into factors with similar characteristics using principal components analysis (PCA) with a varimax rotation to maximize the placement of the variables. Watersheds grouped together using a cluster analysis approach allow for comparisons between similarly grouped watersheds and the factors of impairments. Results of this classification compared with water-quality values from the 303(d) report aid in the assessment of the vulnerability of watersheds to surface-water impairments. The classification performed at a larger HUC 8 scale and an ecoregion scale can provide insight to watershed impairments. Once vulnerable watersheds in Kansas are identified, it is possible to begin remediation efforts and establish management practices for Kansas watersheds to meet their designated uses.

# Ogallala Management Issues

## A Coupled Hydrologic-economic Modeling Tool to Support Ground-water Management Decisions

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Ground-water availability in the High Plains aquifer is crucial for the social and economic vitality of western Kansas. To identify management strategies that can effectively sustain this vitality, it is necessary to understand the interrelated processes causing ground-water decline. Although the processes of hydrology and economics in the High Plains are fairly well understood individually, the links between them are not.

This project develops a framework for coupling hydrologic and economic models to assess various management scenarios. Hydrologic and economic data were assembled for the Sheridan County Study Region in Groundwater Management District #4. A hydrologic model was developed for the area including wells and regional ground-water withdrawal, while an economic model was developed to describe and predict irrigation decisions. These models were run in tandem on a yearly cycle to predict future hydrologic and economic conditions under current ground-water management and policies. The coupled framework developed in the project will ultimately be linked to a GIS interface, which would allow stakeholders to simulate various ground-water management strategies and policies.

# HIPLAIN—The High Plains Aquifer Information Network

## www.hiplain.org

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Many communities, industries, municipalities, and agricultural producers rely on the High Plains aquifer for ground water to thrive in the semi-arid region. Understanding the importance of the aquifer and ensuring its viability in the future is critical. Residential and agricultural users, researchers, consultants, and public policymakers need to have a common source of information to help them acquire the information and knowledge they need to protect this vital resource.

The Internet is an effective method of disseminating data and information. The High Plains Aquifer Information Network (HIPLAIN) establishes an informational site to serve all users of the High Plains aquifer. HIPLAIN focuses on providing information on many aquifer-based issues, including education, agriculture, environmental topics, technical data, and links to organizations that are associated with the aquifer. HIPLAIN is a one-stop source for a broad group of High Plains aquifer users. By consolidating the available information into one website, individuals are able to find answers and utilize resources with a click of their mouse. HIPLAIN will provide opportunities for all potential users to increase their understanding of the region's water resources and provide information to enable improved personal and public decisions on water conservation, development, and management.

Progress on the HIPLAIN web site includes the following: an improved internal search engine, hydrogeologic glossary, additional literature-search capabilities, development of an Ogallala Aquifer Institute (OAI) web site, and acquisition of additional links to the other seven states that overlie the High Plains aquifer (in close coordination with the OAI).

Activities still underway include the following: accessing newly developed data-base front ends and data-analysis tools from the KGS website; development of procedures for future data and information dissemination through coordination with the OAI, Groundwater Management Districts (GMDs), and other educational and governmental groups; providing information on legal issues concerning water rights, enforcement, and water-management programs; and redesign of the website in ColdFusion language to increase efficiency and eliminate the frames format that the current site has. This will help address accessibility issues as discussed in Web Content Accessibility Guidelines for the State of Kansas Guidelines by Priority—Version 2.0 (KS ITEC, 2001).

In March–April 2003, the HIPLAIN website was sent to State, Federal, and local agencies for review. Dr. William Carswell, Jr., USGS Regional Hydrogeologist for the Central Region (Denver), requested that the USGS District Chiefs for the High Plains states review the site and assist us in acquiring additional data-base and informational links for Federal, State and local agencies in the those states. To date we have heard from personnel from most of the states.

As the project moves into its third year, several enhancements are being planned. Keeping with the idea of increasing user-friendliness, a new layout is being designed that will incorporate drop-down menus, allowing users to find their section of interest with fewer clicks of their mouse. To reduce the length of the pages, each subcategory of the main sections will have a dedicated page, with links back to the main topics or subcategories. This style of website will improve visibility of search engines and increase the overall utility of the site.

# Crop Water Allocation Program

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Many irrigators in Kansas are facing immediate challenges with declining water yields from their wells. Estimates have been made that 30–50 irrigation wells in western Kansas are pumping below original capacity. Irrigators in Kansas also face the possibility of shrinking water allocations with changes in water policy or simply enforcement of current water policy. Any of these scenarios will mean more limited irrigation than has been used in the past.

To make these reductions in water use, irrigators will need to consider shifts in cropping patterns. Irrigators who have shrinking water supplies need to know what cropping combinations to select and in what proportions for best water use and profitability. Not every combination of every cropping pattern that an irrigator dreams up can be examined experimentally with research. An agronomic/economic model is needed to predict results for an individual irrigator's situation.

A computerized decision tool had been created based on scientifically developed crop responses to water and formalized budgeting techniques. Two distinct resources serve as building blocks for the scarce water model. The first component is the Kansas Water Budget, which was developed by a team of Kansas researchers led by Dr. Lloyd Stone in the early to mid 1990's. It was based on extensive field research in western Kansas. At the heart of the model are relationships between crop yield and evapotranspiration that were developed from research in the area. The Kansas Water Budget provides a foundation for the second component of a decision model. Extensive crop water budgeting has been conducted by agricultural economists to guide producers in economic decisions concerning their operations. The economic realities of producing irrigated crops at all levels of irrigation inputs must be factored into decisions about water allocations. However, the decisions become complex with multiple choices.

The heart of the decision for allocating water is to divide it among one to several crops and allocate it over all the irrigated land or part of the land. We chose to take an iterative approach to the solution, or solve all of the combinations of possibilities that made sense and then rank them in order of highest net return.

The starting point was to divide the land base into logical proportions of cropping base that might be farmed: 50–50, 75–25, 33–33–33, 50–25–25, and 25–25–25–25. The program user chooses the cropping pattern, maximum crop yields, irrigation-water costs, crop-production costs, and maximum water applied for the season. The program then iterates, by 10% increments, all possible net income solutions for the water-allocation combinations over all crop combinations. For each iteration, the program calculates net income for economic optimization and decision making.

# Depletion Predictions for the High Plains (Ogallala) Aquifer in Northwest Kansas

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Ground-water depletion in the High Plains aquifer in Kansas is a major concern for farmers, the public, and State of Kansas agencies. Heretofore, the majority of scientific analyses on the depletion issue have focused on documenting historical depletion. While valuable, such analyses often have limited ability to predict effects of management decisions affecting the future rate and magnitude of ground-water depletion. This presentation demonstrates that through the use of advanced GIS (geographical information system) methods, we now have the ability to incorporate essentially all of the available data on the High Plains ground-water system directly into regional predictive models that can be used to evaluate alternatives and support management decisions. These methods allow for the efficient and cost-effective setup, calibration, and operation of predictive models. The methods are demonstrated as a case study for the High Plains aquifer in northwest Kansas that includes the area of GMD#4. The predictive model developed for this area was calibrated to 40 years of pumping for the time period from 1961 to 2000. Because all predictive models have uncertainties associated with the predictions, the uncertainties in this model are quantified. The uncertainties in the available data limit development of predictive models that have lower uncertainties than those presented. This model was used to predict ground-water level declines 40 years into the future under management scenarios including current and potential future agricultural crop changes in the areas of severe depletion. A relatively simple linkage between irrigation-water requirements for various western Kansas crops and ground-water depletion effects was developed for use in management planning. As a result of the level of detail included in the model, it is possible to evaluate the effect of various management options down to the township-scale (tens of square miles). Evaluation of smaller areas does not produce meaningful results because of well interference and limitations of the available data. It is illustrated that management alternatives affect the timing but not the overall pattern of depletion, which is primarily controlled by the geometry of the ground-water system.

# **Recreation and Public Water Supply Issues**

## **Marion Reservoir Blue-green Algae Bloom—Summer 2003**

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Marion Reservoir is a 6,200-acre multipurpose reservoir located in south-central Kansas that serves as a source water supply for the cities of Marion and Hillsboro. The reservoir is managed by the US Army Corps of Engineers and provides numerous recreational opportunities including swimming, boating, fishing, and camping.

During the summer of 2003, Marion Reservoir experienced a sizable blue-green algae (cyanobacteria) bloom. The bloom was of such a magnitude that it affected both recreation in and on the reservoir and the water supplies for the cities of Marion and Hillsboro. This paper will provide a retrospective look at the events leading up to the bloom and the State of Kansas response to the bloom, including the coordinated efforts of the Governor's Office, the Kansas Department of Emergency Management, the Kansas Department of Transportation, and the Kansas Department of Health and Environment.

# Sediment Quantity and Quality Issues for Kansas Reservoirs

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An understanding of the quantity and quality of sediment deposited in a reservoir is necessary for effective reservoir and watershed management. Sedimentation affects both the useful life and aesthetic quality of a reservoir. Sediment quality is an important environmental concern because sediment may act as a sink for water-quality constituents and as a source of constituents to the overlying water column and biota. The U.S. Geological Survey (USGS), in cooperation with Federal, State, and local agencies, has completed about 20 reservoir-sediment studies in Kansas using a combination of bathymetric surveying and sediment coring. Specific objectives of the studies were to: (1) estimate total sediment volume and mass, (2) estimate annual sediment deposition and yield, (3) determine occurrence and trends of water-quality constituents, (4) estimate annual constituent loads and yields, (5) assess sediment quality with respect to available guidelines, and (6) provide a baseline for future assessments.

Results indicated that decreases in water-storage capacity due to sedimentation ranged from about 5% or less at Cheney Reservoir (south-central Kansas), Hillsdale Lake (northeast Kansas), and Webster Reservoir (north-central Kansas), to about 55% at Crystal Lake, a small impoundment in east-central Kansas. Decreases in water-storage capacity at Perry and Tuttle Creek lakes (northeast Kansas) were in the range of 20 to 35%. By 2002, sedimentation had already filled the sediment pool at Cheney Reservoir. If the historical rates of sedimentation continue, the sediment pools in Perry and Tuttle Creek lakes may be filled in by 2021 and 2023, respectively. Mean annual net sediment yield ranged from 0.03 acre-ft/mi<sup>2</sup> for Webster Reservoir to 2.03 acre-ft/mi<sup>2</sup> for Mound City Lake, a small impoundment in east-central Kansas. Mean annual net phosphorus yields, which paralleled the sediment yields, ranged from 26 lb/mi<sup>2</sup> for Webster Reservoir to 2,999 lb/mi<sup>2</sup> for Perry Lake.

Sediment quality was assessed on the basis of nonenforceable guidelines adopted by the U.S. Environmental Protection Agency (USEPA). Results from most of the reservoirs studied indicated that arsenic, chromium, copper, and nickel typically were detected at concentrations that exceeded USEPA threshold-effects levels. Concentrations greater than the threshold-effects levels occasionally produce adverse biological effects. Cadmium, lead, and zinc were detected at concentrations that exceeded the threshold-effects levels at some of the reservoirs. Mercury and silver concentrations typically were less than the threshold-effects levels at all reservoirs studied. At Perry Lake, nickel concentrations also typically exceeded the USEPA probable-effects level, which represents the concentration above which adverse biological effects usually or frequently occur. Organochlorine compounds (that is, pesticides and PCBs) typically either were not detected or were detected at concentrations less than the threshold-effects levels. DDE (a degradation product of DDT), which was detected at several reservoirs, had a sediment-deposition profile at Perry and Tuttle Creek lakes that reflected the history of DDT use.

The information provided by the reservoir sediment studies is used by the State in the development, implementation, evaluation, and revision of total maximum daily loads designed to reduce reservoir sedimentation and improve water quality. Also, the information may be used to partly reconstruct historical watershed water-quality conditions and to provide present-day baselines with which to evaluate long-term changes in reservoir sedimentation and water and sediment quality that may reflect changes in human activity in the contributing watersheds.

# Watershed Restoration and Protection Strategy for the Upper Wakarusa River Watershed

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Located in east-central Kansas, Clinton Lake is a multipurpose U.S. Army Corps of Engineers reservoir. The lake provides flood protection for a 156 mi<sup>2</sup> area below the dam, is drinking water source for 100,000 people in several counties, and is used by almost one million people per year for recreational purposes. The Upper Wakarusa River watershed covers 367 mi<sup>2</sup> extending about 40 mi west from the largely forested Lawrence–Douglas County area into northeastern Osage County, and the Tallgrass Prairie area of western Shawnee and eastern Wabaunsee counties.

Over the last 40 years, a considerable amount of data has been collected and numerous studies conducted in Clinton Lake and in the Upper Wakarusa River watershed. All the data and studies pointed to the same general conclusion that the water quality of Clinton Lake is impaired due to nonpoint sources of pollutants entering the river and lake causing eutrophication of the lake, higher than acceptable levels of fecal coliform bacteria in the river, and that the lake is accumulating sediment at a faster rate than anticipated. The Kansas Department of Health and Environment assigned the lake and watershed a high priority for restoration and protection, and in 1999 established Total Maximum Daily Load (TMDL) goals for fecal coliform bacteria and eutrophication.

In 2002 the Kaw Valley Heritage Alliance took up the challenge and, using available information and the TMDLs as a guide, completed a Watershed Restoration and Protection Strategy (WRAPS) for the Upper Wakarusa Watershed in early 2003. Thirteen general water-quality goals and objectives are identified for implementation but with the expectation that the WRAPS will be dynamic to allow for future refinement or addition of goals to keep the document current. The process followed in development of the WRAPS will be presented along with an overview of the goals that range from installation of best management practices to urban/suburban growth management to areas where additional investigation may be needed. Progress toward constructing an implementation plan will be discussed along with the challenges that are anticipated in the effort to protect Clinton Lake and restore the water quality in the Upper Wakarusa River Watershed.

# Assessing the Impact of Maneuver Training on NPS Pollution and Water Quality

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Nonpoint source (NPS) pollution has been called the nation's largest water-quality problem, and its reduction is a major challenge facing our society today. As of 1998 over 290,000 mi of river, almost 7,900,000 acres of lake, and 12,500 mi<sup>2</sup> of estuaries failed to meet water-quality standards. Military-training maneuvers have the potential to significantly alter land surfaces in a manner that promotes NPS pollution, resulting in the inability of military installations to meet water-quality standards and the decline of training lands.

Military readiness depends upon high-quality training. Effective maneuver training requires large areas of land and creates intense stress on this land. Environmental-protection requirements place additional restrictions on land use and availability. Because military-training schedules are set well in advance to make the best use of installation-training facilities and National Training Centers, there is little flexibility to modify training events and maintain readiness. In order to avoid maneuver restrictions, proactive management plans must be developed giving commanders the information they need to assess the environmental cost of training and management practices that reduce the environmental impact.

The objective of this work, funded by the Strategic Environmental Research and Development Program (SERDP), is to identify sources of NPS pollution resulting from military activities, to assess the impact of this pollution on surface-water quality, and to provide information for commanders to lessen the impact of training on water quality. Investigators are assessing the impact of two major sources of NPS pollution: 1) erosion from upland training areas and 2) channel erosion at stream-crossing sites, on surface-water quality at Fort Riley, Kansas. Project objectives will be met through a comprehensive analysis of military activities, climatic factors, and environmental response.

Researchers are using watershed water-quality models in conjunction with remotely sensed information and a geographic information system (GIS) to assess the impact of training on water quality, in particular on the amount of soil erosion. A matrix of training intensity and weather will be created for assessing the environmental cost of training maneuvers. In addition, researchers are collecting surface runoff at three buffer sites to determine the effect of vegetated buffers for controlling NPS pollution and using new real-time data-collection systems to assess the impact of vehicle crossings on stream water quality and erosion dynamics at Low Water Stream Crossings (LWSCs).

## Water Use Issues

### Population Growth and Water Resources: Case Study and Forecast for Phoenix, Arizona, USA

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Any community with a growing population has an increasing demand for water. As demand increases, the frequency and severity of water shortages intensifies. Symptoms of the problem correlate perfectly with drought cycles, so we naturally conclude that our core problem is caused by droughts. Our mindset tells us we simply need to bridge the gap between dry periods to resolve the problem. To accomplish this we tap our aquifers and practice conservation. Unfortunately and ironically, our efforts only serve to intensify the severity of our problem because they leave the core cause, population growth, unaddressed. Metro Phoenix has spent the last 100 years solving the apparent problem of water supply and has enabled our population to grow by an average of 5% every year. Our primary rivers continue to flow into Metro Phoenix, but for the past 11 years we have consumed every drop. We now consume all of our local and imported renewable water inputs—yet our demand continues to grow. To meet the growing demand, we tap deeper and deeper into our nonrenewable ground-water reserve. Our challenge is not finding more water nor becoming more efficient. Our problem is not a water problem and cannot be solved by our water industry. In a very real sense, our primary problem isn't even population growth itself. Our primary problem is the mental barrier that keeps us from seeing the consequences of our actions. We are building long-term demand on a short-term supply. The good news is that we, as individuals in our community, are gradually coming to accept the simple math of our situation. Once we start to openly and publicly acknowledge our situation, we can begin to address it.

# Walnut Creek Intensive Ground-water Use Control Area (WCIGUCA): the First Ten Years

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A very general introduction to the reasons for enacting this IGUCA started in the mid to late 1980's with the Kansas Wildlife Federation expressing their concerns regarding the availability of water in the Walnut Creek. Walnut Creek is one of the sources of water to Cheyenne Bottoms Wildlife Refuge, which is a part of the international migration flyway for a number of shorebirds and other water-dependent birds. After a few years of studies, field work, and public hearings, the Walnut Creek IGUCA order was issued in January of 1992 and includes parts of Barton, Rush, and Ness counties.

Based on information gathered from the research and the hearings, a safe yield of ground water that could be withdrawn from the Walnut Creek alluvial valley was determined to be 22,700 acre-feet (AF) per year. Because the quantity of water use permitted throughout the valley at that time was closer to 66,000 AF/year, a reduction of the total water permitted was needed. Due to the fairly large quantity of water use that needed to be reduced, it was decided that strict first in time, first in right could not be used or too many small farmers would completely lose their ability to irrigate.

Therefore, it was determined that an altered system of priority would be used. All surface rights and vested ground-water rights would not be reduced. All senior permits (priority date prior to October of 1965) would receive 12 to 14 inches of water per acre irrigated (Barton=12, Rush = 13, Ness = 14) and junior permits would receive 5 1/4 to 6 1/4 inches per irrigated acre (Barton = 5 1/4, Rush = 5 3/4, Ness = 6 1/4). The acres irrigated were not based on the permitted acres but the maximum acres irrigated in any one year between 1985 through 1990. All non-irrigation files were reduced by 10% of either their average use during the same time period or the average GPCD and population of that time period.

These reductions were assigned in five-year allocations with the first allocation being from 1992 through 1996 (then 1997 through 2001, etc.). In this manner, a permit owner could use their original permitted quantity in any one year but could not exceed the reduced allocation over a five-year period. This would give each owner some flexibility when deciding how to reduce their own water use. In the first five-year allocation, a request for a partial stay resulted in junior rights receiving the same amount of water as senior rights for only the first year.

Before the end of the first five-year period, it was decided that any permit owner that had not used their full allocation could carry over an amount of water equivalent to one year of their original permit. Also created, so that individual users had some additional flexibility, were temporary transfers. This enabled permitted water users to transfer their allocated water, within a 10-mile radius, from one permit to a different permit that may be in more need of that water as long as the original permitted quantity is not exceeded.

At the 10-year review (which occurred in 2003 to assure the most accurate data possible), the allocations appear to be accomplishing the proposed goals. Not a single year in the first 10 years produced ground-water usage that reached 22,700 AF. The highest usage was reported in 2001 at 19,709.63 AF. Because all ground-water withdrawals were ordered to be equipped with flowmeters at the onset of the order, these numbers are fairly accurate and are field checked on a random basis (ground-water usage values are available for 1988–2002).

# A Field Assessment of a Method For Estimation of Ground-water Consumption by Phreatophytes—Year One

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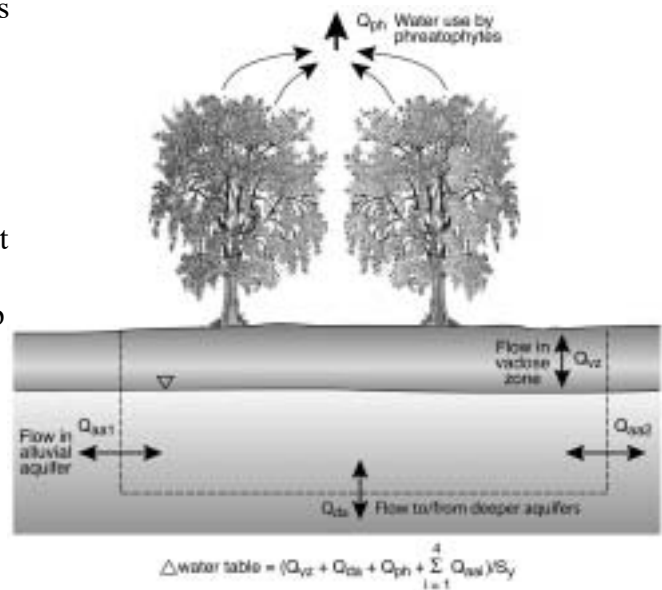
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Consumption of ground water by phreatophytes in riparian zones could be an important factor contributing to periods of reduced streamflow in Kansas and other areas of the United States. Reliable estimates of the magnitude of this consumption, however, have been difficult to obtain. In an effort to address this problem, a team of researchers has been assembled with the goal of developing practical approaches for quantifying phreatophyte consumption of ground water in conditions common to central and western Kansas. The development work is being carried out at the Larned Research Site, a field area of the Kansas Geological Survey that is located in the riparian zone of the Arkansas River near Larned in central Kansas. Although the work is being done at a site with a mix of phreatophytes common in central Kansas, the developed approaches will be equally viable in areas with different phreatophyte communities. This presentation will describe the initial phases of the project.

The early portions of this project have focused on the possibility of using water-table fluctuations as a means of quantifying phreatophyte activity. An approach based on water-table fluctuations has many advantages: 1) it provides direct information on ground-water consumption, which is virtually impossible to quantify using other methods; 2) the water-table variations on which it is based are the integrated response to a highly heterogeneous and difficult-to-characterize group of phreatophyte stresses; 3) the approach is generic in nature and not dependent on any particular mix of phreatophytes; 4) the approach can be implemented at a relatively low cost; and 5) the approach is also a convenient means of assessing the impact of phreatophyte eradication efforts on plant water use. The control volume

concept is being used to assess the relationship between phreatophyte activity and water-table fluctuations. A control volume is essentially a very large lysimeter in which a water balance is performed as shown in the adjacent figure. Water and salinity fluxes into/out of this volume are estimated using a network of monitoring wells, vadose-zone installations, and meteorologic sensors. In addition, transpiration at the leaf- and tree-scale is monitored periodically during the growing season using a portable photosynthesis system and sapflow sensors, respectively. Although much of the initial work has involved establishment of the monitoring network, the water-table measurements that have been collected clearly show prominent diurnal fluctuations that are most likely a product of phreatophyte activity. These fluctuations are only observed in the growing season and are limited to the riparian zone (see figure). In addition, the magnitude of these fluctuations is clearly controlled by the depth to the water table. The assessment of methods for estimating phreatophyte water use from these fluctuations will be a major focus of the second year of this project.

Larned Control Volume for Estimation of Ground-water Consumption by Phreatophytes





# Water Quality in Surface Water

## Occurrence and Fate of Antibiotics in Kansas Wastewater-treatment Facilities

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Municipal wastewater-treatment plants (WWTPs) are among the major sources of surface-water and ground-water contamination by antibiotics and other pharmaceutical agents. The discharge of antibiotics in surface waters and their presence in ground water is of grave environmental concern because these chemicals have the potential to perturb microbial ecology, increase the proliferation of antibiotic-resistant pathogens, and pose serious threat to human health. In order to develop solutions to control the environmental release of pharmaceutical agents from WWTPs, it is important to estimate the amounts of these chemicals discharged into surface waters and on land. The project evaluated the occurrence and fate of selected widely prescribed antibiotics—sulfamethoxazole (sulfonamide), ciprofloxacin (fluoroquinolone), and azithromycin (azilide)—at four Kansas WWTPs. Water and sludge samples collected in late spring, late summer, late fall, and late winter were extracted and analyzed for the target antibiotics. Results from this research are expected to provide critical and timely information about the mass input of these drugs from municipal sewage into the selected Kansas WWTPs and the extent of their environmental release through effluent discharges and biosolids disposal.

# Continuous Real-time Water-quality Monitoring of Kansas Streams

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A continuous, real-time water-quality monitoring system was developed for 13 stream sites in Kansas that eliminates the waiting time inherent in chemical analyses reported by a laboratory and provides continuous estimates of constituent concentrations and loads. The U.S. Geological Survey (USGS) monitoring system is described, and its effectiveness in characterizing water quality is evaluated using discrete water-quality samples collected from 1995 through 2002 and continuous water-quality monitor data from the first four years of operation with examples from stream sites in Kansas. Because sensor technology currently is not available to directly measure many chemicals of interest in a stream, regression models are developed to relate constituents in laboratory-analyzed samples with in-stream continuous-sensor measurements. Concentration estimates traditionally have used continuous streamflow data only; however, most constituents are more accurately estimated with continuous specific conductance or turbidity measurements. As the hourly sensor measurements are transmitted from the stream sites to the USGS computers in Lawrence, Kansas, the models are applied, and the computed estimates displayed on a Web page at <http://ks.water.usgs.gov/Kansas/rtqw/>. Currently, continuous estimated concentrations and loads of sediment, major ions, select nutrients, atrazine, and indicator bacteria, and uncertainty of the estimates are displayed. Information from this system is used by water suppliers to modify treatment of water, by State and local agencies in total maximum daily load (TMDL) programs, and to alert recreational water users of potential health risks.

# Temporal and Spatial Occurrence and Persistence of Pharmaceuticals, Pathogens, and other Wastewater Compounds in an Effluent-dependent Stream, Tucson, Arizona

*Gail Cordy and David Anning, U.S. Geological Survey, Tucson, Arizona;  
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Treated effluent is a valuable resource in Arizona and the Southwest where it is used to recharge dwindling ground-water supplies, both incidentally and intentionally. Reuse of effluent is one of the ways to sustain agricultural and urban irrigation, wetlands, and riparian areas in arid regions. Recent studies of pharmaceuticals, hormones, pathogens, and other organic wastewater compounds (OWCs) in streams indicate that some of these compounds and pathogens are not removed during the wastewater-treatment process, but are being discharged into streams. With support from the U.S. Environmental Protection Agency, staff from the U.S. Geological Survey and the U.S. Department of Agriculture, Water Conservation Laboratory, developed a study to determine the temporal and spatial occurrence and persistence of pharmaceuticals, pathogens, and OWCs in an effluent-dependent stream. Over a 34-hour period, November 5–6, 2002, flow in the effluent-dependent Santa Cruz River near Tucson was sampled at the Roger Road Waterwater Treatment Plant (WWTP) outfall, the Ina Road WWTP flume (6.8 km downstream), the Santa Cruz River at Cortaro Road (2.9 km downstream from the Ina Road WWTP flume), and the Santa Cruz River at Trico Road (11.4 km downstream from the Cortaro Road site). Samples were collected to coincide with low, rising, peak (2), and falling streamflow as identified in the diel (daily) hydrograph for each site. Twenty environmental samples and two field blanks were collected. Samples were analyzed for 24 human and veterinary drugs and 80 other wastewater compounds by methods 3 and 4, respectively, as described in Kolpin and others (2002). The presence of several pathogens was determined by polymerase chain reaction analyses.

Table 1 shows the total number of compounds detected out of 102 possible in each sample at the selected points of the hydrograph at each site. The analytes cotinine (a metabolite of nicotine) and caffeine were included in both methods but were only counted once per sample if detected by both analytical methods. The largest number of compounds detected (47) was in effluent from the Ina Road WWTP as the streamflow was increasing (rising) toward the peak flow for the day. The smallest number of compounds (26) was found in the Santa Cruz River at Trico Road, 14.3 km downstream from the Ina Road WWTP flume, during decreasing (falling) discharge.

**Table 1.** Number of pharmaceuticals and other wastewater compounds detected in water samples at different streamflow conditions over 24 hours.

Site Name	Number of compounds detected during indicated streamflow condition				
	Low	Rising	1st Peak	2nd Peak	Falling
Roger Road WWTP outfall	44	43	44	41	44
Ina Road WWTP flume	36	47	37	41	43
Santa Cruz River at Cortaro Rd	45	42	40	38	41
Santa Cruz River at Trico Rd	33	35	33	32	26

A spatial trend clearly shown by these data is that, regardless of time, fewer compounds were detected in samples collected at the Trico Road site, located farthest from the WWTPs. This is not unexpected given that some of these compounds can be lost from the streamflow through photolysis, volatilization, or adsorption to sediment and organic material. Additionally, during transport downstream, some compounds may biodegrade or be transformed to metabolites that were not analyzed as a part of this study and, thus, were not detected. Compounds that persisted downstream included an insect repellent, detergent metabolites, fire retardants, an antimicrobial agent, cholesterol, as well as various human drugs including antibiotics, a nicotine metabolite, an antiepileptic, an antacid, an antidepressant, an antiasthmatic, an analgesic, an antihypertensive, an antianginal, an antifungal, and caffeine and its metabolite.

Temporal trends in the data are not as clearly defined as the spatial trend. The temporal trend at the Cortaro Road site, where effluent from both of the upstream WWTPs (Roger and Ina Road) passes as a single stream, shows that as discharge increases the number of detections decreases. A review of the nature of the effluent input and compound characteristics and concentrations is in progress to determine the cause of this trend. Temporal trends at the other sites are not apparent from the data (table 1).

Results of the temporal sampling demonstrated that coliform numbers varied considerably during a 24-hour period. There was a correlation between bacterial numbers and discharge at the Ina Road WWTP flume. Coliform numbers were highest (800 CFU/100 mL) in the evening (2100) during the second peak flow and lowest (100 CFU/100 mL) in the early morning (0600) during lowest flow. These results emphasize the need for composite daily-load measurements rather than a single daily measurement near the point of discharge in order to get a more accurate assessment of microbial inputs from effluent discharge into streams.

Spatial distributions of indicator bacteria in the Santa Cruz River demonstrated that, in general, bacterial numbers increased with distance from the discharge point. Numbers of *E. coli* and heterotrophic bacteria were greatest at the Trico Road site, 14.3 km from the Ina Road WWTP flume. Coliform numbers also increased with distance from the Ina Road WWTP flume with the largest numbers reported at the Cortaro Road site (7,000 CFU/100 mL), 2.9 km from the Ina Road WWTP flume. Farther downstream at Trico Road, coliform numbers were less than one-half (3,000 CFU/100 mL) those at Cortaro Road. These results are contrary to what might be expected as a result of microbial die-off once the bacteria are released into the environment. The fact that coliform numbers increased downstream from the Ina Road WWTP flume supports the notion of reactivation of viable, but nonculturable, bacteria in the effluent and (or) survival and regrowth of indicator bacteria (Gagliardi and Karns, 2000) downstream as disinfection compounds such as chlorine are degraded, adsorbed, and (or) volatilized.

These results emphasize the need to better understand the processes affecting bacterial concentrations in streams, such as survival in water and sediment, possible regrowth or reactivation, and inputs from animal and bird feces. In addition, owing to the persistence of indicator bacteria and therefore possibly pathogens, this study raises questions about the potential effects of incidental ground-water recharge in the Santa Cruz River on ground-water quality.

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# Small Artificial Water Bodies: a Neglected but Important Factor in Water Supply and Environmental Quality

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Recent studies<sup>1</sup> have shown that artificial ponds of various types and purposes are ubiquitous features of the landscape in many areas of the U.S., far outnumbering natural water bodies. Because they are small, mostly on private property, and their numbers and locations vary over time, they are very poorly represented on the digital map products and data bases normally used for hydrologic analyses. However, in many areas they are a major factor in controlling the residence time of surface water, in trapping sediment, and in providing a network of biogeochemical reactors that modify loads of nutrients and other solutes. By filtering and slowing the movement of surface water, pond networks have a positive effect on development of surface-water supplies in that they trap sediment and may prolong the life of larger supply reservoirs; however, they also tend to reduce net runoff at the expense of evaporation and infiltration. In terms of water quality, particularly in agricultural areas, ponds may provide some of the beneficial effects of riparian zones by intercepting and transforming nutrients and contaminants. Ecologically, the ponds provide habitat diversity and may partly replace diminished wetland inventories, but many are in areas that lacked natural water bodies and thus can serve as homes or pathways for non-native pest or invasive species.

Kansas straddles the North American transition from very high pond densities in the east to much lower densities in the west,<sup>1</sup> and thus provides an ideal mesocosm in which to explore issues of pond detection, inventory, histories, and hydrologic and biogeochemical effects at the landscape scale. A multi-institutional interdisciplinary project<sup>2</sup> is applying a combination of remote sensing, field characterization, and modeling studies to calibrate satellite observations (Landsat TM and ASTER) with multispectral and conventional aerial photography, and to evaluate the potential application of results to a wide range of water resource and environmental studies. Case study efforts focus on Jefferson and Lyon counties, with detailed investigation of the Midland and Allen SE quadrangles.

Results confirm the under-reporting of ponds in available data sources and show similarly high densities in both the Midland (9.3/mi<sup>2</sup>; 3.5/km<sup>2</sup>) and Allen SE (8.6/mi<sup>2</sup>; 3.2/km<sup>2</sup>) quads, but historical air photos dating back to the 1940's indicate very different temporal patterns of development in the two case study areas. Spectral analysis of satellite and camera images indicates that the tools are capable of identifying a wide range of pond water quality and ecological conditions, and initial watershed spatial model analyses are being used to test and refine earlier, more general results or assumptions about the effects of ponds on the net evaporation budget, filtration effectiveness for sediment retention, and relationships between pond numbers and types and land use. The presentation will illustrate the results being obtained and their potential importance to water-resource and environmental-quality issues.

<sup>1</sup>Smith, S. V., Renwick, W. H., Bartley, J. D., and Buddemeier, R. W., 2002, Distribution and significance of small, artificial water bodies across the United States landscape: *The Science of the Total Environment*, v. 299, p. 21–36.

<sup>2</sup>Supported by NASA and KTECH through the KU EPSCoR Program.



# Water-use Impacts on Critical Habitat

## Spatial and Temporal Changes in Flow and Water Quality in the Cimarron River, Southwestern Kansas

*Donald O. Whittemore and David P. Young, Kansas Geological Survey, Lawrence, Kansas*

The Cimarron River in southwest Kansas crosses the underlying High Plains aquifer. Prior to ground-water development, the surface of the ground-water table in the aquifer along the river was relatively near the bottom of the river channel along the entire length of the river in Kansas. Streamflow measurements in the early 1940's showed that the river generally lost flow from near Elkhart to the northwest part of Seward County and gained flow from northwest Seward to southwest Meade County. High-volume, consumptive pumping from wells in the High Plains aquifer has caused the water table to decline substantially below the river channel in Stevens, Grant, Haskell, and northwest Seward counties. As a result, ephemeral flows from heavy rainstorms are expected to be less along the channel in Stevens, Grant, and Haskell counties, and the start of perennial flow in the river channel has now migrated about 15 mi downstream of the predevelopment location in Seward County. The mean annual flows of the Cimarron River have declined at the USGS gaging stations in southwest Morton County near Elkhart and in southwest Meade County north of Forgan, Oklahoma. The mean annual flow of the river in southwest Meade County during 2000–02 was less than half of that during 1966–69.

Ground water in the High Plains aquifer is fresh across nearly all of southwest Kansas except in southeastern Seward County and the southwest corner of Meade County, where upward intrusion of saltwater from the underlying Permian bedrock causes the aquifer water to become saline. The source of the saltwater in the Permian rocks is primarily dissolution of rock salt (halite, NaCl). The saline water discharges into the Cimarron River and steadily increases the chloride concentration from less than 40 mg/L in central Seward County to over several hundred mg/L in southwest Meade County. The decrease in freshwater discharge from the High Plains aquifer to the Cimarron River in Seward County has caused the chloride concentration to increase in the river water at the USGS gaging station and KDHE sampling station north of Forgan, Oklahoma, from an average of about 500 mg/L in the mid-1960's to over 1,000 mg/L by 2000. Increases in sulfate concentration during the same period have been substantially smaller, from an average of approximately 170 mg/L to 210 mg/L.

Hydrographs of wells in the High Plains aquifer in the river corridor show continuous declines in water levels. Continuation of the declines is expected to cause further decreases in flow of the river where there is currently perennial flow. The decrease in freshwater discharge will result in increasing salinity of the river downstream in southeast Seward and southwest Meade counties. We are examining the relationship between the ground-water levels and the aquifer stratigraphy to better understand the stream-aquifer interactions along the river corridor.

# Critical Habitats: Designation and Protection in Kansas

*Chris Hase, Aquatic Ecologist, Kansas Department of Wildlife and Parks, Pratt, Kansas*

The Kansas Nongame and Endangered Species Conservation Act entails 12 statutes (K.S.A. 32-957 through 963, 32-1009 through 1012, and 32-1033) and was implemented to protect species listed as threatened (T), endangered (E), or species in need of conservation (SINC) within Kansas. An endangered species is defined as “. . .any species of wildlife whose continued existence as a viable component of the state’s wildlife fauna is determined to be in jeopardy. . . .” A threatened species is “. . .any species of wildlife which appears likely, within the foreseeable future, to become and endangered species. . . .” A species considered SINC is a nongame species of wildlife that has been determined to be in need of some level of conservation. A key point of the statutes is the definition of wildlife that is: “. . .any member of the animal kingdom, including, without limitation, any mammal, fish, bird, amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate. . . .” Of the 60 species on the Kansas list of T and E species, 67% of the endangered and 75% of the threatened species are aquatic. Fifty-one percent of the species on the SINC list are aquatic. The act places the responsibility for identifying and undertaking appropriate conservation measures for T and E species directly upon the Department of Wildlife and Parks. The Department must also undertake efforts to conserve listed species and pursue increasing their populations to the point they are no longer T or E. K.S.A. 32-963 and K.A.R. 115-15-3 require special Department action permits for activities that affect species listed as T and E where “action” means an activity “. . .resulting in the physical alteration of a listed species’ critical habitat, physical disturbance of a listed species, or destruction of individuals of a listed species. . . .” These activities must be publicly funded, State or Federally assisted, or require a permit from another State or Federal government agency to be included as activities that fall under the Department’s regulatory purview where action permits could be required. Critical habitats are defined in K.A.R. 115-15-3 and means either of the following: “. . .specific areas documented as currently providing essential physical and biological features and supporting a self-sustaining population of a listed species; or specific areas not documented as currently supporting a listed species, but determined essential for the listed species by the secretary.” Critical habitats are designated by the Department. Designated critical habitats can be represented by a geographical land area, specific habitats within a geographical area, streams, wetlands, or any other area deemed to be critical habitat for a species listed as T or E.

# Water-use Impacts on Critical Habitat Protecting and Enhancing Instream Flow

*Susan Lee, Environmental Scientist, Kansas Water Office, Topeka, Kansas*

Protecting and enhancing instream flows at a level that maintains the ecological functions and processes of a stream or river is a State responsibility. All waters within the state are dedicated to the use of the people of Kansas, subject to State control and regulation. The government has the responsibility to provide stewardship of the water resource where it is held in common, as in a stream.

The droughts of 2000 and 2002 raised concerns about streamflow in several basins in Kansas. Issues surrounding adequate water to sustain aquatic life in the Marais des Cygnes, Neosho, and Verdigris river basins were encountered. These drought-induced conditions highlight a larger concern of adequately providing and protecting minimum flow in Kansas' streams for the beneficial use of fish and wildlife survival, recreation, and water quality. All but four of Kansas' streams are fully appropriated, at least during irrigation season, and many are headed towards full appropriation year round. The level of administration required to meet minimum desirable streamflows greatly increased during 2002, and into 2003. This increased administration was certainly a result of the drought of 2002, but increased development also plays a role.

In 2002, under the direction of the Natural Resources Subcabinet, a Water Issue Strategic Team (WIST), composed of representatives from the State's natural resource agencies, was formed to identify the high-priority current issues they held in common. In 2003, the WIST identified the protection and enhancement of instream flows as an issue in need of further coordination and study. As a result, an inter-agency working group was formed to specifically address this issue. The working group has developed a Water Issue Strategic Plan (WISP) that defines the issue, goals, objectives, strategies, and activities related to the issue.

The goals identified in the Instream WISP include:

- Mitigate transit losses between endpoints of specified stream reaches to maintain dynamic stream hydraulics to efficiently route water through reaches
- Maintain adequate baseflow and habitat along mainstem
- Maintain adequate baseflow and habitat along tributaries
- Test instream flow-management techniques
- Identify and inventory reaches needing instream flow protection

Several strategies and activities have been proposed to accomplish these goals, many of which were initiated in 2003 and will continue in 2004. Some of these activities include modeling the hydrology and demand on Verdigris and Neosho river basins to examine effects on a system of various flow scenarios, determining the dry weather flow contributions of tributaries through summer synoptic flow measurements, and establishing an inter-agency team to identify criteria for stream evaluation and inventory for future instream strategy development.

# Water-Use Impacts to Endangered Species in Kansas: the Case of the Least Tern

*William H. Busby*, Kansas Biological Survey, Lawrence, Kansas

The effect of human uses of water on natural systems and component species vary greatly with the nature of the water modification, the aquatic system, and the ecology of the particular species. This presentation will examine how one species, the Federal- and State-endangered Least Tern (*Sterna antillarum*), has been affected by water modifications at three sites. The sites, Cimarron River, Quivira National Wildlife Refuge, and the Kansas River, each have differing water-use characteristics that illustrate differing impacts on an endangered species.

The Least Tern is a migratory bird that breeds on coastal beaches, riverine sandbars, and salt marshes in North America. It nests near water in areas with sparse or no vegetation. Least Terns arrive in Kansas in May and early June and depart after nesting is completed in late summer. Formerly, Least Terns nested along the Cimarron River in Meade and Clark counties. As the effects of dewatering in due to ground-water pumping of the Ogallala aquifer became more severe in the 1970's–1980's, surface flow in the Cimarron River declined. This affected terns in several ways. First, portions of the river ceased to flow, eliminating tern habitat. Second, high flow events became increasingly rare and no longer scoured vegetation resulting in the invasion of salt cedar. By the mid 1980's, Least Tern nesting activity on the Cimarron River in Kansas had all but ceased.

A second nesting site is Big Salt Marsh in the Quivira National Wildlife Refuge. Here, terns nest on unvegetated salt flats and raised areas such as access roads. Nesting populations are stable, and nesting success has been enhanced by management measures such as installation of raised nesting platforms and predator-exclusion fencing. The primary water source for the Big Salt Marsh is subsurface flow through sands of the Arkansas Lowlands. However, due to dewatering in the Arkansas basin, water supply to Quivira has continued to decline and concern has grown about the viability of the refuge in the face of reduced water availability.

The third site is the Kansas River where small colonies of the Least Tern and the Federally endangered Piping Plover (*Charadrius melodus*) nest along the river between Manhattan and Topeka. Low nesting success may be in part attributable to the altered hydrology of the Kansas River. Flood control by reservoirs on the major tributaries result in reduced peak flows. This has the effect of reducing the formation of high-relief sandbars and the removal of streamside vegetation by scouring action. The large devegetated sandbars currently available tend to have low relief and are readily flooded by minor increases in water level. Sites at higher elevation become vegetated and are not used by terns and plovers.

In summary, water-use threats to the Least Tern differ from site to site. At nesting sites in central and western Kansas dewatering has been the primary threat. In contrast, in eastern Kansas where water supply is adequate, it is altered hydrology due to large reservoirs that is impacting endangered species habitat.

# Covering Water Issues

## Reporters Involved in Reporting Water Issues in Kansas

*Rex Buchanan*, Moderator, Kansas Geological Survey, Lawrence, Kansas

Managing natural resources relies on an informed public, and much of the public relies on the news media for its information. A panel of five veteran reporters, from all parts of the state and including broadcast and print media, will discuss the media's coverage of Kansas water issues. They will describe the challenges of reporting on water issues; their sense of the public's knowledge of water issues; and what we can do to more effectively communicate with the media and the public concerning water-related issues in Kansas.

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# High Plains Aquifer

## 1. Modeling Ground-water Flow and Economics in Sheridan County, Kansas

*Mauricio Herrera and Dr. David R. Steward, Department of Civil Engineering, and Dr. Jeffrey M. Peterson, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas*

A coupled hydrologic-economic model is being developed in Sheridan County, Kansas. This model tries to understand the economic implications of ground-water irrigation in a study area identified in cooperation with Groundwater Management District #4.

The spatial data being used in these models come from a variety of sources. Data for the hydrologic model have been gathered from the Kansas Geological Survey's Data Access Service Center (DASC) and the United States Geological Survey (USGS). Data for the economic model have been gathered from the Water Information Management and Analysis System (WIMAS) data base and from additional parcel-level and time-series sources.

Data between the two models are linked through information about irrigation wells, because these features are common to both hydrology (points of diversion) and economy (input to cost-benefit functions). Models are being applied to the data to forecast future hydrologic and economic conditions and the associated land-use changes in the study area. The aims of this study are to prototype and evaluate a technical support tool to aid in future management strategy and policy decisions across the state.

## 2. Understanding GIS Ground-water Elevation Data Trends Using Transient Ground-water Models

*Wei Jin and David Steward, Department of Civil Engineering, Kansas State University, Manhattan, Kansas*

Understanding the trends of ground-water elevation data is important in predicting the change of ground-water elevation and in developing ground-water management strategies to handle the ground-water fluctuation process.

In this research, transient ground-water models are developed to simulate ground-water elevation changes using aquifer properties and water-usage data derived from Geographic Information System (GIS) datasets. These models are calibrated using the observed ground-water elevation data. GIS is used to visualize both the observed and the simulated ground-water elevation datasets.

Stagnation points, where the discharge vector vanishes in the flow, are identified and tracked to interpret the trends of elevation. Representing the local highs and lows of elevation, the stagnation points can be used to analyze the transient process of ground-water fluctuation, identifying and predicating the propagation of the cones and mounds of ground water. The positions of the stagnation points at an instant can be located by solving a system of algebraic equations derived from the fact that the discharge vector vanishes at a stagnation point. The propagation velocity of the stagnation points is derived using a mathematical theorem called the Theorem of Implicit Function.

The information provided by the transient ground-water models and the analysis of stagnation points helps to understand the trends of ground-water elevation due to different water-management strategies. This understanding will aid in developing ground-water management strategies.

### 3. High Plains Aquifer Analysis Based on Water Usage per Square Mile

*John Huslig*, Independent Researcher, Western Kansas Family Farm Owner and Financial Analyst  
by Occupation with U.S. Department of Agriculture, Alexandria, Virginia

Aquifer analysis using the following techniques is shown:

- (1) Based on the average water use per square mile within the 2-mi radius from the center of each section (a 1-mi<sup>2</sup> area), each section is characterized and grouped in one of three categories:
  - i. those sections with an average 2-mi water use approximately in balance with the average water use in the surrounding 5-mi radius area;
  - ii. those sections with an average 2-mi water use significantly in excess of the average water use in the surrounding 5-mi radius area (high-use sections in these 2-mi areas are categorized as locally gaining water from their surrounding 5-mi area); and
  - iii. those sections with an average 2-mi water use significantly less than the average water use in the surrounding 5-mi radius area (these sections in the 2-mi area are categorized as locally losing water to high use sections in their surrounding 5-mi area).
- (2) Ground-water recharge and return flow are estimated with improved accuracy by focusing analysis on areas of the aquifer that are in relative balance, those areas in (1) (i) above. Support for this analysis is provided by comparison and contrast calculations for areas (1) (ii) and (1) (iii) above.
  - i. More accurate estimates for recharge and return flow are necessary to support any management decisions regarding needed curtailments of pumping to reach sustainability.
  - ii. Areas are mapped that categorize water declines over the 1991 to 2001 period as being understated, overstated, or relatively accurate based on my water-balance categories described in (1) above.
  - iii. From these maps, one sees that the areas in significant decline are areas already receiving significant inflow contributions from their surrounding areas, and their water-level declines are understated due to this inflow. Stabilizing water levels in declining areas is desirable due to the approaching marginal individual well yields in these areas. Reductions in pumping required in the overdraft areas will also stabilize water levels in their lesser pumped surrounding areas.
  - iv. Analysis using my technique indicates average sustainable recharge from precipitation and return flow (40% or greater average return flow) of approximately 60 and 100 ac-ft per section in most areas of the aquifer in GMD #1. Some areas appear to have reached sustainability (no significant decline in the 10-year period analyzed) with usage of over 200 ac-ft per section, with inflow from surrounding stabilized contributing areas. These are much higher than safe yields that have been estimated at .25 to .5 inches per year, or 13 to 27 ac-ft per section.
  - v. Water rights are established to be permanent. A water right that diminishes the resource to the point of its own impairment cannot be considered a valid water right. Impairment is here defined to occur when the well in question, due to water-level declines, can no longer pump the volume of water throughout the season for which it was approved. Additional hours of pumping a well to reach its annual ac-ft allotment should be curtailed and considered as evidence of an impaired aquifer at that well's location.
- (3) To avoid complicating recharge issues from the Arkansas River in GMD #3, my analysis is currently focused on GMD #1 and GMD #4. However, by the time of the conference, analysis of areas in GMD #3 considerably south of the river would be available.

## 4. The Kansas Water Congress

*David A. Brenn, Executive Director, Topeka, Kansas*  
<http://www.gmd3.org/KansasWaterCongress>

The mission of the Kansas Water Congress is to promote the wise management and stewardship of the state's water resources and to protect, conserve, and develop Kansas water resources for the benefit of Kansas' present and future generations. The Congress is a not-for profit, fee-funded entity separate and distinct from existing State agencies, associations, other organizations, and direct political affiliation.

The members of the Kansas Water Congress come from every watershed and represent every type of water user in the state, recognizing the necessity for the unity of purpose and objective in supporting the formation and execution of a stable water policy for a unified state of Kansas. The Board of Directors is composed of 29 members from 12 geographic and 17 general divisions, representing a broad-based statewide governance. The members join in dedicating themselves to the task of securing responsible development, protection, and management of all our available water resources, grounding their actions upon the fundamental proposition that equity must be done to and among all areas in the state.

In recognition of the fact that utilization of the state's limited and precious water resources will fix the limits of greatness that the state can attain in the future, the Congress is dedicated to the end that responsible development, protection, and management of our water resources become the first order of business of the entire state and its people.

The Kansas Water Congress recognizes the significant importance and need to achieve harmony between the water resources and other natural resources of the state, and strives to ensure a quality environment in Kansas.

### **OBJECTIVES AND PURPOSES**

The objectives of the Congress shall be to bring about institution and advancement of programs for the conservation, development, and protection of the water resources of the state of Kansas and fully recognize the role and function of existing State agencies and Districts related to water resources.

In support of this, the Congress will:

- Provide a forum where the water users strive to reach consensus on water issues;
- Advocate positions on water policy;
- Promote and advocate interactions between water-related State agencies and water districts and facilitate cooperation and efficiency in the process;
- Provide education and information on water issues affecting Kansas;
- Promote a broad base of membership, including both sustaining and individual members representing a diversified base of water interests and users.

In furtherance of these objectives, the Congress shall cooperate with and support organizations working for the same general objectives. It shall provide its membership with a forum for the discussion of water issues to the end that, where possible, conflicts among water users may be resolved through the medium of mutual discussion of the facts and proposed solutions. It shall, to the greatest extent possible, provide information for the education of its membership and for the enlightenment of the people of the state, to the end that the people will, through the democratic process, insist upon and support a well-defined and strong State water program.

Based on development of fact, dissemination of information, resolution of conflicts, and the democratic process, the Congress shall make its influence felt in each area of public authority over water matters.

## 5. High Plains Aquifer Information Network (HIPLAIN)—Year 2

<sup>1</sup>David Young, <sup>2</sup>Steven Briggeman, <sup>1</sup>Margaret Townsend, and <sup>2</sup>Gary Clark,

<sup>1</sup>Kansas Geological Survey, Lawrence, Kansas, and <sup>2</sup>Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas

The High Plains Aquifer Information Network (HIPLAIN; [www.hiplain.org](http://www.hiplain.org)) provides hydro-geologic, agricultural, economic, water-quality, and general information concerning the High Plains aquifer to the public. The High Plains aquifer is a valuable resource to the state of Kansas. Many concerns exist about the availability of long-term irrigation, water quality, agricultural changes, and economic impacts associated with continued depletion of the aquifer. Making data and information concerning the High Plains aquifer easily available to the public should increase their knowledge level and facilitate discussion and consideration of various options for the conservation, development, and management of this resource.

Year 2 accomplishments for HIPLAIN include an improved internal search engine, access to additional hydrogeologic glossaries, and increased literature-search capabilities. In addition, the program was charged to create and support a web site for the Ogallala Aquifer Institute (OAI; [www.hiplain.org/oai/](http://www.hiplain.org/oai/)), working closely with the OAI. The resulting OAI site includes information concerning the governing board, current events and conferences surrounding the High Plains aquifer, and a printable brochure about the OAI.

The final objectives for the year 2 program are to access newly developed data-base front ends and data-analysis tools from the Kansas Geological Survey (KGS) and other web sites; to continue the posting of relevant links and maintenance of the current web site; and to disseminate data and information by coordination with the OAI, GMDs, libraries, and other educational and governmental groups. An on-line and hard-copy brochure for distribution to libraries and school districts will be available at the end of the second-year program. Presentations concerning the web site will be made to the Kansas Ground Water Association, the 3-I meeting in Great Bend, the Ogallala Aquifer Symposium in Wray, Colorado, and other venues. During Year 2, HIPLAIN was extensively reviewed by the Great Plains Foundation, State agencies and groundwater management districts, USGS district chiefs, and others. Largely due to the feedback from the USGS, information and web links to all seven states were obtained and included.

Third-year plans include further acquisition and development of links with all eight High Plains states concerning water policies and issues, technical information, and access to available datasets for use by the public. HIPLAIN developers are working closely with OAI to form working relationships with the other states and to permit web access to available online datasets.

The Year 3 program will include a redesigned web site using ColdFusion in order to increase efficiency. The site will have a clickable map to enable users to obtain information on statewide and regional basis. We will provide access through the KGS web site to Kansas water-quality data, USGS and EPA Storet data bases, and recharge estimates. We also plan to discuss with the KWO and DWR presentation of legal materials regarding water rights, water law, water policy, and water-management issues.

## 6. A Preliminary Updated Bedrock Surface-elevation Map for the Ogallala Region of Western Kansas

*P. Allen Macfarlane and Brownie B. Wilson, Geohydrology Section, Kansas Geological Survey, Lawrence, Kansas*

An up-to-date, detailed map of the bedrock-surface elevation beneath the Ogallala will be crucial for generating a more accurate assessment of the remaining saturated thickness and for targeting high-priority aquifer subunits. With GIS Policy Board and Southwest Kansas Groundwater Management District #3 (GMD 3) funding, the Kansas Geological Survey (KGS) is producing a revised bedrock-surface elevation map for the western Kansas region underlain by the Ogallala aquifer. The project goals are to (1) develop a western Kansas regional map based on the driller's logs contained in the WWC-5 water-well records and the test-hole logs in the KGS county bulletins and (2) to enhance the regional map in GMD 3 using the test-hole logs of wells from water-well drilling contractors' files, Kansas Department of Transportation files, and geophysical logs. Shown in this poster is a preliminary regional map of the bedrock-surface elevation in western Kansas using only the driller's logs from the WWC-5 records and from the KGS county bulletins. To generate the preliminary map, the elevation of the land surface and the depth to bedrock at each well or drill site must be estimated. The depth to bedrock is picked for each boring using the provided descriptions on the driller's log. The land-surface elevation is determined from the latest digital elevation model of the land surface for Kansas. Also shown is a map showing the elevation difference between preliminary bedrock surfaces map and the one in current use.

## 7. Ground-water Levels and Storage-volume Changes in the Equus Beds near Wichita, Kansas, 1940–2003

*Cristi V. Hansen*, U.S. Geological Survey, Lawrence, Kansas

Quaternary alluvial deposits, known as the Equus beds, are as much as 250 ft thick northwest of Wichita, Kansas, and consist primarily of sand and gravel interbedded with clay and silt. A part of the Equus Beds aquifer that is within the 165-mi<sup>2</sup> study area in southwestern Harvey and northwestern Sedgwick counties was developed to supply water to the city of Wichita beginning in 1940.

By 1957, increases in city and agricultural pumpage combined with a drought in the mid-1950's resulted in water levels declining by more than 20 ft in large parts of the aquifer in the study area. By 1957, storage volume in the aquifer had decreased about 171,000 ac-ft since 1940.

Increased city and agricultural pumpage from 1978 to 1993 and the 1988–1992 drought caused substantial water-level declines. By October 1992, water levels had reached the low of record and storage volume in the aquifer had decreased about 283,000 ac-ft compared to 1940.

Following the lows at the end of the 1988–1992 drought, water-level recoveries resulted from above-average precipitation and reduced city pumpage despite increased agricultural pumpage. City pumpage in the study area decreased as withdrawals increased from Cheney Reservoir, the other major water-supply source for Wichita. From 1993 to 2003, city pumpage in the study area decreased from about one-half to less than one-third of Wichita's water usage. Although city pumpage decreased, agricultural pumpage in the study area increased following 1993 until it was almost double city withdrawals in 2002. Water-level recoveries from 1993 to 2003 exceeded 10 ft in a large part of the study area. Water levels in January 2003 represented a recovery of about 124,000 ac-ft or about 44% of the aquifer storage volume lost between August 1940 and October 1992.

## 8. Ground-water Depletion and Agricultural Land-use Change in Wichita County, Kansas

*Lisa M. B. Harrington, Nathan Kettle, and John A. Harrington, Jr., Department of Geography, Kansas State University, Manhattan, Kansas*

The High Plains is a region dependent on reliable ground-water supplies for the continued existence of agriculture and rural communities in their current form. Despite an abundance of ground water, burgeoning production of crops, and past rates of economic development, crucial and urgent sustainability issues have emerged. Concerns over economic, social, and environmental sustainability are especially evident in areas of high dependency on, and rapid depletion of, ground-water resources. The High Plains Ogallala region is ideal for the examination of human/environmental interactions and change because it has experienced, and continues to undergo, significant transformation due to changes in ground-water availability.

While previous studies have documented changes in ground-water levels and agricultural land-use change in the High Plains, few studies have investigated the interactions between ground water and agricultural land-use change. This research examines the relationship between agricultural land-use change and ground-water depletion in greater detail than has been attempted previously. A single county overlying the High Plains aquifer system, Wichita County, Kansas, with conditions that have led to high proportionate decreases in ground water and with significant variability in ground-water availability, has been chosen for analysis. Such conditions may be indicative of likely future changes in other parts of the region overlying the Ogallala and High Plains aquifers.

Visual comparisons of ground water and land-use changes between 1975 and 2001 indicated a strong spatial relationship between ground-water depletion and land-use change. Areas of the county undergoing the greatest amount of ground-water depletion were transitioning away from irrigated cropland, whereas areas experiencing less ground-water depletion had fewer land-use changes. The  $\chi^2$  statistical tests supported the visual comparisons and revealed that there was a significant difference between the observed land-use changes and land-use changes that might be expected under conditions of no relationship between ground-water depletion and land-use change.

It appears that dryland farming, which requires less capital investments of resources and time than irrigated agriculture, has been more sustainable through periods of transition. These detailed findings, based on an intensive local study, are consistent with other studies that have shown that water-intensive crops are located above significant aquifer-saturated thickness and that irrigated land had decreased where aquifer depletion was the greatest.

## 9. Estimating Resilience of Ground-water Resources in Western Kansas

*Robert W. Buddemeier, Blake B. Wilson, and Geoffrey C. Bohling, Geohydrology Section, Kansas Geological Survey, Lawrence, Kansas*

Substantial differences can exist in how various regions of an aquifer respond to pumping. In addition to the amount and distribution of pumping stress, differences in factors such as horizontal and vertical recharge and the water storage (specific yield or effective porosity) can result in significant differences in the amount of water-level decline per unit of water extracted. However, although recharge and porosity are primary hydrologic variables they are extremely difficult to determine. The combination of reported water use and ground-water-level records provides a much more general and simpler means to evaluate the responses of particular aquifer subunits to pumping.

As ground-water resources decline and more and more areas overlying the Ogallala aquifer approach the point of transition from full irrigation to other uses, management and conservation approaches need to consider factors beyond the traditional variables, rate of decline, and amount of resource remaining. One potentially important factor is the ability to withstand or recover from stresses. We term this “resilience,” and evaluate it on the basis of the relationship between water use and water-level decline. In general, the lower the decline per unit use (or the poorer their correlation), the greater the recovery or sustainability potential of a given aquifer subunit.

Previous studies have shown major variations in the correlation between water use and water-level decline across the Kansas Ogallala (Wilson and others, 2002). We build on that work to explore the potential applications of a “resilience index,” which could be compared to other factors such as use density, water in storage, saturated thickness, etc., to help to identify realistic yield targets, and to identify and prioritize actions in areas that are most suitable for various types of uses: full irrigation, supplemental irrigation, municipal and industrial, etc. Examples of this type of mapping and classification approach are presented.

### Reference

Wilson, B. B., Young, D. P., and Buddemeier, R. W., 2002, Exploring relationships between water-table elevations, reported water use, and aquifer lifetime as parameters for consideration in aquifer subunit delineations: Kansas Geological Survey, Open-file Report 2002-25D, 28 p. (<http://www.kgs.ku.edu/HighPlains/OHP/index.htm>)

# 10. Ogallala Management Issues

*Tina Alder, Mindy Sieck, Beth Cooper, and Eve Tracy, Kansas Department of Agriculture, Water Resources SWRMP, Topeka, Kansas*

## **Project Status**

Declines in ground-water levels and the economic future of the water resource has become a growing concern in the Ogallala–High Plains region of Kansas. In response to this growing concern, the Ogallala Aquifer Management Advisory Committee of the State water-planning process recommended setting incremental milestones to extend and conserve the life of the Ogallala aquifer through the establishment of protocols. The State Water Plan outlines each Groundwater Management District (GMD#4, GMD#1, and GMD#3), and the Division of Water Resources’ Subbasin Water Resource Management Program (addressing the area outside the GMDs’) responsibilities in developing protocols that outline their objectives for setting management goals within their area. The Kansas Geological Survey, Division of Water Resources, Kansas State University, and Kansas Water Office cooperate and assist through the water-planning process.

The Subbasin Water Resource Management Program (SWRMP) has completed their protocol and is currently working on identifying preliminary hydrologic subunits. After identifying hydrologic subunits, SWRMP will classify hydrologic subunits as high, medium, or low priority (tentatively scheduled for November 2004), and then establish preliminary water-management goals for high priority subunits.

As outlined in the State Water Plan, each Groundwater Management District and the Subbasin Water Resource Management Program of the Division of Water Resources should follow the guidelines below in their protocols:

- 1) Delineate the Ogallala aquifer into aquifer subunits to allow management decisions in areas of similar aquifer characteristics.
- 2) The Groundwater Management Districts and the Subbasin Water Resource Management Program should identify each aquifer subunit in decline or suspected decline and establish water-use goals to extend and conserve the life of the Ogallala aquifer.
- 3) Identify aquifer subunit priorities to extend the life of the aquifer and sustain the vitality of western Kansas.
- 4) Support and expand programs and activities to extend and conserve the life of the Ogallala aquifer.
- 5) Support and expand research and education on the Ogallala to extend and conserve the life of the aquifer.

Objectives, as outlined by Ogallala Aquifer Management Advisory Committee:

### **Identify preliminary hydrologic subunits**

- Identify key parameters for water-resource management
- Identify hydrologic subunits

### **Classify hydrologic subunits as high, medium, or low priority**

- Rate of decline
- Time to reach selected threshold value

- Water-right criteria
- Socioeconomic impact of declines

**Establish preliminary water-management goals for high-priority subunits**

- Water Management Plans based on priority
- Analysis of data needed for plans

**Identify and develop management-plan options**

- Define criteria for determining success
- Define level of progress in water reduction
- Course of action if goals are not achieved
- Assistance programs for farmers to transition to dryland farming

Supporting documents are online: Protocol and Guidelines: <http://www.accesskansas.org/kda/dwr/basinteam/Ogallala/ogallala.html>

Powerpoint presentation: <http://www.ks-agr.org/basinteam/powerpoint/ogallala03.pps>



# Education

## 11. Kansas Geological Survey Geohydrologic Information on the Internet

*Daniel R. Suchy and Dana Adkins-Heljeson, Kansas Geological Survey, Lawrence, Kansas*

The Kansas Geological Survey (KGS) has been distributing information over the World Wide Web since 1995. While early web pages focused on educational information and news, since then we have worked continuously to add data from our many natural-resources data bases and to add selected in-print and out-of-print publications. A wide range of geohydrologic data and information is available via the KGS website (<http://www.kgs.ku.edu>), including the following:

- 1) Information from water well forms (WWC5 forms) that are required to be filed any time a water well is drilled in Kansas, and, in some cases, scanned images of the forms themselves (both a high-resolution TIFF for downloading and a quick-to-load GIF for viewing).
- 2) Water levels for wells in the GWSI data base of the USGS and in the water-level measuring program carried out each year by the KGS and the Kansas Division of Water Resources (DWR); we call this our WIZARD data base.
- 3) Mapping applications for both the WWC5 and WIZARD data bases, by which water wells can be mapped interactively online, and various overlays, such as topographic maps or aerial photos, can be chosen.
- 4) Scanned KGS Bulletins, many of which cover the geology and ground-water resources of individual counties.
- 5) Information and reports from various geohydrology projects of the KGS, such as the Dakota Aquifer Program, High Plains Aquifer Evaluation Program (including the *Atlas of the High Plains Aquifer*), Upper Arkansas River Corridor Study, Equus Beds Mineral Intrusion Study, and several others.
- 6) Public Information Circulars, which are available in paper form and online, covering such topics as the Dakota aquifer, the High Plains aquifer, salt contamination, safe yield and sustainable development, nitrate in ground water, the KGS/DWR water-level measuring program, and ground-water recharge in Kansas.

Adding raw data to the web site has been facilitated through the use of relational data bases and a consistent use of the Internet as the only interface to the data. Using a centralized data base to tie together related data for each water well allows users to learn everything about a well in one query. Web pages are used exclusively to edit data bases as well, so that the only software needed for retrieving or creating data is a web browser. Customers from anywhere in Kansas, the U.S., and the world can access original data directly from the KGS website.

## 12. Kansas Environmental Leadership Program (KELP)

*Judy Willingham and G. Morgan Powell, Biological and Agricultural Engineering Extension,  
Kansas State University, Manhattan Kansas*

The Kansas Environmental Leadership Program (KELP) was developed to meet a need for local leadership to protect and improve water quality in Kansas communities. The goal of KELP is to teach citizens the environmental knowledge and leadership skills to be a central part of environmental change at the local level. KELP training centers around people with diverse backgrounds, ages, professions, interests, and attitudes toward water quality.

U.S. Environmental Protection Agency 319 Grant funds supported curriculum development and personnel to conduct class sessions. Scholarships and other funding support were provided by the Kansas Water Plan Fund, State agencies, employers, and participants themselves. A pilot class was held in 1999; four more classes have been completed, and 108 graduates are applying the principles learned.

Participants in KELP attend five sessions spaced over 10 months. Each three-day session convenes at a different location in the state, and includes field trips, group activities, and speakers related to leadership, watersheds, surface- and ground-water protection, and other water-quality issues. An important experience is developing a locally applied leadership project (ALP). Teams identify a water-related issue, choose a vision, develop a plan, write a grant-funding proposal, and then complete the project.

Graduates take back to their communities improved leadership skills, better comprehensive environmental understanding, and a manual filled with resources and information. The \$850 registration fee includes meeting rooms, meals, lodging (2/room), field trip transportation, and materials for all sessions.

Website: <http://www.oznet.ksu.edu/kelp/>

## 13. The Prototype Interactive Ground-water Tutor: a New Tool for Computer Assisted Instruction in Secondary- and Undergraduate-level Earth and Environmental Science Education

*P. Allen Macfarlane, Geoffery Bohling, and Margaret Townsend, Geohydrology Section, Kansas Geological Survey, Lawrence, Kansas; Alison Reber, Kansas StreamLink, Lawrence, Kansas; and Steve Case, Pathfinder Science, Lawrence, Kansas*

We have developed a potentially Web-based, interactive Java application and accompanying web pages in which students use their knowledge of ground-water flow principles and contaminant transport to solve an environmental disaster. The application simulates movement of a plume from a pipeline break through a shallow alluvial aquifer towards a major river just upstream from a municipal water-supply intake. The student plays the role of an environmental consultant hired by the pipeline owner to locate and remediate the plume at a minimum cost and before the contamination reaches the river. In the plume-finding phase, the student places observation wells on the grid representing the study area and the simulation returns the contaminant concentrations at those locations on the appropriate sample dates. Once the plume is located, the student is able to place pumping and injection wells on the study area grid to begin remediation. The simulation then computes the movement of particles to the pumping wells and returns the cumulative mass removed by the production remediation well. The accompanying web pages provide students with background material on ground-water flow and transport principles, establish the contamination scenario simulated in the application, and emphasize the potential ecological and economic impacts of the contamination. Thus, the Tutor fosters in students the application of science to the solution of real-world problems through role-play.

In parallel to the development of the Tutor, a teacher's manual has been prepared to provide guidance on (1) the appropriate context of the Tutor with respect to instruction on water-cycle concepts and the principles of ground-water flow and transport of contaminants; (2) the national and Kansas earth science, environmental science, mathematics, and geography science education standards and goals addressed by the Tutor; and (3) additional lesson plans and resources that can be used to prepare students for their educational experience with the Tutor.

Field-testing of the Tutor will be conducted throughout calendar year 2004 using 11–12th grade and college undergraduate student populations to assess the functioning of Tutor and what students learn from using the Tutor.

## 14. Kansas StreamLink

*Alison Reber and Jeff Severin, Kansas StreamLink, Kaw Valley Heritage Alliance, Lawrence, Kansas*

Kansas StreamLink is a diverse network of schools, classrooms, youth groups, civic groups, non-profit organizations, government entities, businesses, and water-quality professionals, all connected by a common interest in water. By utilizing the skills, talents, insights, and resources of the entire network, the activities of each individual group are enhanced. StreamLink can provide logistical and technical support for stream-study groups and for groups planning service-learning projects geared toward protecting water resources. As a program of the Kaw Valley Heritage Alliance, StreamLink also serves as a repository for Kansas stream-team observations and activities. The StreamLink website is designed for the general public to learn about local stream teams, watershed history, and water-quality concerns. To find out how stream teams can play a role in community projects and watershed planning, contact Kansas StreamLink at 785-840-0700, or visit them at [www.streamlink.org](http://www.streamlink.org).

# Ponds

## 15. Assessing Temporal Changes in Ponds and Pond Numbers Using Historical Air Photos: a Comparison Between the Midland and Allen SE Quadrangles

*R. O. Sleezer<sup>1</sup>, D. P. Young<sup>2</sup>, J. Vopata<sup>1</sup>, E. Wilson<sup>1</sup>, and Z. Andereck<sup>1</sup>*

<sup>1</sup> Department of Physical Sciences, Emporia State University, Emporia, Kansas; and <sup>2</sup> Kansas Geological Survey, Lawrence, Kansas

Recent work has demonstrated the importance of the cumulative effects of small artificial impoundments (ponds) on landscape-scale cycles of water, sediment, and carbon at scales ranging from local to continental. Initial analyses of data currently available for the contiguous 48 United States indicate that commonly used available maps and electronic coverages under-represent the number and areal density of small pond features by up to two orders of magnitude. They also do not provide a clear picture of the temporal changes in ponds and pond numbers that have occurred over the past 60 years. There are four basic questions that need to be addressed. How do we accurately detect and count small artificial water bodies (ponds)? 2) How many ponds have been built? 3) How have the numbers and spatial distribution of ponds changed during the last 60+ years? 4) What are the ecological, biogeochemical, and environmental functions and effects of ponds in an altered landscape?

This research addresses the first three perceived needs by studying ponds using historical air photos for two topographic quadrangles in eastern Kansas. Eastern Kansas contains a high density of ponds within a variety of topographic and land-use settings, making it an ideal site to evaluate detection and classification techniques for ponds as well as their environmental effects. Air-photo coverage begins in the 1940's for both quadrangles, and at least six sets of air photos from different time intervals are available for both areas. By digitizing ponds using digital imagery in a GIS format, temporal changes in the numbers of ponds, their variations in size, and their life expectancy in different topographic, land use, and geological settings can be assessed.

Results indicate that more ponds were built earlier (1940's) in areas dominated by cattle grazing (Allen SE quad, Lyon County). Pond numbers in the Midland quad (Jefferson County) have increased through time at a rate of about 10 per year from 24 in 1941 to 642 in 2002. The functional intention of ponds within the Allen SE quad appears to still be water for cattle while many of the new ponds in the Midland quad appear to be used for other purposes. Ponds also appear to be temporal features in that some appear to fill in and disappear from the landscape thereby complicating their detection in relatively short periods of time ( $\leq 40$  years) while others are apparently more permanent.

## 16. Watershed Parameterization Using Geospatial Modeling and Preliminary Assessment of the Effects of Small Impoundments (Ponds)

*D. P. Young<sup>1</sup>, R. O. Slezzer<sup>2</sup>, X. Zhan<sup>1</sup>, and R. W. Buddemeier<sup>1</sup>*

<sup>1</sup>Kansas Geological Survey, Lawrence, Kansas; and

<sup>2</sup> Department of Physical Sciences, Emporia State University, Emporia, Kansas

Small watershed impoundments (ponds) have cumulative effects on surface drainage and on the transport of suspended and dissolved materials through and out of the larger watersheds in which they reside. However, they are often small enough to be missed in most mapping and water-body inventory activities, many have lifetimes on the order of a few decades, and they may be “replaced” by new ponds in different locations or periodically “rebuilt” to remove accumulated sediment, increase capacity, and/or enhance runoff-catchment area. In areas of relatively high pond density, the hydrologic landscape is, therefore, a shifting mosaic of small sub-watersheds and this may influence the accuracy of runoff, non-point source pollution, and sediment-yield modeling efforts.

Determination of the influence of small ponds on runoff and sediment yield for their respective larger watersheds is a laborious and therefore expensive process. It is similarly difficult and time-consuming to parameterize the small drainage basins above each small pond to determine factors that affect sediment yield and therefore pond lifespan, which in turn affects the ‘shifting mosaic’ of small sub-watersheds mentioned above. The cumulative importance of these networked impoundments places a premium on the ability to understand and predict pond functions from knowledge of the environment and land use, and on the ability to extrapolate or generalize from case studies, or from limited samples and information. Specifically, there is a need to understand the ecological, biogeochemical, and environmental functions and effects of ponds in an altered landscape, and how they relate to environmental characteristics such as soils, topography, and land use/land cover. This will ultimately lead to a better understanding of how ponds may affect (and be affected by) runoff, sediment yield, and the transport and cycling of nutrients and other constituents (such as carbon).

We have begun to address these issues in four ways. First we have derived the drainage-related topographic parameters needed to apply an existing model (AnnAGNPS) to a small watershed using the computer model TOPAZ (Topographic Parameterization). Second we used spatial-analysis techniques in GIS to determine the most likely major sediment-producing areas within the drainage basin of a large impoundment (Lyon County State Lake, LCSL) within the selected watershed boundary based on the derived model parameters for slope and soil characteristics. Third, we compared the likely sediment-producing areas with the spatial distribution of small ponds through time to help determine the cumulative effects of ponds on runoff and sediment yield from the LCSL watershed. Fourth, we compared derived model parameters to selected small ponds within the LCSL watershed to determine the influence of these parameters on small pond history and current condition.

## 17. A Comparison of Pond Inventories Using Satellite and Airborne Sensors

*S. L. Egbert<sup>1</sup>, B. N. Mosiman<sup>1</sup>, and P. Taylor<sup>2</sup>*

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Artificial ponds exist throughout the Kansas landscape, far outnumbering natural water bodies, and they play a substantial role in modifying the environment. For example, they trap sediment, thereby affecting biogeochemical cycles, and they also provide habitat diversity and may provide a partial counterbalance to lost wetlands. For a number of reasons, including their small size, their location primarily on private property, and variations in their numbers and locations over time, small artificial ponds are often under-represented on the digital map products and data bases normally used for hydrologic analyses. To address the issue of the underestimation of ponds, images from three different satellite and airborne sensors were used to see how accurately they could locate and inventory ponds in three different study areas in Lyon and Jefferson counties. Landsat Enhanced Thematic Mapper (ETM+) 30m multispectral imagery, Terra ASTER 15m multispectral imagery, and digital orthoquads (DOQs) derived from 1-m aerial photography were used to create maps of water impoundments. For the Landsat and ASTER imagery, an unsupervised clustering and classification technique was applied; for the DOQs both traditional manual methods (primarily heads-up on-screen digitizing) as well as object-oriented segmentation algorithms were applied. For each study area, we computed the number of water bodies, their size classes, and the total water-surface area. Based on our assumption that the maps derived from the DOQs would provide the most detailed and accurate estimate of the actual number of ponds in the study areas, we used them as the basis for comparison with the maps derived from Landsat and ASTER imagery. Because it is generally impractical (due to cost and time considerations) to manually map small ponds from detailed imagery, our objective was to determine by how much we underestimate the number of ponds in the Kansas landscape using satellite imagery. In addition to comparing results of the DOQ inventory to maps from the two satellite sensors, we also compared them to two inventories of water bodies that were previously created. The most recent is the Kansas Surface Water Database (KSWD) which was derived from 2000 and 2001 Landsat ETM+ imagery at a minimum mapping unit of 1.5 acres and became available for use in 2003. The second inventory of water bodies is the Surface Waters Information Management System (SWIMS). This data base was created using the Environmental Protection Agency's (EPA) River Reach Files (RF3). The RF3 files were developed from 1:500,000-scale NOAA aeronautical charts and 1:100,000-scale digital line graphs developed by the USGS.

## 18. Using Multispectral Airborne Imagery to Inventory and Assess Rural Water Bodies

*Michael Houts<sup>1</sup>, Jerry deNoyelles<sup>2</sup>, Richard Sleezer<sup>3</sup>, and David P. Young<sup>4</sup>*

<sup>1</sup> Kansas Applied Remote Sensing Program, Kansas Biological Survey, Lawrence, Kansas; <sup>2</sup> Kansas Biological Survey, Lawrence, Kansas; <sup>3</sup> Department of Physical Sciences, Emporia State University, Emporia, Kansas;

<sup>4</sup> Kansas Geological Survey, Lawrence, Kansas

Multispectral satellite imagery is commonly used to map water bodies and vegetation conditions, but the coarse spatial and temporal resolution often make it less than ideal for certain projects. To address this issue, a multispectral airborne imaging system was developed around a DuncanTech MS3100 digital camera that can provide sub-meter data when and where researchers need it. The system acquires data from the blue, red, and near infra-red portions of the spectrum while a log file records the GPS location of each picture allowing for easy geo-referencing.

The imaging system was recently utilized to inventory and assess the conditions of the numerous small rural ponds that are scattered across Kansas. Airborne imagery was acquired over 100 experimental ponds at the University of Kansas and approximately 56 mi<sup>2</sup> in Lyon County. Researchers analyzed spectral patterns against field observations and documentation about the pond's history. Special emphasis was placed on identifying shoreline vegetation conditions and the succession stage of the pond. It was found that the imagery could distinguish a variety of pond-shoreline conditions and was also useful for assessing water-turbidity levels (indication of sedimentation rate). Using the imaging system, researchers were able to obtain information about a much larger area for the same time and cost than would have been possible using traditional field sampling.

# Water Use Issues

## 19. Water Use in Kansas, 1990–2000

*Joan F. Kenny and Cristi V. Hansen, U.S. Geological Survey, Lawrence, Kansas*

About 416 million gallons per day (Mgal/d) were used for public water supply in Kansas during 2000, about 11% more than in 1990. During this time, the state's population increased about 8%, from 2.5 to 2.7 million people. Public supplies in Kansas are derived primarily from ground-water sources in the western part of the state and from surface-water sources in the eastern part. In 2000, about 59% of all public-supply water was from surface sources and 41% was from ground sources. The percentage of public-supply water obtained from surface sources increased between 1990 and 2000, especially in the Lower Arkansas and Missouri river basins.

Irrigation is the largest use of water in Kansas, totaling 3,714 Mgal/d in 2000. About 92% of this irrigation water was from ground-water sources, and about 95% was withdrawn in western Kansas. Most of the surface water used for irrigation is withdrawn in the Solomon, Upper Arkansas, and Kansas–Lower Republican river basins. Irrigation withdrawals in most of the state were smaller in 1995 than in either 1990 or 2000 due to more precipitation. Irrigation withdrawals in 2000 were 11% less than they were in 1990. The largest decreases occurred in the Smoky Hill–Saline and Cimarron river basins.

Industrial (including mining) water use totaled 85 Mgal/d in 2000. Most of the industrial water use in Kansas occurs in the Kansas–Lower Republican, Lower Arkansas, and Upper Arkansas river basins. Statewide, 72% of industrial supply is withdrawn from ground-water sources. Industrial water use increased by 7% between 1990 and 2000.

Water is used for livestock throughout Kansas and totaled 116 Mgal/d in 2000. Livestock water supplies are derived primarily from ground water in western Kansas, where usage increased substantially between 1990 and 2000. In the Cimarron and Upper Arkansas basins, water usage for livestock increased 32% during this period.

Water used to generate thermoelectric power totaled 2,556 Mgal/d in 2000, although most of this water use is nonconsumptive. The largest uses of water for power generation occur in eastern Kansas where adequate supplies of surface water are available.

## 20. Estimates of Flow Duration and Peak-discharge Frequency for Kansas Stream Locations

*Charles A. Perry, David M. Wolock, and Joshua C. Artman, U.S. Geological Survey, Lawrence, Kansas*

Streamflow statistics of flow duration and peak-discharge frequency were estimated for 4,771 individual locations on streams listed in the Kansas Surface Water Register. These statistics included the flow-duration values of 10%, 25%, 50%, 75%, and 90%, as well as the mean flow value. Peak-discharge frequencies were estimated for the 2-, 5-, 10-, 25-, 50-, and 100-year floods.

Least-squares multiple regression techniques were used, along with Tobit analyses, to develop equations for estimating flow-duration values and the mean flow for uncontrolled stream locations. The drainage areas of 149 U.S. Geological Survey streamflow-gaging stations in Kansas and parts of surrounding states that were uncontrolled by large reservoirs were used in the regression analyses. Significant climatic and basin characteristics, in order of importance in the regression analyses, were drainage area, mean annual precipitation, mean basin permeability, and mean basin slope. Regression equations used to estimate peak-discharge-frequency values at ungaged locations were obtained from a previous report.

The regression equations and an interpolation procedure were used to compute flow durations, mean flow, and estimates of peak-discharge frequency for locations along uncontrolled streams listed in the Kansas Surface Water Register. Flow durations, mean flow, and peak-discharge frequency determined at available gaging stations were used to interpolate the regression-estimated flows for the stream locations where available. The locations that were uncontrolled by reservoirs were interpolated using data from gaging stations weighted according to the drainage area and the bias between the regression-estimated and gaged flow information. At controlled locations on Kansas streams, the streamflow information was interpolated between gaging stations using only gaged data weighted by drainage area.

This information will be useful for a wide variety of hydrologic, engineering and regulatory applications. This information will be available on the Internet prior to the conference at: <http://ks.water.usgs.gov/Kansas/studies/strmstats/index.shtml>.

## 21. Mobile Irrigation Lab (MIL) Project Overview

*Dan Rogers, Gary Clark, Mahbub Alam, Robert Stratten, and Steven Briggeman, Research and Extension, Biological and Agricultural Engineering; and Dale Fjell, Department of Agronomy, Kansas State University, Manhattan, Kansas*

The Mobile Irrigation Lab (MIL) Project goal is to promote improved irrigation-water management practices and educate irrigation-water users and managers on the use of irrigation-decision support software and in-field evaluation of center-pivot nozzle packages. Irrigation-support software, developed as a part of MIL, is provided to irrigation farmers. Farmers are trained on MIL software in hands-on computer-training seminars in classrooms converted to computer labs using MIL laptop computers. MIL information and software is also made available via the MIL website. Center-pivot nozzle packages evaluations are also conducted as part of MIL.

## 22. KanSched—An Irrigation Scheduling Tool

*Dan Rogers, Gary Clark, Mahbub Alam, Robert Stratten, and Steven Briggeman, Research and Extension, Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas*

ET-based irrigation scheduling has been promoted as an improved irrigation-water management technique for a number of years. Weather-station networks and improved information-transfer systems have increased the availability of ET or crop-water use information to producers. KanSched is a user-friendly ET-based irrigation-scheduling program developed and distributed to Kansas irrigators as part of the Mobile Irrigation Lab project. The poster highlights KanSched features.

## 23. SDI—An Irrigation System Option for Kansas

*Dan Rogers, Research and Extension, Biological and Agricultural Engineering; Freddie Lamm, NW REC; Gary Clark, Biological and Agricultural Engineering; and Mahbub Alam, SW REC, Kansas State University, Manhattan, Kansas*

Subsurface Drip Irrigation (SDI) is a possible irrigation-system option for Kansas irrigators. Kansas State University Research and Extension research studies have been conducted since 1989. Since then, a number of research trends and economic analyses have been conducted to help identify proper management technique and strengths and weaknesses of the SDI system. The poster overviews SDI systems, research results, economics, and information sources.

## 24. Center-pivot Nozzle Package Performance Testing

*Dan Rogers, Gary Clark, Mahbub Alam, and Robert Stratten, Research and Extension, Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas*

Center-pivot nozzle packages can efficiently and uniformly apply irrigation water to a crop if properly designed, installed, and operated. However, it is difficult to tell by visual inspection if a nozzle package is performing well. Physical evaluation of packages can be accomplished by using a catch can evaluation. Full-scale field evaluations have been streamlined by the use of non-evaporating catch can devices, called IrriGages, as part of the Mobile Irrigation Lab project. Testing procedures and test-result examples are illustrated.

## 25. Water-right Development in Kansas

*Brownie Wilson, Geohydrology Section, Kansas Geological Survey, Lawrence, Kansas*

This poster shows the current water-right development in Kansas by source of water and the use made of water. Spatial patterns in the distribution, density, and types of use demonstrate an east-west distinction in the state with surface-water municipal and industrial use being prevalent in the eastern regions of Kansas with ground-water-based irrigation usage being more common in the western portions.

## 26. Republican River Compact Settlement and Ground-water Model

*David Barfield, Interstate Water Issues, Division of Water Resources, Kansas Department of Agriculture  
Topeka, Kansas*

In 1943, the States of Kansas, Colorado, and Nebraska, and the United States entered into the Republican River Compact. The Compact allocates the basin's water supply among the three states and paved the way for the construction of nine federal reservoirs and six irrigation districts. Kansas' interests in the basin include water uses within its tributaries of northwest Kansas; surface-water and ground-water users on the Republican River mainstem in north-central Kansas, including the Kansas Bostwick Irrigation District; and users of Milford Reservoir. The Republican River is a major tributary to the Kansas River.

Late in the 1980's, Kansas began to complain about Nebraska's failure to comply with the terms of the Compact, primarily due to their lack of adequate regulation of ground-water pumping. In 1998, after failing to resolve the dispute through the Compact Administration, Kansas filed suit against Nebraska in the U.S. Supreme Court. During 1999, the Supreme Court agreed to hear the case and in 2000, the Court denied Nebraska's motion to dismiss the case based on its theory that ground-water use was not governed by the Compact. The States decided to enter into settlement discussions in October 2001. On December 15, 2002, after 14 months of intensive efforts, the State of Kansas announced they had reached a settlement of the dispute.

The final settlement's 700 pages include:

- a moratorium on drilling of new large-capacity wells with minor exceptions;
- detailed accounting formulas and reporting requirements to determine Compact compliance, including use of a jointly developed computer ground-water model to determine ground-water pumping impacts;
- significant flexibility on location of use of a State's allocation and five-year averaging except during water-short years, when the averaging period is reduced to protect downstream uses;
- when the available water supply is limited, additional restrictions on use above Guide Rock, Nebraska;
- procedures for mediation and arbitration to help resolve any future disputes; and
- a commitment of the States to explore alternatives to improve operational efficiencies and increase the usable water supply in the lower Republican River basin.

A key component in future Compact accounting is the determination of the impacts of ground-water pumping on the basin's water supply. The States combined the efforts of their computer modeling and data experts to construct the joint ground-water model to make these determinations. During August 2003, the model was adopted by the Republican River Compact Administration (RRCA).

The RRCA ground-water model utilizes the U.S. Geological Survey modular ground-water model, MODFLOW 2000. The RRCA model simulates the long-term steady-state conditions prior to 1918 and transient conditions from 1918 to 2000 using 1 mi<sup>2</sup> grid cells and a one-month time step. The model domain extends northward to the Platte River and to the south, east, and west to the boundaries of Ogallala aquifer outcrops.

Major components of the model include recharge from precipitation, surface-water irrigation, and ground-water pumping; ground-water pumping; phreatophytic use of ground water; stream losses and gains; change in ground-water storage; and fluxes across constant head boundaries. Pumping and pumping-recharge estimates were prepared by each of the States and subjected to extensive review by the committee. Precipitation recharge was extensively evaluated in the modeling process due to its significance to the total water budget and model calibration. In the final model, precipitation recharge varies by precipitation, soil type and terrain, and whether the land is irrigated or not.

The model was calibrated against 350,000 ground-water level records at over 10,000 locations in the USGS's Ground Water Site Inventory and baseflow estimates prepared by the States at 65 stream gages in the basin.

The model will be updated annually as part of the Compact accounting to determine States' compliance with the settlement's terms.

# Water Quality

## 27. TMDL Implementation to Improve Water Quality

*Will Boyer, Watershed Specialist, Herschel George, Mike Christian, Ron Graber, and Robert Frisbie, Kansas State University Research and Extension – KCARE, Lawrence, Kansas*

The Clean Water Act of 1972 required states to set water-quality standards. The standards for any given body of water depend on the designated uses, such as public drinking water, fish and wildlife, recreation, agricultural, industrial, etc. The act required states to identify and set priorities on waters not meeting those standards. These waters include streams, rivers, reservoirs, lakes, and wetlands.

For streams in Kansas, a major issue is reduction of fecal coliform bacteria levels. A major issue for lakes is reduction of pesticide and phosphorus levels. TMDL implementation is done on a watershed basis. The sources of fecal coliform bacteria in surface waters can be from concentrated livestock-feeding operations, home septic and other on-site wastewater-treatment systems, urban runoff, and wildlife.

The educational efforts of Kansas State University watershed specialists focuses on key strategies for fecal coliform abatement. Hopefully, through a comprehensive education program, farmers, landowners, and homeowners are becoming aware of fecal coliform contamination and how to prevent it.

Awareness is raised through a variety of methods, including:

- public presentations to civic, business, conservation, environmental, and agricultural groups
- booths, exhibits, and materials for public events
- newsletters, news releases, and radio programs
- demonstrations, field days, and tours

In addition, one-on-one education and individual consultations is necessary for success in reducing pollution. A key aspect of implementation is the availability of financial assistance for implementing practices. A variety of State and Federal financial assistance programs are available.

Watershed Specialists work closely with local conservation districts and State and Federal agencies to identify financial assistance opportunities and direct participants to appropriate sources. Whether it is a one-on-one farm assessment or a group presentation, the watershed specialists are resources available to you.

## 28. Occurrence of Antibiotics in Water from Fish Hatcheries

*Elisabeth A. Scribner<sup>1</sup>, J. E. Dietze<sup>1</sup>, M. T. Meyer<sup>1</sup>, and D. W. Kolpin<sup>2</sup>,*

<sup>1</sup>U.S. Geological Survey, Lawrence, Kansas, and <sup>2</sup>U.S. Geological Survey, Iowa City, Iowa

The recent discovery of antibiotics in streams across the United States has raised awareness and need for monitoring antibiotics in the environment. Because antibiotic use is common in aquaculture to treat and prevent bacterial infections in fish, hatcheries may contribute to the presence of antibiotics in water resources. The U.S. Food and Drug Administration approved antibiotics for use as feed additives include oxytetracycline, sulfamerazine, and a combination of ormetoprim and sulfadimethoxine.

From January 2001 through June 2002, samples were collected with the assistance of hatchery operators from seven extensive and six intensive fish hatchery sites in seven states. Extensive fish hatcheries have an earthen, farm-pond appearance; whereas, intensive hatcheries raise the fish in concrete ponds or raceways. Water samples were analyzed for 34 antibiotic compounds and three degradation products using online solid-phase extraction and liquid chromatography/mass spectrometry. Of the 189 water samples collected during January 2001 through June 2002, antibiotics were detected in 27 samples collected from five of the 13 fish hatcheries. Oxytetracycline (0.23 to 10 5g/L) and sulfadimethoxine (0.10 to greater than 15 5g/L) were the most frequently detected antibiotics for this study.

A follow-up study was conducted in May through September 2003 for three (two in Kansas and one in Iowa) of the previously studied fish hatcheries to better determine antibiotic concentrations before, during, and after antibiotic treatments. Antibiotics were detected in 29 of 126 samples collected from the three fish hatcheries. Similar to the previous study, oxytetracycline (0.35 to 9.02 5g/L) and sulfadimethoxine (12 to 36 5g/L) were the most frequently detected antibiotics in the fish hatcheries sampled. Ormetoprim, an antibiotic added to the analytical method after the initial fish-hatchery study, was also detected (3.1 to 12 5g/L). No antibiotics were found in the source waters for these hatchery samples suggesting the concentrations measured in the ponds and raceways were derived from antibiotic use within these hatcheries. Results of this study can be used by fish-hatchery operators to consider management options (for example, settling ponds, water recycling, etc.) to minimize the possible release of water containing trace levels of antibiotics to the aquatic environment.

## 29. Identifying Sources of Fecal Bacteria in the Upper Arkansas River

*Thomas C. Willson*, Kansas State University Southwest Research-Extension Center, Garden City, Kansas; and *George L. Marchin*, Department of Biology, and *Robert L. Frisbie*, Cooperative Extension, Kansas State University, Manhattan, Kansas

The most commonly violated standard for surface-water quality in Kansas is the primary contact recreation standard for fecal coliform bacteria. Of 1,463 TMDLs established in Kansas since 1996, 517 (35%) are for contamination by fecal bacteria in rivers and streams. While the risk of waterborne illness is probably greatest if the source of contamination is human (e.g. from leaking sewage lines, ineffective septic systems, or incomplete municipal treatment), all warm-blooded animals produce the bacteria routinely used to indicate fecal contamination (fecal coliform, fecal streptococcus [*Enterococcus*], or *E. coli*), and there has never been a reliable and cost-effective means of determining which of the many potential nonpoint sources of fecal bacteria may be causing a specific incident of contamination in a specific location. Such information would allow us to target the limited funding available for TMDL implementation where it would have the greatest impact on the watershed, and would help identify unusual sources of bacteria that might otherwise be overlooked. This poster presents the preliminary results of an effort to develop cost-effective strategies for identifying the nonpoint sources of fecal bacteria entering the Arkansas Rive between Deerfield and Ford, Kansas, historically one of the most contaminated stream segments in the state, and a high-priority TMDL for remediation efforts. In the first phase of the project, fecal coliform levels were monitored in a network of sites along the main river channel to identify locations where concentrations of bacteria tended to increase after or between rain events (indicating either point or nonpoint source contamination). The second phase of the project focused in greater detail on fecal bacteria levels within the main storm drain in Garden City, a consistent source of point source and nonpoint source contamination during phase one. The third phase of the project has involved the development and testing of antibiotic-resistance analysis (ARA) as a cost-effective method for differentiating between bacteria from livestock, humans, and wildlife. We present data indicating the usefulness of this method in identifying hidden sources of bacteria in the watershed and testing its limitations when confronted with bacteria from unusual sources.

## 30. Attitudes and Behavior: Exploring the Relationship between Water-quality Attitudes and Best Management Practices

*Mary Dobbs*, Department of Geography, Kansas State University, Manhattan, Kansas

Nonpoint source pollution of surface waterways continues to be a national and local concern. Because agriculture is the dominant land use in Kansas, agricultural producers in Kansas are in a position to significantly affect the quality of Kansas' surface waters. A survey of rural landowners in two hydrologic units in north-central and northwestern Kansas revealed little correlation between the attitudes of agricultural producers toward water quality and their adoption of best management practices (BMPs). An attitude index and a behavior index were used to measure correlations and associations between variables. The survey revealed that 30% of producers in the Big Creek and Middle Smoky Hill River hydrologic units have a low attitude index (i.e., a low level of awareness of a problem, perceived ability to make difference, and desire to affect change) and a low behavior index (i.e., adoption of specific BMPs). Twenty-six percent report both a high attitude index and a high behavior index; these producers have a greater awareness of the consequences of management practices and employ practices that support higher surface water quality. Twenty-three percent report a low attitude index and a high behavior index, indicating that they engage in environmentally friendly practices, but for reasons other than supporting surface-water quality. Twenty-two percent report a high behavior index but a low attitude index. These individuals would like to be able to improve water quality but are unable to do so due to other constraints. This study suggests the continued need for education about basic hydrologic processes as well as the environmental impact of agricultural practices. In addition, agricultural policy should include sufficient inducements to overcome the economic obstacles that inhibit adoption of practices that will support improved surface-water quality.

## 31. Performance Characteristics of a Magnetic Particle-based Immunoassay (ELISA) for the Analysis of Atrazine Metabolites in Water Samples

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Pesticides are frequently applied in agriculture to protect crops from pests, and to increase the yield of the harvest. Atrazine is one of the most widely used herbicides in the U.S.; it is most often used with corn, sorghum, and sugar cane for the control of annual broadleaf and grass weeds. Atrazine, as well as other triazines, are metabolized in plants and animals and undergo environmental degradation to form dealkylated chlorotriazines. Pesticides can leach into ground and surface water after application. The occurrence of triazines in surface waters has become a topic of concern because of their potential adverse effects, which include the disruption of the endocrine system of aquatic organisms by the presence of trace amounts of these pesticides and their metabolites. The U.S. EPA has established a MCL in drinking water of 3 ppb for atrazine, and regulatory levels for the metabolites are under discussion. The use of immunoassays to detect environmental contaminants has increased dramatically in recent years. Immunochemical analysis using an enzyme-linked immunosorbent assay (ELISA) is sensitive, rapid, reliable, cost-effective, and can be used for lab and field analysis. A magnetic-particle based ELISA has been developed for the quantitation of atrazine metabolites at sub parts-per-billion concentration (ng/mL) in water samples without the need of sample extraction or pre-concentration. The performance characteristics of the ELISA demonstrated by recovery, precision, and correlation of water samples against GC analysis are presented. The use of cost-effective analytical methods such as immunoassay should enable the monitoring of these pesticide metabolites in the environment and facilitate the evaluation and optimization of removal mechanisms in the treatment process, therefore minimizing their discharge into the aquatic environment.

## 32. Water Quality Prior to Implementation of Best Management Practices on Two Urban Golf Courses

*Amanda Reed and Karen Brown Sullivan, Wichita State University, Wichita, Kansas*

Two golf courses, Auburn Hills Golf Course and Willowbend Golf Club (AH and WB respectively), in Wichita, Kansas, were chosen to monitor water quality, both nutrients and pesticides, during a three-year study being conducted to examine potential effects of best management practices (BMPs). Results of water-quality measurements taken for the first year prior to implementation of management practices will be presented. The two golf courses chosen are distinct in that AH is a recently designed, city-managed course while WB is a long-established course. Also, AH is bordered both by significant agricultural and residential areas whereas WB is contained within a gated residential community. Each course is situated along a natural stream corridor that is interrupted with constructed ponds. At each course, an upstream and downstream pond, a mid-point site, and a nearby residential pond were chosen as sampling sites. Water-quality measures were taken twice each month from July 2002 through June 2003 at periods of low water flow corresponding to no recent rain events. Water quality was also monitored during six rain events. Water was sampled during each rain event at 2, 12, and 24 hours from rain initiation. Preliminary results based on the first 12 months indicate that the upstream and downstream ponds at AH consistently exhibited the greatest values for nutrient loading (total suspended solids, ammonia, phosphates, and total nitrogen) compared to all sites, including those at WB. The only site at WB that compared in nutrient values was the residential pond. The downstream and upstream locations at AH also exhibited the highest average levels for the herbicide atrazine. On the WB course, the residential pond site consistently showed the highest measures for nutrient loading while the mid-point pond, which receives storm-water runoff from both the course and the residential area, exhibited higher pesticides levels. Pesticides associated with the first two rain events showed no consistent trends, increasing at some sampling locations but decreasing at others. At this preliminary point of data analysis, we assume that the increased nutrient concentrations at AH are due to two factors, the surrounding agricultural areas and the recent development of the course, which precludes a complex plant community.