Kansas Earth Resources Field Project

Kansas Water Issues

1996 FIELD CONFERENCE
June 12–14, 1996

Sponsored by Kansas Geological Survey and Kansas Water Office

Kansas Earth Resources Field Project

FIELD GUIDE

1996 FIELD CONFERENCE

"Kansas Water Issues"

June 12-14, 1996

Edited by

Robert S. Sawin
and
Rex C. Buchanan

This project is operated by the Kansas Geological Survey and funded, in part, by the State Water Plan Fund of the Kansas Water Office.

KGS OPEN-FILE REPORT 96-23

KANSAS GEOLOGICAL SURVEY
Geology Extension
1930 Constant Ave. - Campus West
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KANSAS EARTH RESOURCES FIELD PROJECT

"Kansas Water Issues"

1996 FIELD CONFERENCE

June 12-14, 1996

SCHEDULE AND ITINERARY

Wednesday June 12, 1996

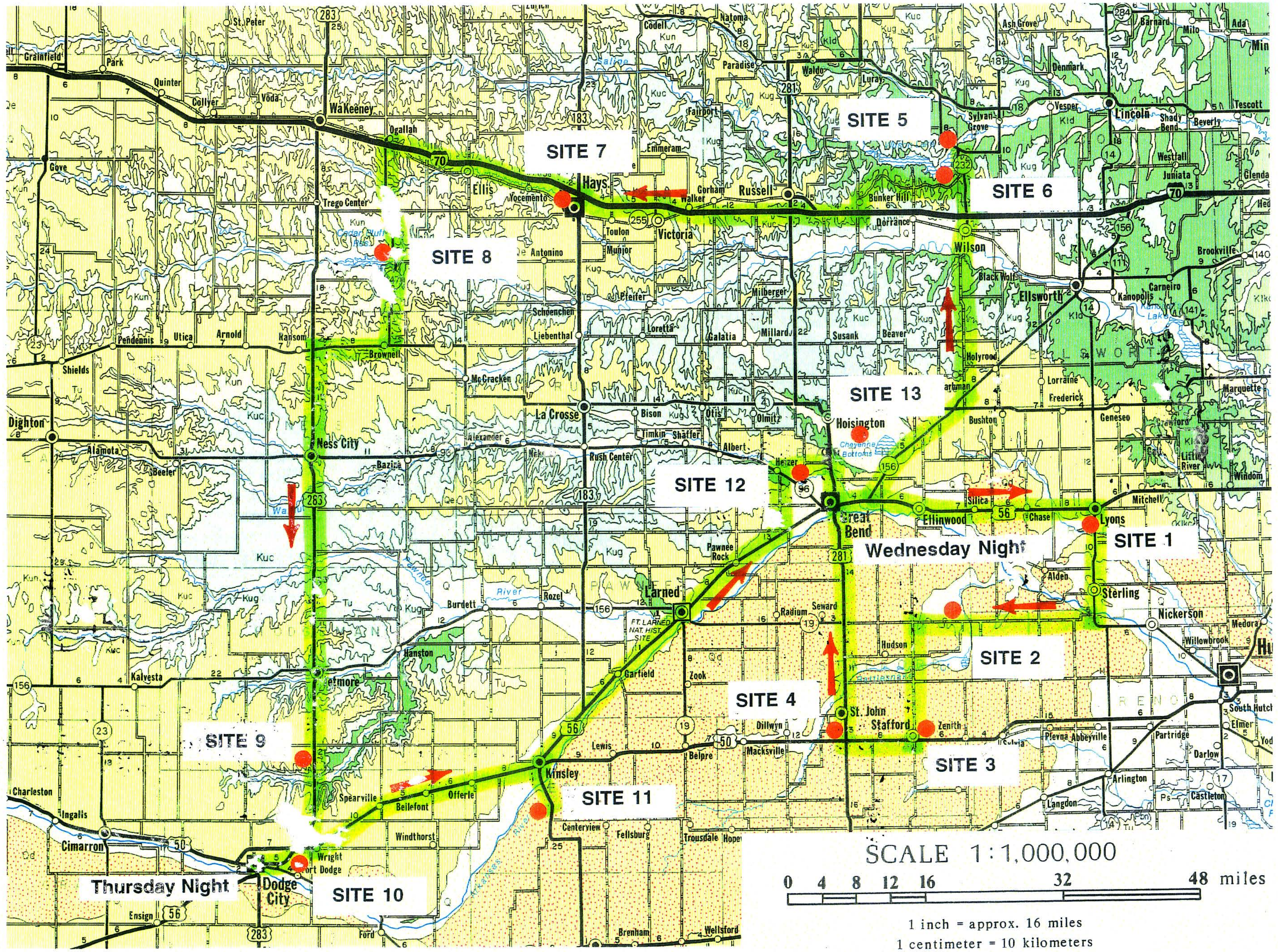
7:00 am	Breakfast
7:20 am	Greetings, Conference Overview
7:45 am	**Leave Holiday Inn, Great Bend**
8:30 am	**SITE 1** - Salt Mine and Plant, Lyons
12:30 pm	Lunch/Quivira NWR Env.Ed.Center
1:15 pm	**SITE 2** - Tour Quivira National Wildlife Refuge
2:45 pm	**SITE 3** - Big Bend GMD office, Stafford
4:30 pm	**SITE 4** - KSU's Sandyland Experiment Field, St. John
6:00 pm	Arrive Holiday Inn, Great Bend
7:00 pm	Dinner at Holiday Inn, Great Bend
7:30 pm	Evening Session - David Pope, DWR and Al LeDoux, KWO

Thursday June 13, 1996

7:00 am	Breakfast
7:30 am	Bus to Wilson Lake
8:30 am	**SITE 5**- Wilson Lake and Dam
9:00 am	**SITE 6** - Corral Cove - Dakota Outcrop/Aquifer
10:45 am	**SITE 7** - City of Hays - FHSU, Tomanek Hall
12:00 am	Lunch - Tomanek Hall
2:45 pm	**SITE 8** - Cedar Bluff Reservoir
4:45 pm	**SITE 9** - Ogallala Outcrop
6:00 pm	Arrive Days Inn, Dodge City
7:00 pm	Dinner
7:30 pm	Evening Session - Ogallala and U. Arkansas River Aquifers

Friday June 14, 1996

7:00 am	Breakfast
7:30 am	Bus to Feed Yards
7:45am	**SITE 10** - Tour Feed Yard - Feed Yard/Packing Plant Overview
9:15 am	**SITE 11** - Circle K Ranch, Edwards County
10:30 am	Larned - Rest Stop, Schnack Park
11:15 am	**SITE 12** - Walnut Creek Drainage Basin
11:30 am	**SITE 13** - Tour Cheyenne Bottoms
1:00 pm	Lunch/Discussion
2:30 pm	**Arrive Holiday Inn, Great Bend**


SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
Wednesday Night
Thursday Night
SCALE 1:1,000,000
0 4 8 12 16 32 48 miles
1 inch = approx. 16 miles
1 centimeter = 10 kilometers

KANSAS EARTH RESOURCES FIELD PROJECT

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FRIDAY, JUNE 14

POCKETS

KANSAS EARTH RESOURCES FIELD PROJECT

"Kansas Water Issues"

1996 FIELD CONFERENCE

June 12-14, 1996

PARTICIPANTS LIST

Name	Title	Affiliation	Business Address
Dan Devlin	Extension Specialist and Coordinator	Kansas State University	2014 Throckmorton Manhattan, KS 66506 913/532-5776
Christine Downey	Senator, 31st District	Kansas Senate/ Agriculture Comm.	10320 N. Wheat State Rd. Inman, KS 67546 316/543-2628
Bruce Falk	Water Commissioner	Ks. Dept. of Agriculture Div. of Water Resources	105 N. Main Stafford, KS 67578 316/234-5311
Sharon Falk	Manager	Big Bend GMD #5	P.O. Box 7 125 S. Main Stafford, KS 67578 316/234-5352
Joann Freeborn	Representative, 107th District	Kansas House of Representatives/ Energy and Natural Res. Comm.	Rt. 3, Box 307 Concordia, KS 66901 913/446-3675
Raney Gilliland	Principal Analyst	Legislative Research	Rm 545-N, State Capitol Topeka, KS 66612 913/296-3181
Ray Haner	Member	Kansas Water Authority	The Boeing Company P.O. Box 7730, MSK 12-03 Wichita, KS 67277-7730 316/526-2321
Carl Holmes	Representative, 125th District/ Chairman	Kansas House of Representatives/ Energy and Natural Res. Comm.	P.O. Box 2288 Liberal, KS 67905 316/624-7361
Becky Hutchins	Representative, 50th District	Kansas House of Representatives/ Energy and Natural Res. Comm./Agriculture Comm.	700 Wyoming Holton, KS 66436 913/364-2612
Wayne Lebsack	Chairman	The Nature Conservancy Kansas Chapter	603 S. Douglas Lyons, KS 67554 316/938-2396
Al LeDoux	Director	Kansas Water Office	109 SW 9th St., Ste. 300 Topeka, KS 66612-1249 913/296-3185

Janis Lee	Senator, 36th District	Kansas Senate/ Energy and Natural Res. Comm.	Rural Route 1, Box 145 Kensington, KS 66951 913/476-2294
Ned Marks	Owner/ Hydrogeologist	Terrane Resources Co.	P.O. Box 173 Stafford, KS 67578 316/234-5200
Laura McClure	Representative, 119th District	Kansas House of Representatives/ Energy and Natural Res. Comm./Agriculture Comm.	202 S. 4th Osborne, KS 67473 913/346-2715
James O'Connell	Secretary	Kansas Department of Health and Environment	900 SW Jackson, Ste. 620 Topeka, KS 66612 913/296-0461
Marvin Odgers	Owner	3M Farms, Inc.	HCR 1, Box 84 Sublette, KS 67877 316/675-8181
David Pope	Director-Chief Engineer	Ks. Dept. of Agriculture Div. of Water Resources	901 S. Kansas Ave. Topeka, KS 66602 913/296-3717
John Strickler	Executive Director	KACEE	2610 Claflin Rd. Manhattan, KS 66502 913/537-7050
Carolyn Tillotson	Senator, 3rd District	Kansas Senate/ Energy and Natural Res. Comm./ Agriculture Comm.	1606 Westwood Dr. Leavenworth, KS 66048 913/682-7790
Mary Torrence	Assist. Revisor of Statutes	Revisor of Statutes Office	300 SW 10th, Ste. 322 Topeka, KS 66612 913/296-2321
Jim Triplett	Chairman/ Professor	Statewide Council of Basin Advisors Comm./ Pittsburg State University	1701 S. Broadway Pittsburg, KS 66762 316/235-4730
Kerry Wedel	Water Resource Manager	Kansas Water Office	109 SW 9th St., Ste. 300 Topeka, KS 66612-1249 913/296-0876
Richard Wenstrom	Owner	Wenstrom Farms	Route 1, Box 107 Kinsley, KS 67547 316/659-3210
Steve Williams	Secretary	Ks. Department of Wildlife and Parks	900 SW Jackson Topeka, KS 66612 913/296-2281
Carol Williamson	Science Teacher	Kansas Earth Science Teachers Association	2619 W. 131st Street Olathe, KS 66061 913/764-6036

BIOGRAPHICAL INFORMATION

Daniel L. Devlin
Title
Extension Specialist and Coordinator
Environmental Quality
Affiliation
Kansas State University
Address and Telephone
2014 Throckmorton
Manhattan, KS 66506
913/532-5776
Current Responsibilities
Soil and water quality programs; prevention of nutrient and pesticide contamination educational programs.
Experience
Current position, 2 years; Extension Agronomist, KSU, 9 years.
Education
Kansas State University - BS, 1979
Kansas State University - MS, 1983
Washington State University - PhD, 1985

Christine Downey
Title
Senator, 131st District
Affiliation
Kansas Senate
Address and Telephone
10320 N. Wheat State Rd.
Inman, KS 67546
316/543-2628
Current Responsibilities
Senate Agriculture Committee (Ranking Minority Member); Adjunct Professor, Education Department, Bethel College.
Experience
Public School Teacher, 20 years.
Education
Wichita State University - BS 1980
Wichita State University - MEd 1986

Bruce Falk
Title
Water Commissioner
Affiliation
Kansas Department of Agriculture
Division of Water Resources
Address and Telephone
Stafford Field Office, DWR
105 N. Main
Stafford, KS 67578
316/234-5311
Current Responsibilities
Regulate water in 26 counties, south-central Kansas.
Experience
DWR, 24 years.
Education
Friends University - BS, 1990

Sharon Falk
Title
Manager
Affiliation
Big Bend Groundwater Management District No. 5
Address and Telephone
P.O. Box 7
125 S. Main
Stafford, KS 67578
316/234-5352
Current Responsibilities
Manage district operations under the direction of a nine member Board of Directors.
Experience
Big Bend GMD, 16 years.
Education
Friends University - BS, 1990

Joann L. Freeborn
Title
Representative, 107th District
Affiliation
Kansas House of Representatives
Address and Telephone
Rt. 3, Box 307
Concordia, KS 66901
913/446-3675
Current Responsibilities
House Energy and Natural Resources Committee (Vice Chairwoman).
Experience
Teacher
Education
Kansas State University - BS, 1966

Raney Gilliland
Title
Principal Analyst
Affiliation
Kansas Legislative Research Dept.
Address and Telephone
Rm 545-N, State Capitol

Topeka, KS 66612
913/296-3181
Current Responsibilities
Staffing House and Senate Energy and Natural Resources and Agriculture Committees.
Experience
Legislative Research, 18 years; grew up on farm in northeast Kansas.
Education
Kansas State University - BS, 1975
Kansas State University - MS, 1978

Ray Haner
Title
Member, Kansas Water Authority
Affiliation
The Boeing Company
Address and Telephone
P.O. Box 7730, MSK 12-03
Wichita, KS 67277-7730
316/526-2321
Current Responsibilities
Director of Safety, Health, and Environmental Affairs, Boeing Wichita Division.
Experience
Director of Safety, Health, and Environmental Affairs, Rockwell International; Director of Safety, Health, and Environmental Affairs, Owens Corning Fiberglas.
Education
Safety and Loss Control Sc. - BS, 1984

Carl Dean Holmes
Title
Representative, 125th District
Affiliation
Kansas House of Representatives
Address and Telephone
P.O. Box 2288
Liberal, KS 67905
316/624-7361
Current Responsibilities
House Energy and Natural Resources Committee (Chairman).
Education
Colorado State University - BS, 1962

Becky Hutchins
Title
Representative, 50th District
Affiliation
Kansas House of Representatives
Address and Telephone
700 Wyoming
Holton, KS 66436
913/364-2612
Current Responsibilities
House Energy and Natural Resources Committee; House Agriculture Committee.
Education
Washburn University - BA, 1985

Wayne Lebsack
Title
Chairman
Affiliation
The Nature Conservancy, Kansas Chapter
Address and Telephone
603 S. Douglas
Lyons, KS 67554
316/938-2396
Current Responsibilities
Chairman, Kansas Board of Trustees
Experience
Oil and gas exploration; Ground water exploration and pollution research.
Education
Colorado School of Mines - Geol. Eng., 1949
Colorado School of Mines - Geol. Eng., 1951
Colorado School of Mines - 2 years grad. studies

Al LeDoux
Title
Director
Affiliation
Kansas Water Office
Address and Telephone
109 SW 9th St., Ste. 300
Topeka, KS 66612-1249
913/296-3185
Current Responsibilities
Plan, market, develop, implement, and evaluate policies/programs for current and future water needs.
Experience
Work with Kansas Legislature, 13 years;
Rancher and livestock producer, 30 years.
Education
Baker University - BA, 1969
University of Kansas - Grad. Sch.

Janis K. Lee
Title
Senator, 36th District
Affiliation
Kansas Senate
Address and Telephone
Rural Route 1, Box 145
Kensington, KS 66951
913/476-2294
Current Responsibilities
Senate Energy and Natural Resources Committee (Ranking Minority Member).

Experience

Ranching and farming.

Education

Kansas State University - BS, 1970

Ned Marks

Title

Owner/Hydrogeologist

Affiliation

Terrane Resources Company

Address and Telephone

P.O. Box 173
Stafford, KS 67578
316/234-5200

Current Responsibilities

Consultant - ground-water investigations, geologic studies, water rights review; Technical Director, Kansas Ground Water Association.

Experience

Terrane Resources, 6 years; Research Geologist, 6 years.

Education

Dodge City Community College - AS, 1975
Fort Hays State University - BS, 1984

Laura McClure

Title

Representative, 119th District

Affiliation

Kansas House of Representatives

Address and Telephone

202 S. 4th
Osborne, KS 67473
913/346-2715

Current Responsibilities

House Energy and Natural Resources Committee; House Agriculture Committee.

Experience

Owner/operator flower and antiques shop; nutrition site manager, Beloit Senior Center.

Education

Mankato High School - 1968

James J. O'Connell

Title

Secretary

Affiliation

Kansas Department of Health and Environment

Address and Telephone

900 SW Jackson, Ste. 620
Topeka, KS 66612
913/296-0461

Current Responsibilities

Administer Kansas statutes to insure protection of public health and the environment.

Experience

Attorney, private practice; Hospital Administrator; Retired Colonel, US Air Force.

Education

University of Connecticut - BS
Washington University, St. Louis - MHA
University of Missouri, Kansas City - JD

Marvin C. Odgers

Title

Owner

Affiliation

3M Farms, Inc.

Address and Telephone

HCR 1, Box 84
Sublette, KS 67877
316/675-8181

Current Responsibilities

President, 3M Farms; John Deere Dealership.

Experience

Farmer, 35 years.

Education

Kansas State University

David L. Pope

Title

Director-Chief Engineer

Affiliation

Kansas Department of Agriculture
Division of Water Resources

Address and Telephone

901 S. Kansas Ave., 2nd Floor
Topeka, KS 66612-1283
913/296-3717

Current Responsibilities

Administration of laws related to conservation, management, use, and control of water and watercourses in Kansas.

Experience

Assistant Chief Engineer, DWR, 5 years; Manager, Southwest Kansas GMD No. 3, 3 years; Extension Irrigation Engineer, Cooperative Extension Service, 5 years.

Education

Oklahoma State University - BS
Oklahoma State University - MS

John Strickler

Title

Executive Director

Affiliation

KACEE (Kansas Association for Conservation and Environmental Education)

Address and Telephone

2610 Claflin Rd.
Manhattan, KS 66502
913/537-7050

Current Responsibilities

Executive Director, KACEE

Experience

Special Assistant for Environment and Natural Resources to Governor Mike Hayden, 2 years; Acting Secretary, Kansas Department of Wildlife and Parks, 1987 and 1995; Kansas State and Extension Forestry, Kansas State University, 33 years; US Forest Service, 4 years.

Education

University of Missouri - BSF, 1957
Kansas State University - MS, 1968

Carolyn Tillotson

Title

Senator, 3rd District

Affiliation

Kansas Senate

Address and Telephone

1606 Westwood Dr.
Leavenworth, KS 66048
913/682-7790

Current Responsibilities

Senate Energy and Natural Resources Committee; Senate Agriculture Committee.

Experience

Journalism, newspapers, wire services, and health care public relations, 20 years.

Education

University of Arkansas - BA, 1959

Mary Torrence

Title

Assistant Revisor of Statutes

Affiliation

Revisor of Statutes Office

Address and Telephone

300 SW 10th, Ste. 322
Topeka, KS 66612
913/296-2321

Current Responsibilities

Legislative staff; drafting legislation and staffing legislative committees; legal advisor.

Experience

Revisor of Statutes Office, 22 years.

Education

University of Kansas - BA, 1970
University of Kansas - JD, 1974

James R. Triplett, Ph.D.

Title

Professor

Affiliation

Pittsburg State University

Address and Telephone

1701 S. Broadway
Pittsburg, KS 66762
316/235-4730

Current Responsibilities

Statewide Council of Basin Advisors Committee, Chairman; Neosho Basin Advisory Committee, Chairman; Grand/Neosho River Committee, Chairman; Professor and Chairman, Biology Dept., aquatic and fish courses.

Experience

Chairman, Biology Department, Pittsburg State University, 12 years; Assistant Professor, PSU, 4 years; Assistant Professor, Division of Fisheries and Wildlife Management, Ohio State University, 5 years.

Education

Kansas State College of Pittsburg - BA, 1966
Kansas State College of Pittsburg - MS, 1968
University of Kansas - PhD, 1976

Kerry Wedel

Title

Water Resource Manager

Affiliation

Kansas Water Office

Address and Telephone

109 SW 9th St., Ste. 300
Topeka, KS 66612-1249
913/296-0876

Current Responsibilities

Manager, planning unit.

Education

Kansas State University - BS, 1980
Kansas State University - MLA, 1982

Richard J. Wenstrom

Title

Owner

Affiliation

Wenstrom Farms

Address and Telephone

Route 1, Box 107
Kinsley, KS 67547
316/659-3210

Current Responsibilities

Owner and operator, irrigated farming operation south of Kinsley, Kansas; Water PACK, Board of Directors.

Experience

Farming, 20 years; founder and owner, Pumping Plant Testing Engineering Company (1983 to present); Manager for Agriculture, Rainbird, 6 years.

Education

North Dakota State University - BSAgEng, 1964
Colorado State University - MSAgEng, 1966

Steve Williams
Title
Secretary
Affiliation
Kansas Department Wildlife and Parks
Address and Telephone
900 SW Jackson
Topeka, KS 66612
913/296-2281
Current Responsibilities
Administer wildlife, fish, parks, boating, and administrative programs.
Experience
Deputy Executive Director, Pennsylvania Game Commission; Assistant Director for Wildlife, Massachusetts Division of Fisheries & Wildlife.
Education
The Pennsylvania State University - BS, 1979
University of North Dakota - MS, 1981
The Pennsylvania State University - PhD, 1986

Carol Williamson
Title
Science Teacher
Affiliation
Kansas Earth Science Teachers Association/ Olathe Unified School District No. 233
Address and Telephone
2619 W. 131st Street
Olathe, KS 66061
913/764-6036
Current Responsibilities
Junior High earth science and physical science teacher; Olathe Secondary Science Curriculum Facilitator; KESTA; KACEE, Vice President; National Science Teachers Association (NSTA), Board of Directors.
Experience
District Elementary Science Resource Person and 4th grade classroom teacher, Potwin, KS; KESTA, Past President.
Education
Bethel College - BS, 1983
University of Kansas - MS, 1993

KANSAS GEOLOGICAL SURVEY STAFF

Lee C. Gerhard

Title
: Director and State Geologist

Affiliation
: Kansas Geological Survey

Address and Telephone
: 1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965

Current Responsibilities
: Director of administration and geologic research at the Kansas Geological Survey.

Experience
: Kansas Geological Survey, 9 years; Colorado School of Mines, 5 years; North Dakota Geological Survey, 6 years; W. Indies Lab., Fairleigh Dickinson Univ., 3 years; Univ. of Southern Colorado, 6 years; Sinclair, 2 years; Consultant and Independent Petroleum Geologist.

Education
: Syracuse University - BS, 1958
University of Kansas - MS, 1961
University of Kansas - PhD, 1964

Lawrence L. Brady

Title
: Deputy Director

Affiliation
: Kansas Geological Survey

Address and Telephone
: 1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965

Current Responsibilities
: Geologic research and administration.

Experience
: Kansas Geological Survey, 24 years; Oklahoma State University, 1 year; U.S. Corps of Engineers, 5 years.

Education
: Kansas State University - BS, 1958
University of Kansas - MS, 1967
University of Kansas - PhD, 1971

Rex C. Buchanan

Title
: Associate Director

Affiliation
: Publications and Public Affairs Section, Kansas Geological Survey

Address and Telephone
: 1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965

Current Responsibilities
: Supervise publication and public outreach activities, media relations, and non-technical communications.

Experience
: Kansas Geological Survey, 17 years; University-Industry Research, University of Wisconsin, 3 years; Salina Journal, 4 years.

Education
: Kansas Wesleyan University - BA, 1975
University of Wisconsin-Madison - MA, 1978
University of Wisconsin-Madison - MS, 1982

Robert W. Buddemeier

Title
: Senior Scientist

Affiliation
: Geohydrology Section, Kansas Geological Survey

Address and Telephone
: 1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965

Current Responsibilities
: Saltwater intrusion project, south-central Kansas; climate, surface water, and ground-water interactions.

Experience
: Kansas Geological Survey, 5 years; Lawrence Livermore National Laboratory, 11 years; University of Hawaii, 10 years.

Education
: University of Illinois - BS, 1958
University of Washington - PhD, 1969

John R. Charlton

Title
: Research Assistant

Affiliation
: Publications and Public Affairs Section, Kansas Geological Survey

Address and Telephone
: 1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965

Current Responsibilities
: Staff photographer and photographic services for publications, presentations, and exhibits.

Experience
: Kansas Geological Survey, 14 years; Kress

Foundation, Spencer Museum of Art, 5 years.
Education
University of Kansas - BA, 1976
University of Kansas - MA, 1982

P. Allen Macfarlane
Title
Assistant Scientist
Affiliation
Geohydrology Section, Kansas Geological Survey
Address and Telephone
1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965
Current Responsibilities
Dakota Aquifer Project; hydrogeology of sedimentary basins; ground-water-resource evaluations.
Experience
Kansas Geological Survey, 16 years; Environmental Protection Agency, 2 years.
Education
Colorado School of Mines - BS, 1970
University of Kansas - MS, 1978
University of Kansas - PhD, 1993

James R. McCauley
Title
Assistant Scientist
Affiliation
Geologic Investigations Section, Kansas Geological Survey
Address and Telephone
1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965
Current Responsibilities
Geologic mapping, remote sensing, and public inquires.
Experience
Kansas Geological Survey, 19 years; KU Remote Sensing Laboratory, 6 years.
Education
University of Kansas - BS, 1970
University of Kansas - MS, 1973
University of Kansas - PhD, 1977

Robert S. Sawin
Title
Research Assistant
Affiliation
Geology Extension, Publications and Public Affairs Section, Kansas Geological Survey
Address and Telephone
1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965
Current Responsibilities
Public outreach activities, Kansas Earth Resources Field Project, and public inquires.
Experience
Kansas Geological Survey, 4 years; Petroleum Geology, 15 years; Engineering Geology, 6 years.
Education
Kansas State University - BS, 1972
Kansas State University - MS, 1977

Marios Sophocleous
Title
Senior Scientist
Affiliation
Geohydrology Section, Kansas Geological Survey
Address and Telephone
1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965
Current Responsibilities
Surface water/ground water interaction; watershed hydrology; unsaturated/saturated flow theory; modeling recharge dynamics.
Experience
Kansas Geological Survey, 8 years.
Education
University of Athens, Greece - BS, 1971
University of Kansas - MS, 1973
University of Alberta, Canada - PhD, 1978

Donald O. Whittemore
Title
Senior Scientist
Affiliation
Chief, Geohydrology Section, Kansas Geological Survey
Address and Telephone
1930 Constant Ave.
Campus West
Lawrence, KS 66049
913/864-3965
Current Responsibilities
Chief, Geohydrology Section; environmental geochemistry; geochemistry of ground- and surface-water resources.
Experience
Kansas Geological Survey, 8 years; Assistant Professor, Kansas State University, 6 years.
Education
University of New Hampshire - BS, 1966
Pennsylvania State University - PhD, 1973

KANSAS EARTH RESOURCES FIELD PROJECT

"Kansas Water Issues"

1996 FIELD CONFERENCE

June 12-14, 1996

Welcome to the 1996 Field Conference. This year's conference will examine a number of water issues Kansans are confronted with now and in the future. All of us are involved, either directly or indirectly, with water. The challenges we face with this critical resource are many and complex, and, as we will observe on this trip, in many ways interrelated. During this trip we will be able to observe how people have altered the natural hydrologic system with dams, irrigation, farming and erosion control practices, and other methods, to their benefit. But are these "benefits" short term, and what effect will they have on the future water resource, the environment, and the people that rely on it? This year's trip is structured to examine different aspects of various water issues and experience the connections that bind these issues together.

This year, the Field Conference acknowledges the Kansas Water Office, which is helping fund this trip through the State Water Fund Plan.

The theme for the 1996 Field Conference is *Kansas Water Issues*. During the two and one-half day conference, participants will travel via chartered bus to selected sites. The sites will include an underground salt mine, ground-water management and agricultural sites, municipal facilities, Federal reservoirs, and State and Federal wetlands areas. When applicable, participants will analyze the technology implemented at these sites to prevent or to remediate environmental degradation.

En route, at the sites, and at various other times, local and regional experts in resource development will brief participants about what they will see and what issues relate to the sites. In addition, a comprehensive Field Guide provides background on the sites and issues. When possible, participants will interact with county, state, and regional officials, environmental groups, and citizens' organizations. This information base provides participants with new and broader perspectives useful in formulating energy policies.

The 1996 Field Conference is more than merely a guided tour of the sites. Rather, the sites are selected to demonstrate particular perspectives on an issue, and the program is designed to be both experientially and educationally rewarding.

The Kansas Earth Resources Field Project does not seek to resolve policy or regulatory conflicts, but rather provides unique opportunities to acquaint decision-makers and policy-makers with the various perspectives on resource problems and issues. Furthermore, the Field Project goes beyond merely identifying the issues by bringing together experts who examine the issues in light of the unique technical, geographical, geological, environmental, social, and economic realities of the situation.

The Field Project provides an opportunity for participants to visit a variety of earth-resource production sites and discuss problems and issues with industry and government experts, residents, and community leaders. Participants will gain a better understanding and appreciation of the technology and issues surrounding such development.

About the Kansas Earth Resources Field Project

The Kansas Earth Resources Field Project is an educational outreach program of the Kansas Geological Survey administered through its Geology Extension program. The mission of the Field Project is to provide educational opportunities to individuals who make and influence policy about earth resources and related social, economic, and environmental issues in Kansas. Earth resources are defined as the mineral, energy, water, and soil resources of the earth. The industries that deal with earth resources include energy, mining, quarrying, and agriculture.

The Field Project consists of a series of onsite conferences at which the participants are introduced to the technical, economic, environmental, social, and policy-related aspects of earth-resource development. Using a field experience, the goal of the program is to provide participants with an educational opportunity that will assist them in making better informed, efficient, and effective decisions when dealing with earth-resource issues.

The Kansas Earth Resources Field Project strives to facilitate the exchange of information and ideas between working professionals who deal with earth-resource related issues. The programs are designed to open channels of communication among federal, state, and local governments as well as the private sector. The contacts established during the conference will provide a network for future information and idea exchange among the participants, and between participants and regional water, soil, energy, and mineral specialists.

The Kansas Earth Resources Field Project is modeled after a similar program of national scope, the Energy and Minerals Field Institute, operated by the Colorado School of Mines. The Kansas Geological Survey appreciates the support of Dr. Erling Brostuen, Director of the Energy and Minerals Field Institute, in helping develop the Kansas project.

Kansas Geological Survey

The Kansas Geological Survey is a research and service division administered by the University of Kansas. The Survey is responsible for studying and providing information about the state's geologic hazards and resources, particularly ground water, oil, natural gas, and other minerals. The Kansas Geological Survey's role is strictly one of service, research, and reporting of the various results, and it has no regulatory or operational responsibility within State government.

The Kansas Geological Survey is organized into four research sections and several support groups. Research sections are Geologic Investigations, Geohydrology, Petroleum Research, and Mathematical Geology. Support sections include Analytical Services, Computer Services, Editing, Publication Sales, Exploration Services, Library/Archives, Geology Extension, Technical Information Services, and Administration. The Survey also has a branch office in Wichita, whose primary function is to collect, store, and loan cutting samples from oil and gas wells drilled in the state. In addition, the Wichita office provides publications sales and conducts geologic studies. The Kansas Geological Survey consists of more than 50 scientists, assisted by about 80 full-time staff members and student employees, specializing in a variety of geologic disciplines.

The Geologic Investigations Section studies and maps the state's surficial geology, paleontology, and industrial and metallic minerals deposits. This section has been the focus for the Survey's geologic-mapping activities.

The Geohydrology Section studies the state's ground-water resources. The section conducts research and service projects directed toward accurately assessing the state's ground-water problems and finding effective ways of maintaining ground-water supplies to ensure availability for future generations. Research is designed to further the scientific understanding of the hydrology and water resources of Kansas and to disseminate research results and other hydrologic-related information to the people of the state.

The Petroleum Research Section conducts research to increase the scientific understanding of the geologic and economic factors controlling the occurrence and production of hydrocarbon resources in Kansas. The section also works on the efficient transfer of research results and information to the people of Kansas in order to advance the understanding and effective management of its hydrocarbon resources. The section participates with other University of Kansas units in projects funded by the U.S. Department of Energy on the transfer of technology to Kansas operators through workshops held throughout the state, demonstration projects done in cooperation with independent producers, and the publication of results.

The Mathematical Geology Section applies statistical and mathematical techniques to various aspects of geology, such as mapping, analysis of the records of wells drilled in search of oil and gas, the movement of fluids through underground rocks, and other areas. These techniques can be applied to questions about natural-resource availability or the analysis of water contamination..

The Survey's Geology Extension program is designed to develop materials, projects, and services that communicate information about the geology of Kansas, the State's earth resources, and the products of the Kansas Geological Survey to the people of the state. The Kansas Earth Resources Field Project is managed and administered through this program.

Kansas Geological Survey Staff Participating in the 1996 Field Conference:

Lee C. Gerhard, Director and State Geologist
Lawrence L. Brady, Deputy Director
Rex C. Buchanan, Associate Director, Publications and Public Affairs
Robert W. Buddemeier, Senior Scientist, Geohydrology Section
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Marios Sophocleous, Senior Scientist, Geohydrology Section
Donald O. Whittemore, Chief, Geohydrology Section

Kansas Water Office

The Kansas Water Office is the water planning, policy, and coordination agency for the state of Kansas. It prepares a state plan of water resources development, management, and conservation, reviews all water laws, and makes recommendations to the Governor and Legislature for new or amendatory legislation.

The Office administers the Kansas Water Plan Storage Act, The Kansas Weather Modification Act, and the Water Assurance Act. It also reviews the plans of any state or local agency for the management of the water and related land resources of the State.

The Kansas Water Authority is within and a part of the Kansas Water Office. It is responsible for advising the Governor, the Legislature, and the Director of the Kansas Water Office on water policy issues, for approving water storage sales, Federal contracts, administrative regulations, and legislation proposed by the Office.

Basin Advisory Committees provide the working link between the Kansas Water Authority, Kansas Water Office, and the public in formulating and implementing the Kansas Water Plan. The Basin Advisory Committees 1) identify water-related problems, issues, and concerns within the basin and help identify goals and objectives that can be used to direct subsequent planning efforts, 2) advise and assist the Office in the formulation of revisions to the Kansas Water Plan, 3) serve as a liaison between residents of the basin and the Office by encouraging an awareness of the importance of the basin's water resources, and 4) provide input on water plan implementation priorities and encourage local action necessary to implement the basin plan.

SCHEDULE & ITINERARY

Wednesday June 12, 1995

7:00 am	Breakfast
7:20 am	Conference Overview - Themes, Objectives, and Goals *Lee Gerhard*, Director, Kansas Geological Survey Remarks *Al LeDoux*, Director, Kansas Water Office
7:45 am	Bus to Lyons
8:30 am	**SITE 1** - Tour Underground Salt Mine and Evaporation Plant, Lyons, KS *Steve Kadel*, General Manager, Lyons Salt Company *Rich Hill*, Acting Manager, North American Salt Company
11:45 am	Bus to Quivira National Wildlife Refuge Natural Salt Contamination, South-central Kansas *Bob Buddemeier*, Senior Scientist, Kansas Geological Survey
12:30 pm	Lunch at Quivira National Wildlife Refuge, Environmental Education Center Stream-Aquifer Interaction in South-central Kansas *Marios Sophocleous*, Senior Scientist, Kansas Geological Survey
1:15 pm	**SITE 2** - Tour Quivira National Wildlife Refuge *Dave Hilley*, Manager, Quivira National Wildlife Refuge
2:15 pm	Bus to Stafford
2:45 pm	**SITE 3** - Big Bend Groundwater Management District, Stafford, KS *Sharon Falk*, Manager, Big Bend GMD #5 *Mike Dealy*, Manager, Equus Beds GMD #2
4:15 pm	Bus to KSU's Experiment Field
4:30 pm	**SITE 4** - Kansas State University's Sandyland Experiment Field, St. John, KS Dryland Conservation Technologies *Alan Schlegel,* Southwest Research Extension Center, Kansas State University Precision Agriculture Research *Gerard Kluitenberg*, Department of Agronomy, Kansas State University
5:30 pm	Bus to Great Bend
6:00 pm	Arrive Holiday Inn, Great Bend
6:30 pm	Cash Bar
7:00 pm	Dinner in the Heritage Room, Holiday Inn
7:30 pm	Evening Session *David Pope*, Director and Chief Engineer, Division of Water Resources *Al LeDoux*, Director, Kansas Water Office

Lyons Salt Mine and Evaporation Plant

Introduction

Rock salt was discovered near Lyons in Rice County in 1887 while boring a series of experimental wells in search of oil and natural gas. Salt was encountered at a depth of about 800 feet. Continued drilling revealed thick layers of salt interbedded with thin shale layers to a depth of nearly 1,100 feet. Commercial production of salt from a mine on the northeast edge of town began in 1891. Present-day operations are located southeast of Lyons.

Halite is the mineral name for salt. The composition of halite is NaCl, or sodium chloride. Rock salt is the term used for natural salt deposits composed of halite and other impurities, mainly thin beds of shale. The total thickness of the salt in Rice County consists of about 80% salt and 20% impurities.

In Kansas, rock salt is mined from the Hutchinson Salt Member of the Wellington Formation, which was deposited during the Permian Period about 275 million years ago in a shallow sea that covered Kansas. The salt layers are a result of evaporation of saline sea waters. The Hutchinson Salt Member covers about 27,000 square miles in the subsurface of central and south-central Kansas and northwestern Oklahoma (Fig. 1). The maximum thickness is over 500 feet in Oklahoma. The eastern edge of the Hutchinson Salt is actively being eroded, or dissolved, by contact with near-surface waters (Fig. 2). Because salt is so easily dissolved in water, outcrops at the surface are never seen, as is more likely for harder rocks. This dissolved salt sometimes winds up in rivers, streams, marshes, and lakes where it creates a natural contamination problem. Thus, the Hutchinson Salt has an important impact on the water resources of central Kansas.

Salt dissolution, either natural or human-induced, is also responsible for surface subsidence areas (sinkholes) in Kansas. Salt layers in the subsurface are dissolved by water, creating underground void spaces. When the ceiling above those voids can no longer support the weight above, the rock layers collapse, causing subsidence at the surface. Human-induced subsidence areas are rare, but when they occur, they are usually attributed to salt mining or oil and gas operations.

Salt is mined in Kansas using two methods - underground mining and solution mining. At the Lyons plant, the underground mine and the solution mining operation are owned and operated by separate companies.

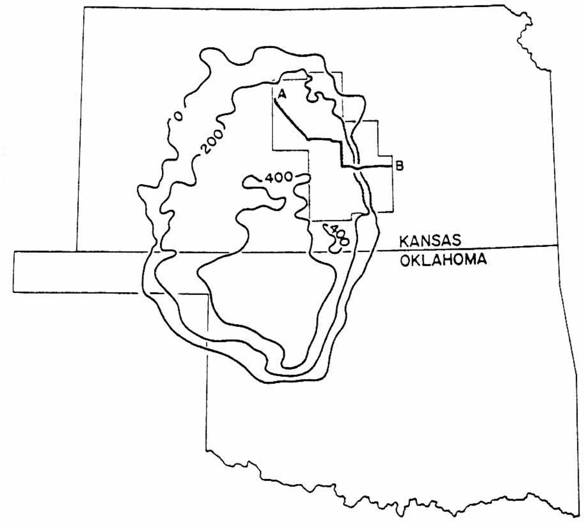

Figure 1. Extent and thickness in feet of the Hutchinson Salt Member. Cross Section A-B in shown in Figure 2 (modified from Walters, 1978).

Underground Salt Mining

Lyons Salt Company, a subsidiary of B.S.C. Holding, Inc., operates the underground mine that was started at its present site in 1916. Lyons Salt Company bought the mine in 1990. Rock salt is mined at a depth of about 1,000 feet. The mine uses the "room and pillar" method of mining, which begins with a shaft sunk through the overlying rock to the salt deposit. The salt is removed in checkerboard fashion leaving large square caverns alternating with pillars of salt that serve as support for the rock above. Blasting breaks the salt into manageable pieces, which are conveyed to crushers and removed to the surface through the shaft with large buckets. Rock salt mined at the Lyons mine is used for highway de-icing, or processed into table salt and agricultural products. In 1995, Lyons Salt produced 302,000 tons of salt that generated revenues of $3.7 million.

Solution Mining

The Lyons solution mining and evaporation plant was founded in 1908 and acquired by North America Salt Company in 1988. North American Salt is part of the Harris Chemical Group, a major industrial minerals producer with operations in the U.S., Canada, and Europe. Evaporation plants produce a variety of salts for which purity is essential, such as table salt, food-processing salt, salt for animal feeds, and water softening salt. To reach the salt deposits, a well is drilled through the overlying rock. Water pumped into the salt deposit dissolves the salt, and the brine solution is pumped back up to the plant (Fig. 3). The brine is then evaporated in a series of large vessels called vacuum pans. As the water evaporates, salt settles and is removed as a slurry to a classifier tank where sulfates are removed. In the final phases, salt is passed to a filter-dryer and then on to a processing area. The result is a high-purity product consisting of over 99.8% sodium chloride. The Lyons plant produces about 325,000 tons of salt products each year. It utilizes 15 brine wells at depths of 700 - 1,000 feet below the surface. Two evaporators and eight vacuum pans process the brine pumped from the wells.

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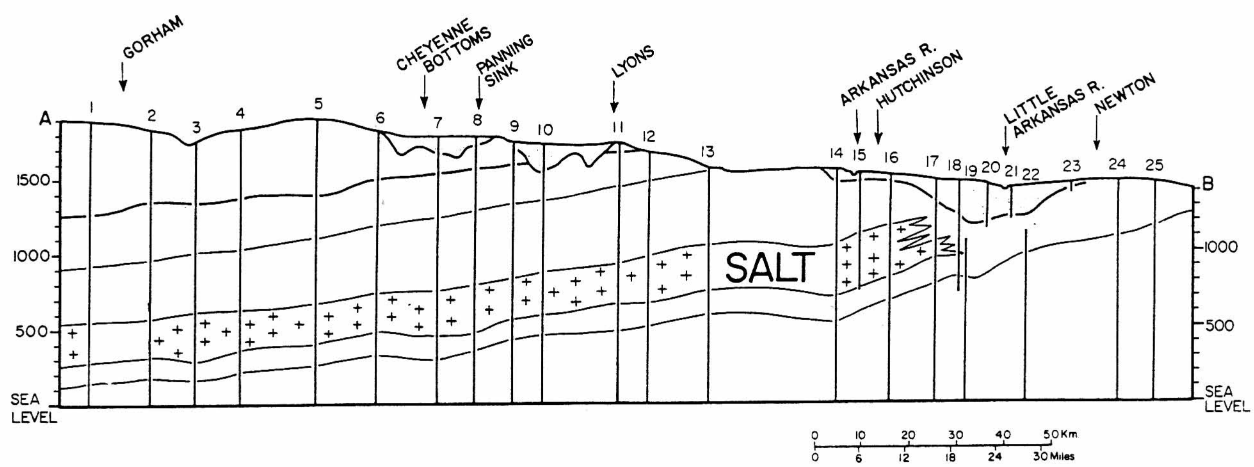

Figure 2. Cross section A-B showing the Hutchinson Salt Member in the subsurface in central Kansas. Distance from A to B is about 150 miles. Vertical exaggeration X 100 (modified from Walters, 1978).

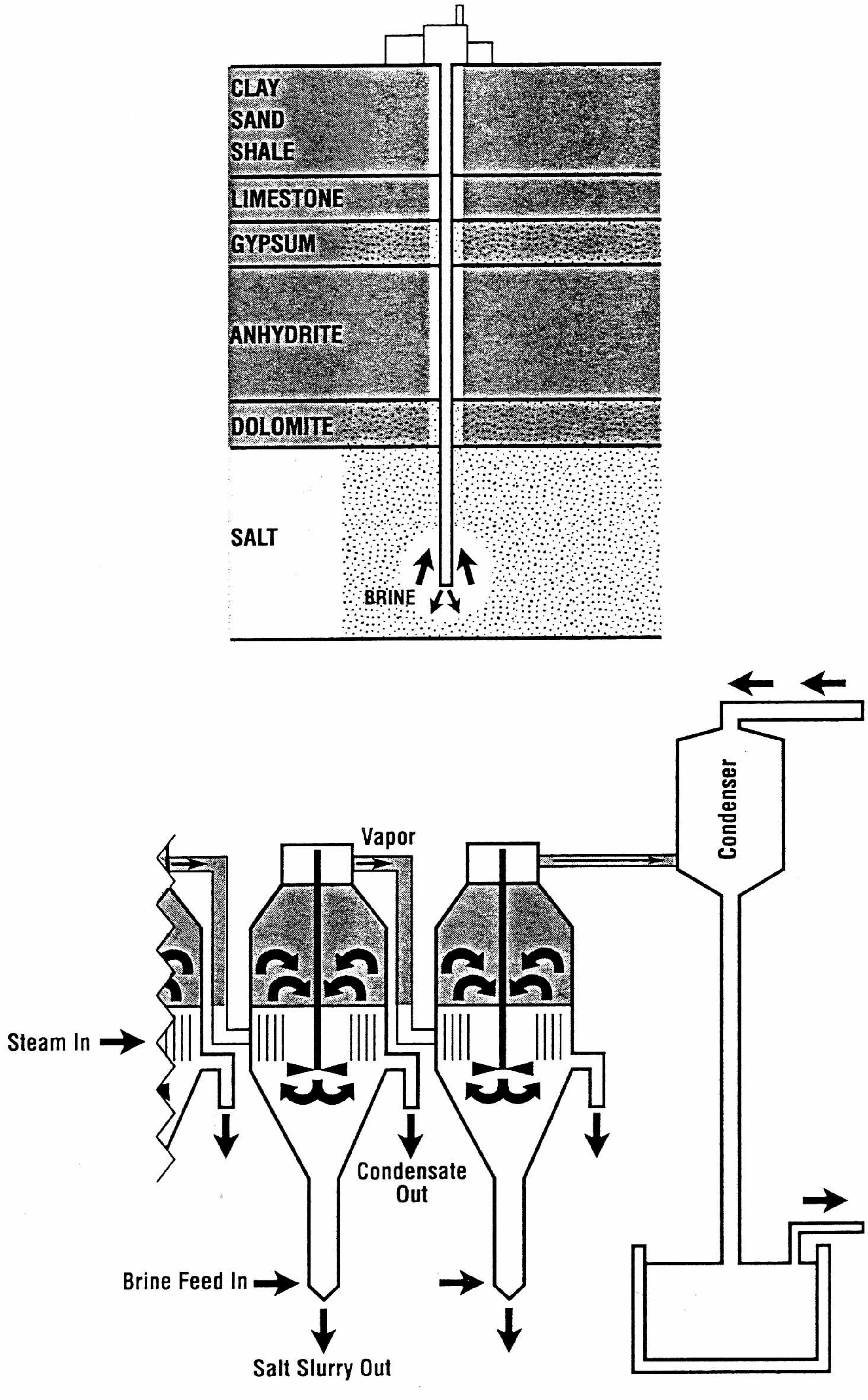

Figure 3. Schematic diagram of the solution mining and evaporation process.

Quivira National Wildlife Refuge

Quivira National Wildlife Refuge (Fig. 1) is one of a system of over 400 refuges administered by the U.S. Fish and Wildlife Service. Refuges provide valuable habitat for hundreds of species of birds, mammals, reptiles, amphibians, fish, and plants. National Wildlife Refuges are managed to protect endangered plants and animals, to provide for the needs of migratory birds, to preserve natural diversity, and to provide places for people to understand and enjoy wildlife. Quivira is primarily managed to provide food, water, and resting areas for migratory waterfowl. A system of canals and water control structures divert water from Rattlesnake Creek to 30 water areas ranging in size from 10 to 1,500 acres.

Public hunting is permitted on 8,000 of the Refuge's 21,820 acres. Public fishing is permitted on all Refuge waters. The hunting and fishing programs are managed in accordance with State and Federal regulations.

Located in south-central Kansas, Quivira National Wildlife Refuge lies in the transition zone between eastern and western prairies. The name "Quivira" comes from an Indian tribe living in the area when the Spanish explorer Coronado visited in 1541. In quest of gold, treasures and the fabled "Seven Cities of Cibola," Coronado found, instead, fertile grasslands, abundant wildlife, and small agricultural villages of Indians.

Located where the relatively lush vegetation of the east blends into the more arid grasslands of the west, the Refuge supports numerous and varied plant communities, which attract birds common to both eastern and western North America. Over 250 species of birds have been observed on the Refuge. Spring and fall are the best seasons to visit Quivira, because wildlife, especially waterfowl, is abundant and more easily viewed. Early or late in the day is the best time to visit the marsh when wildlife is most active and more frequently seen. Much of the Refuge is open to hiking, and visitors may drive through the Refuge on any roads not closed by signs or barriers. In addition, two photography blinds are available on a first-come, first-served basis.

Big and Little Salt marshes provide food, cover, and a resting place for thousands of waterfowl migrating between breeding and wintering areas. Indians and early settlers hunted waterfowl in these marshes, and shortly after the turn of the century, commercial hunting provided wagonloads of waterfowl to Kansas City restaurants and other eastern points. The Refuge was established in 1955 to protect valuable waterfowl habitat, and today, these marshlands remain a major stopover for thousands of migrating birds.

Why Is The Quivira Marsh Salty?

Mineralized surface waters and salt flats at Quivira Marsh are caused by natural saltwater in the underlying bedrock. Quivira Marsh and the surrounding area are a common discharge center (an area where ground water moves upwards toward the surface) where three major aquifers converge (Fig. 2). The aquifers are the Permian-age (270 million years ago) Cedar Hills Sandstone aquifer, the Cretaceous-age (100 million years ago) Dakota aquifer, and the Pleistocene-age (less then 1 million years ago) Great Bend Prairie aquifer. The surface is capped by a veneer of wind-blown dune sand.

Water is a universal solvent, dissolving and chemically reacting with the rock formations it encounters. The longer water remains in the aquifer and the greater the distance traveled, the more mineralized it becomes, especially if it encounters salt deposits, as is the case with the Permian bedrock. Permian red beds function as an aquitard, or permeability barrier, that will not allow the transmission of water between aquifers, and will not yield water to wells. The Cedar Hills Sandstone aquifer is recharged in southwest Kansas. Regional ground-water flow carries this water, which becomes increasingly saline, in an easterly direction until it is discharged at the surface in central Kansas (Fig. 2B).

In the vicinity of Quivira Marsh, Permian formations cropping out near the surface discharge saltwater into the overlying Great Bend Prairie aquifer. The Cedar Hills Sandstone and the overlying and underlying Permian red beds contain salt-cemented sandstone and salt-minerals (halite, the mineral name for sodium chloride or common table salt; and anhydrite, a form of gypsum). Little and Big Salt marshes are located above the buried Permian bedrock. A north-south-trending ridge of bedrock below the marshes blocks the easterly movement of ground water toward the Arkansas River and forces discharge of saltwater upwards into the streams and marshes.

Salt concentrations are further increased at the surface by evaporation. The average salinity of Little Salt Marsh is approximately 2,500 parts per million (ppm) chloride, whereas that of Big Salt Marsh ranges from 5,000 to 10,000 ppm (sea water averages 19,000 ppm chloride, and drinking water about 250 ppm).

Quivira Marsh is characterized by poor drainage, springs and seeps with high salt concentrations, and salt-tolerant vegetation. Evaporation of shallow lakes concentrates salts on the bare ground, creating the white salt flats characteristic of the salt marsh.

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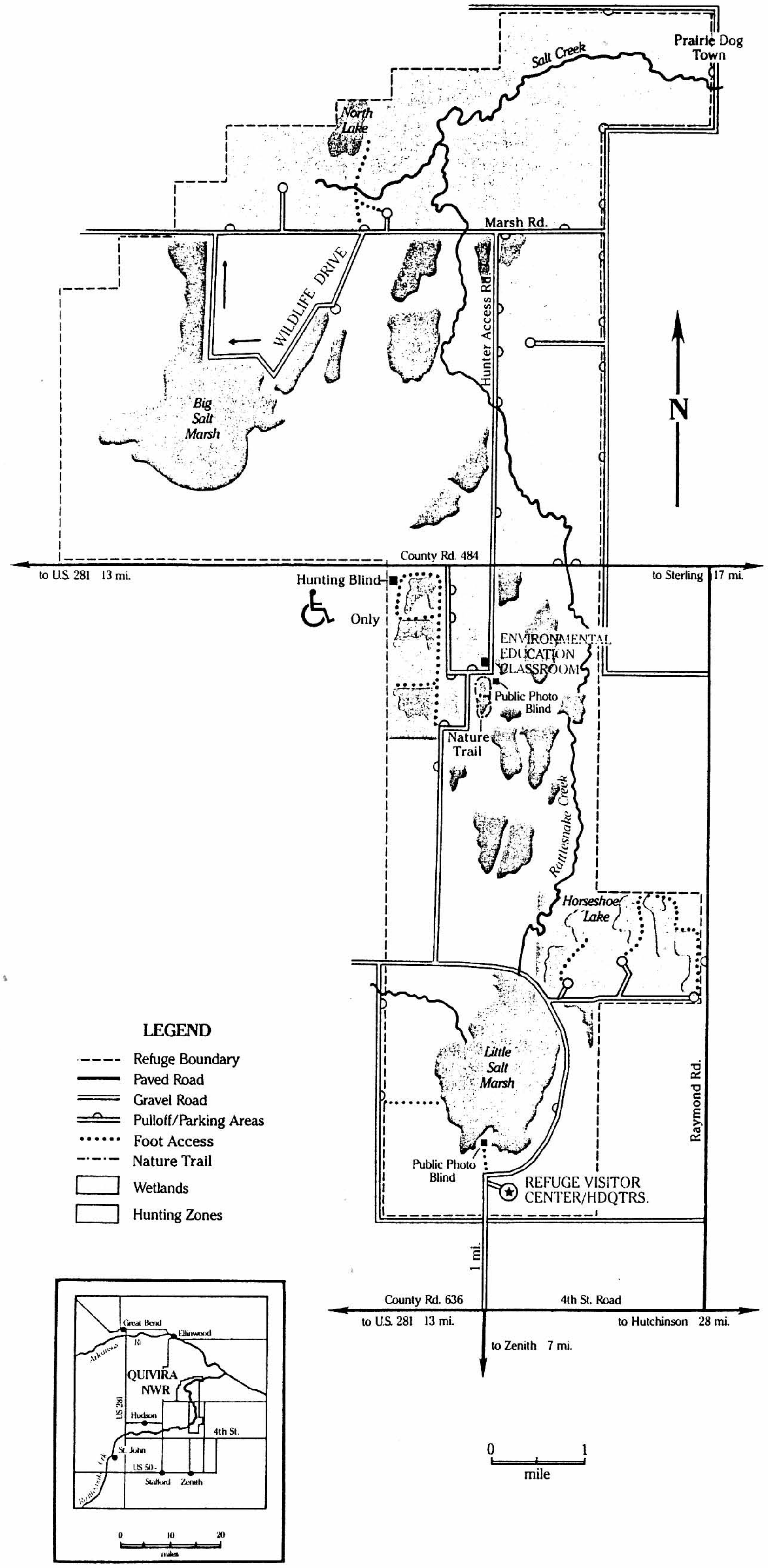

Figure 1. Quivira National Wildlife Refuge.(illustration from U.S. Fish and Wildlife Service).

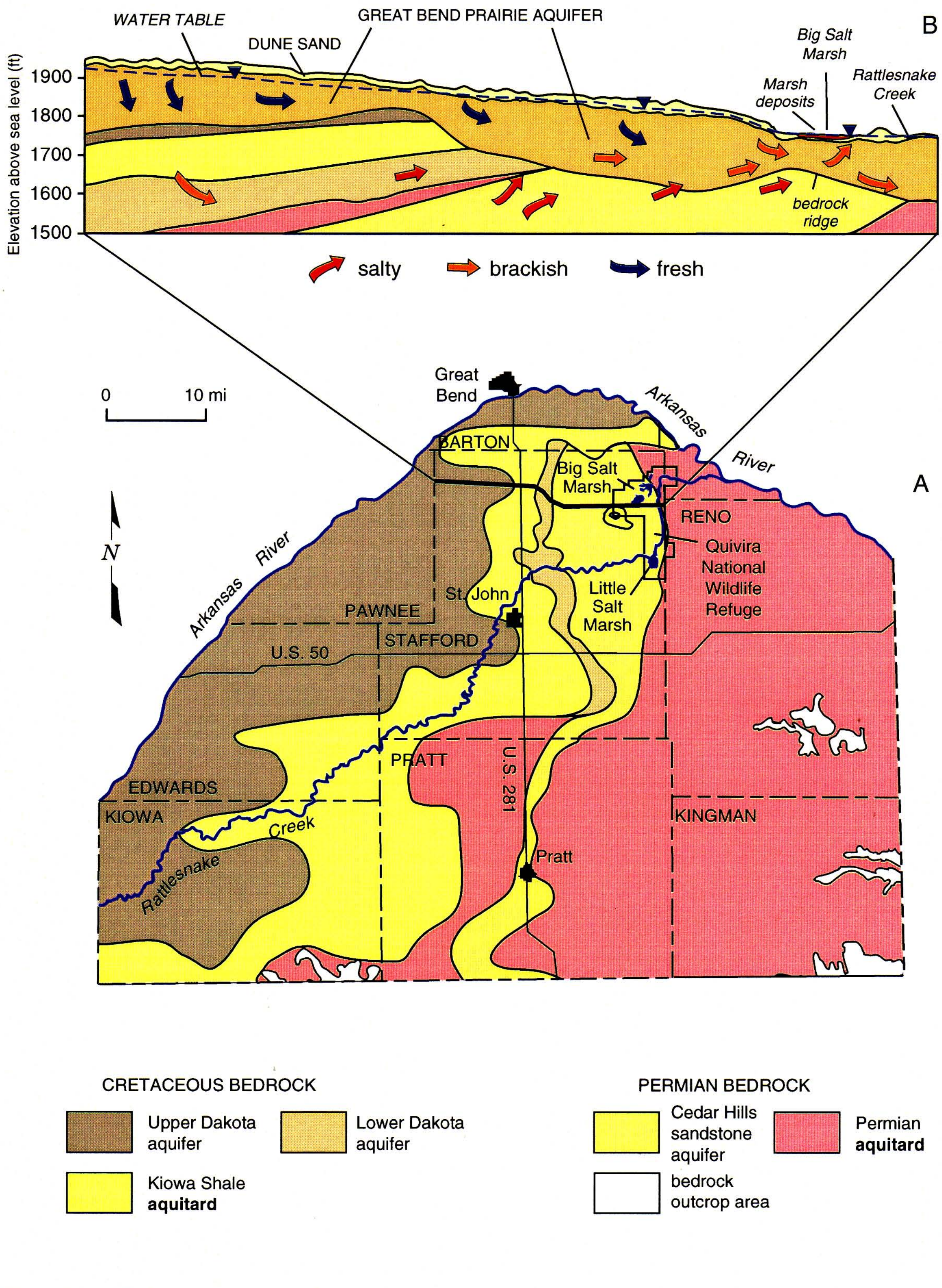

Figure 2. A. Geology underlying the Great Bend Prairie region (adapted from Fader and Stullken, 1978). B. West-east cross section through Quivira Marsh showing the relationship of the Great Bend Prairie aquifer to the underlying Cretaceous and Permian bedrock (adapted from Latta, 1950). (A and B are further modified by Allen Macfarlane, 1996, oral communication).

Stream-aquifer Interaction in South-central Kansas

Marios Sophocleous
Kansas Geological Survey

Ground water and surface water systems are closely interrelated. Ground water feeds springs and streams, and surface water recharges ground-water reservoirs. The decline of ground-water levels around pumping wells located near a surface-water body creates gradients that capture some of the surrounding ground-water flow that would have otherwise discharged to the surface water. At high pumping rates, water flows from the surface into the aquifer, a process known as induced infiltration. The sum of these two effects leads to streamflow depletion. Stream-aquifer interactions are also important in situations of ground-water contamination by polluted surface water, and of degradation of surface water by discharge of saline or other low-quality ground water. In fact, streams and their adjacent aquifers (called alluvial aquifers) are so closely linked, in terms of water supply and water quality, that neither can be properly understood or managed by itself, and therefore, the combined stream-aquifer system must be considered. The interdependence of surface water and ground water is also evident in the flow of canals, drainage ditches, recharge pits, ponds, lakes, reservoirs, and wetlands.

During the last few decades, many regions of western and central Kansas have experienced significant ground-water and streamflow declines. According to the Kansas Water Office (KWO), "extensive ground-water appropriations in the Big Bend Prairie (fig. 1) have contributed to extreme low flows in the Arkansas River and Rattlesnake Creek" (Water Research Needs Conference, Wichita, Kansas, Nov. 14, 1984). Also, according to the Kansas Department of Wildlife and Parks, "fish and wildlife resources in and along the Arkansas River, the Smoky Hill River, the Pawnee River, Rattlesnake Creek, and other streams in western and south-central Kansas have been significantly affected because of losses of baseflows" (Water Research Needs Conference, Wichita, Kansas, Nov. 14, 1984). (Baseflow is the natural ground-water discharge to a stream, i.e. streamflow derived mainly from ground-water seepage into the stream.)

In response to streamflow declines, the Kansas legislature passed the minimum instream flow law in 1982, which requires that minimum desirable streamflows be maintained in different streams in Kansas, including Rattlesnake Creek.

Implementation of this law requires a better understanding of the stream-aquifer system. According to the Division of Water Resources (DWR), Kansas Department of Agriculture (Water Research Needs Conference, Wichita, Kansas, Nov. 14, 1984), "a more thorough understanding of this stream-aquifer relationship would allow quantitative determination of the effect of ground-water withdrawals on streamflows and would be valuable in the administration of the minimum desirable streamflow program."

However, the trend in reduction of stream discharge observed since the mid-1970's appears to be continuing, despite the establishment of minimum desirable streamflow standards. As a result, Big Bend Groundwater Management District #5 is now considering following the lead of Equus Beds Groundwater Management District #2, which recently amended its safe yield regulations to include baseflow as ground-water withdrawals along with water permit appropriations -- within the standard two-mile radius circle around the proposed diversion -- when evaluating a ground water permit application. According to the Kansas Water Plan document (Kansas Water Plan, subsection: Minimum Desirable Streamflows, FY 1990, KWO, July 1988): "The safe yield policy of Groundwater Management District No. 5 has not protected low flows in the [Rattlesnake] Creek." Such amended safe yield policies require that baseflow be reliably estimated for each stream under consideration. Direct measurement of baseflow, however, is extremely difficult, and baseflow estimation has relied upon empirical or graphical techniques that have limited validity under Kansas conditions.

Associated with the baseflow quantification problem are many other related stream-aquifer problems particularly prevalent in western and central Kansas, such as:

- Stream-aquifer depletion due to ground-water pumping.
- Stream depletion due to diversion of water from the streams.
- Water-quality deterioration in both streams and aquifers from natural saline ground-water discharge from underlying consolidated aquifers.
- Aquifer deterioration by recharge or induced flow of poor quality of stream waters.
- Stream water quality deterioration from human-induced pollution.
- Impacts of riparian vegetation on quantity and quality of baseflows.

The two major central Kansas wetlands -- Cheyenne Bottoms Wildlife Area and Quivira National Wildlife Refuge, both of which are classified as "outstanding natural resource areas of unique significance" [KAR 28-16c(3)] -- are being threatened because of decreasing water supplies, and probably deteriorating water quality. Natural conditions, such as low streamflows and mineral intrusion (i.e. mineralized or salty water moving into a freshwater stream, lake, or aquifer), result in violations of water quality standards for dissolved oxygen, chloride, fluoride, and metals criteria for streams during the summer in several parts of Kansas, according to the Kansas Department of Health and Environment. In addition to natural conditions, oil and gas production activities, especially from the past, and agricultural non-point source pollution are suspected to have increased the mineral content of some streams in the area.

Quivira National Wildlife Refuge obtained a permit in 1957 to divert up to 22,000 acre-ft of water per year from Rattlesnake Creek. This water right, however, has just been certified by the Division of Water Resources for approximately 14,500 acre-ft per year. The availability of adequate amounts of water of suitable quality directly affects the future of Quivira and the economic development of the Rattlesnake Creek basin and hence the welfare of the people living in the region.

Following a number of stream-aquifer studies, the Kansas Geological Survey is now involved in providing technical assistance to the Division of Water Resources in its water management program for the Rattlesnake Creek Subbasin. According to DWR, the purpose of that program is to develop a comprehensive, long-term water management strategy to implement solutions to water problems within the framework of existing state water law on a proactive basis. It is intended to be holistic, addressing concerns related to surface water depletions, ground-water declines, and deterioration of the quality of water in the Rattlesnake Creek basin in south-central Kansas caused primarily by saltwater intrusion from underlying formations. A detailed analysis of the impacts of water rights and agricultural and other land use on the water resources of the area are of particular interest to DWR. KGS and Kansas State University, in cooperation with DWR, have initiated development of a comprehensive computer simulation of the Rattlesnake Creek watershed and associated aquifers. This model is to be used by DWR to evaluate alternative water management strategies in the Rattlesnake Creek basin.

In addition, the Kansas Geological Survey, in cooperation with the U.S. Geological Survey, is assisting the U.S. Fish and Wildlife Service to more efficiently manage water at Quivira National Wildlife Refuge. User-friendly PC-based water budget and stream routing models of the Refuge are used to develop water management strategies that maintain and increase desired wetland habitat combinations. Pond-aquifer interaction is also an issue because the marshes at the Refuge are within a ground-water discharge area and some units receive a large portion of their total water supply from ground-water sources.

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Groundwater Management Districts

Groundwater Management Districts (GMD) are locally managed political subdivisions in Kansas that have been formed to manage ground-water resources. GMDs are not affiliated with any state agency, but do cooperate with other water-related agencies and are bound by State ground-water laws and regulations. The Legislature authorized formation of GMDs by the Groundwater Management District Act of 1972. There are five GMDs in Kansas (Fig. 1): Big Bend Groundwater Management District No. 5, Equus Groundwater Management District No. 2, Southwest Kansas Groundwater Management District No. 3, Western Kansas Groundwater Management District No. 1, and Northwest Kansas Groundwater Management District No. 4.

Big Bend Groundwater Management District No. 5

The Big Bend Groundwater Management District No. 5 was formed in 1976 and is composed of portions of eight counties - Barton, Edwards, Kiowa, Pawnee, Pratt, Reno, Rice, and Stafford (Fig. 2). Within the District, 2.5 million acres are under management . Big Bend District was so named because of the proximity to the large bend of the Arkansas River in south-central Kansas. Portions of the District are located in both the High Plains and Arkansas River Lowlands physiographic provinces. Six major drainage basins are part of the District: the Arkansas River, Pawnee River, Walnut Creek, Rattlesnake Creek, North Fork Ninnescah River, and the South Fork Ninnescah River. Quivira National Wildlife Refuge and Cheyenne Bottoms are also located within the boundaries of the District.

The Big Bend District was organized by concerned citizens to conserve, promote, and manage the ground-water resources so that quality and quantity of that resource will be maintained for present and future needs. These citizens saw the need for ground-water management at the local level, allowing local landowners and water users the opportunity to determine their own destiny with respect to the use of ground water within the basic law of the State. The District is governed by a locally elected board of directors representing the eight counties.

The responsibilities of the District are to:

- Maintain a data bank of water level, ground-water withdrawal, and aquifer-recharge measurements
- Operate a water quality monitoring program
- Discourage wasteful water use
- Develop an educational program
- Develop well-spacing and safe yield programs
- Prevent water pollution
- Explore artificial recharge methods
- Promote conservation methods
- Conduct research to gain a better understanding of the ground-water system

Equus Beds Groundwater Management District No. 2

The Equus Beds Groundwater Management District No. 2 is located in south-central Kansas and occupies portions of McPherson, Harvey, Reno, and Sedgwick counties (Fig. 3). It covers about 900,000 acres. The Equus Beds GMD lies almost entirely within the Arkansas River Lowlands physiographic provinces, except for the extreme eastern edge, which is in the Flint Hill province.

The Equus Beds Groundwater Management District was formed in 1975 to manage ground-water supplies within its boundaries. The Equus Beds aquifer is the principal source of fresh and usable water within the District. The aquifer is managed on two fundamental management principles: 1) the Aquifer Safe Yield Principle, which limits ground-water withdrawal to annual ground-water recharge; and 2) the Ground Water Quality Principle, which seeks to maintain by protection and remediation the naturally occurring water quality of the aquifer. The purpose of the Equus Beds Groundwater Management District No. 2 and its Board of Directors is to properly manage ground-water resources of the District for the benefit of the resource and the public interest.

The Equus Beds Groundwater Management District's goal is to manage ground-water supplies within its boundaries by balancing ground-water withdrawals with annual recharge to the aquifer to prevent ground water mining and protect the natural water quality of the aquifer and remediate ground-water contamination.

The District relies on the following actions to achieve its goal:

- Manage the Equus Beds aquifer on a "safe yield" principle
- Educate and inform the public on ground-water issues

- Monitor both quality and quantity of water in the aquifer
- Investigate or study the physical and hydrologic characteristics of the aquifer
- Investigate alternative sources of water
- Encourage reclamation or recycling of waste water
- Investigate ways to improve recharge and prevent its deterioration
- Support legislative changes which enhance good ground-water management practices
- Cooperate with appropriate local, State, and Federal agencies and organizations

References

Big Bend Groundwater Management District No. 5, Revised Management Program, March 1988.

Equus Beds Groundwater Management District No. 2, Management Program, May 1, 1995.

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Northwest Kansas Groundwater Management District #4
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Colby, KS 67701
913/462-3915

Sharon Falk, Manager
Big Bend Groundwater Management District #5
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Stafford, KS 67578
316/234-5352

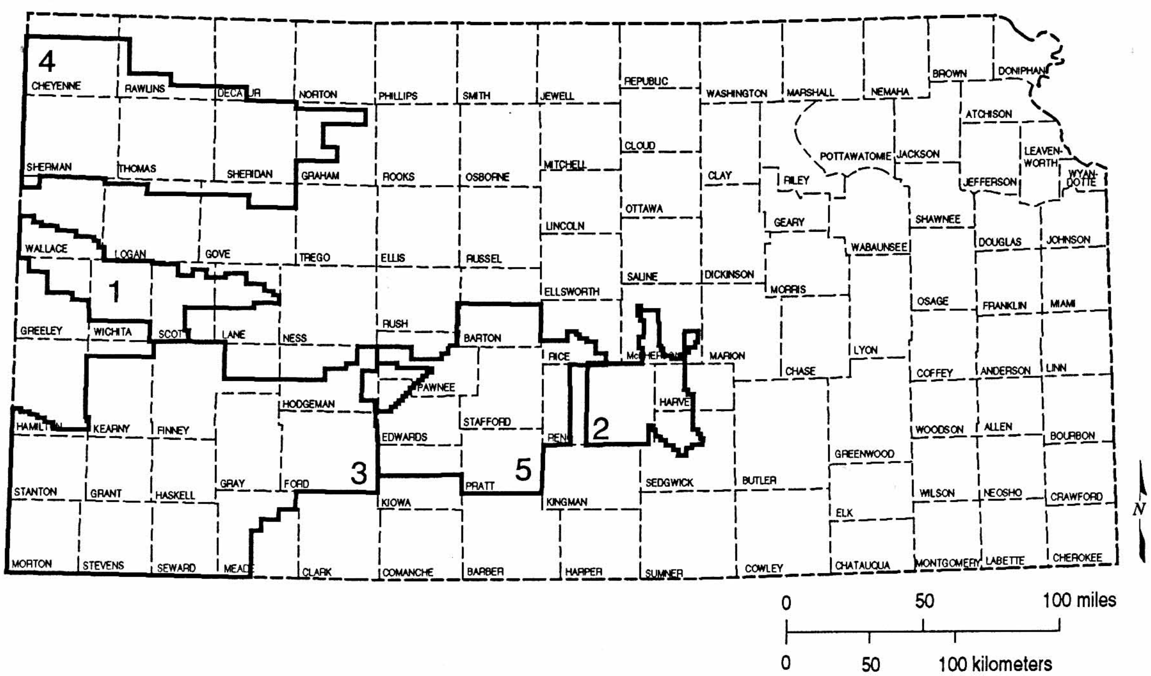

Figure 1. Groundwater management districts is Kansas.

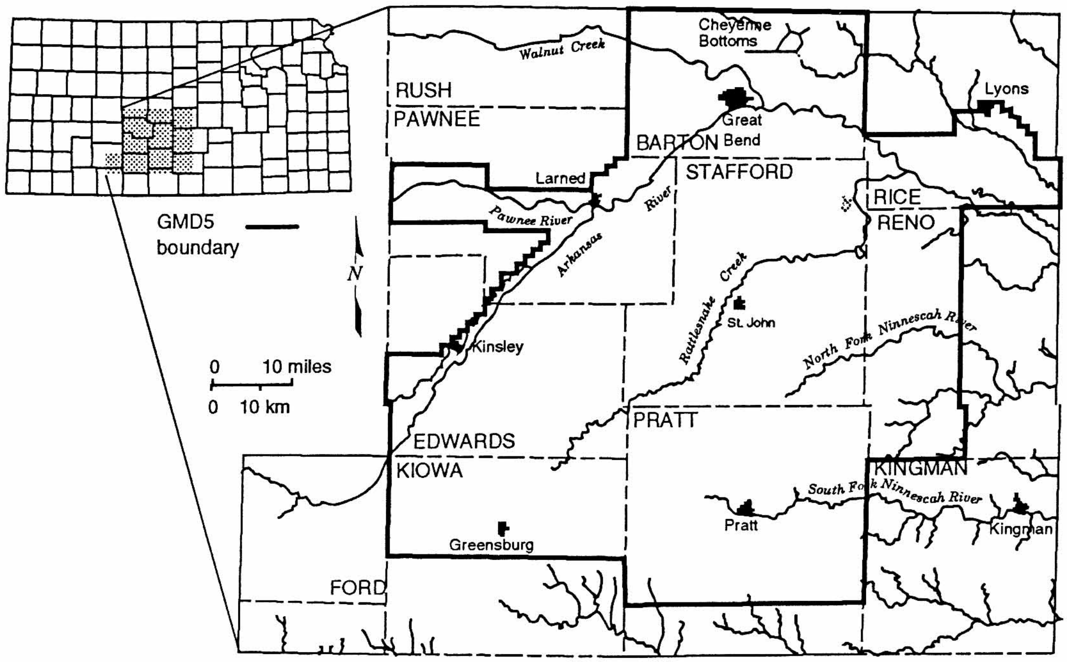

Figure 2. Big Bend Groundwater Management District #5.

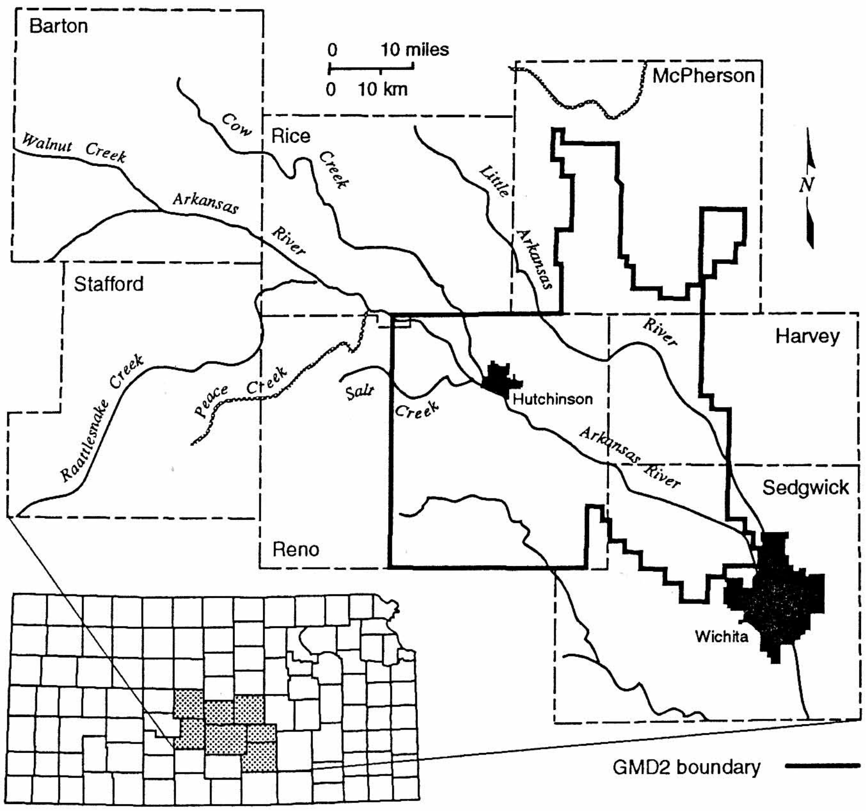

Figure 3. Equus Beds Groundwater Management District #2.

Dryland Conservation Technologies

John L. Havlin and Alan J. Schlegel
Kansas State University

The adoption of dryland conservation technologies can significantly increase productivity and profitability in dryland agriculture. These technologies are based on maintaining surface residue cover and conserving as much water as possible for use by marketable crops. Dryland conservation technologies involve 1) reducing soil water evaporation, 2) eliminating water use by weeds, 3) reducing water runoff and soil erosion, 4) increasing water infiltration, and 5) increasing snow catch. These critical components primarily involve maintaining crop residues on the soil surface throughout the year. Increasing the quantity of residues added to the soil and reducing organic matter oxidation by reducing tillage will increase soil organic matter, and subsequently soil productivity. Two major benefits are realized when producers adopt dryland conservation technologies. First, producers realize increased profitability, which improves the standard of living and increases the cash flow through the rural community. Second, soil erosion is dramatically reduced as a result of the high surface residue cover. Therefore, producers must reduce tillage intensity to increase surface residue cover and quantity of soil water stored. To increase profitability producers must reduce their dependence on fallow by increasing their cropping intensity with alternative spring and summer crops. The future and viability of agriculture in the Great Plains depends on sustaining the soil resource base and increasing producer profitability. Dryland conservation technologies provide the greatest opportunity to achieve agricultural sustainability and profitability in the Great Plains.

Precision Agriculture Research

John L. Havlin, Gerard J. Kluitenberg, and Mark Schrock
Kansas State University

Fertilizer nitrogen (N) significantly contributes to nitrate contamination of ground water, especially under irrigated cropping systems. The goals of this project are to evaluate the influence on variable fertilizer N management on grain yield, N fertilizer efficiency, and residual profile N concentration after harvest. Variable application of N is being compared to uniform N management under irrigated corn grown on sandy soils. Based on spatially variable yield goal and preplant soil profile NO_3 concentration, spatially distributed N recommendations were developed using the KSU N recommendation model. Although average grain yield production was similar for both N management systems, fertilizer N efficiency was slightly greater and total fertilizer N applied was slightly less with variably applied N compared to uniformly applied N. Yield goal influences the distribution of N recommendations more than preplant profile NO_3 concentration. Therefore, accurate estimates of the spatial distribution of yield goal is an important data layer for precise N management. In fact, drastically reducing the number of profile soil samples used to establish the spatial distribution of profile NO_3 had little effect on the spatial distribution of N recommendations. Complete results of these studies will be discussed at the field day in addition to the basics of GPS (Global Positioning System), GIS (Geographic Information System), and yield monitoring technologies for use in crop production.

State Water Planning in Kansas

History of Planning

In 1917, the Kansas Water Commission was created to develop a general plan for each watershed in the state. This planning function was later transferred to the Division of Water Resources, State Board of Agriculture, upon abolishment of the Commission in 1927. Limited progress was made in State water planning until the Kansas Water Resources Board was created in 1955. Removal of a constitutional restriction on State financial participation in water projects in 1958 and the 1958 Federal Water Supply Act created interest in long-range water supply development. In 1965, legislation was passed by the Legislature as the State Water Plan. Since then, numerous studies and reports on water-resources issues, including estimates of future water needs, were undertaken by the Board.

In 1978, a Governor's Task Force made several recommendations regarding legal, policy, and administrative water issues. A revised State water plan with increased emphasis on water conservation and management was passed by the Legislature in 1981. On July 1, 1981, the Kansas Water Resources Board was abolished and the Kansas Water Office and Kansas Water Authority were created. They assumed many of the duties and responsibilities of the former Board.

Since creation of the Kansas Water Office and the Kansas Water Authority, progress has been made in development and implementation of a comprehensive State water plan. In November 1984, the Kansas Water Authority approved the comprehensive Kansas Water Plan and submitted it to the Governor and Legislature for approval. On February 18, 1985, House Concurrent Resolution 5010 officially endorsed the planning process of the Kansas Water Office and asked the State's other water agencies to submit legislation to implement the Plan's proposals.

In 1985, basin advisory committees for each of the state's 12 major river basins were established to advise the Kansas Water Office and Water Authority on local water issues (Fig. 1). In May 1989, the State Water Plan Fund was established, thus providing a dedicated source of revenue for implementation of the Kansas Water Plan.

Organizational Structure

State water planning in Kansas is accomplished under the direction of the Kansas Water Authority and the Kansas Water Office. The Kansas Water Office is the water planning, policy, coordination and marketing agency for the state. It is composed of full-time professional staff serving four organizational units within the office: hydrology, planning, conservation and evaluation, and administrative services. Office staff work with other State, local, and Federal water-related agencies, local advisory committees, technical-advisory committees, special interest groups, and the general public on a variety of water-related issues through the State water planning process and through implementation of ongoing Kansas Water Plan programs (See Fig. 2).

The Kansas Water Authority is a 23-member body with responsibility for advising the Governor, Legislature, and the Director of the Kansas Water Office on water-policy issues, for approving water-storage sales, for additions and revisions to the Kansas Water Plan, Federal contracts, and regulations and legislation proposed by the Kansas Water Office. Membership on the Authority consists of 10 representatives of various water user groups appointed by the Governor including municipalities, groundwater management districts, conservation districts, watershed districts, commerce and industry, rural water districts, environmental interests, and the public. The Governor also appoints the chairperson. In addition, the Speaker of the House of Representatives and the President of the Senate each appoint a member to the Authority. The remaining 10 members are ex-officio (non-voting) and are made up of the heads of each of the State's water-related agencies (See Table 1).

The basin advisory committees each consist of 11 members representing various water users including irrigation, municipal, domestic, industrial, and wildlife and recreation interests. Memberships are approved by the Kansas Water Authority and are for a four-year term. These committees work with the Kansas Water Office and other water-related agencies to identify priority basin issues addressed through the water planning process and provide local input for implementation of State water plan programs and projects. Each water-related agency appoints an advisor to each of the basin advisory committees. In most cases, agency field personnel serve as basin advisors.

Technical advisory committees are also used to advise the Kansas Water Office on various issues, such as the development of new or revised State water policies, which warrant more formal input from a diverse group of interests. Membership can consist of various agencies, organizations, or individuals with expertise in a particular topic area.

The Kansas Water Plan

The Kansas Water Plan serves as a vehicle for coordinating the management, conservation, and development of the water resources of the state. The statutory framework for development of the plan is outlined in the State Water Resources Planning Act K.S.A. 82 -901 et seq.

The plan contains two primary components: State water policy sections and individual basin plan sections. In general, the policy sections address management, conservation, water quality, and fish, wildlife, and recreation issues. Individual subsections address specific policy issues and contain various policy recommendations regarding State programs and actions. Implementation of these recommendations may require new or amendatory legislation, development of a new state-level program, or significant changes to existing programs.

The basin plan sections address water-related issues in each of the State's twelve major river basins. Various subsections address water quantity, water quality, flooding, and wildlife and recreation issues. Guidelines in each subsection direct the utilization of State programs to address issues within the basin. Initial development and subsequent revisions of basin are accomplished by basin advisory committees and the staff of various water-related agencies.

A summary of the Kansas Water Plan is provided for general distribution and is updated periodically as new or revised subsections are approved by the Kansas Water Authority.

The Planning Process

The water planning process in Kansas is coordinated with numerous local, State, and Federal agencies, special interest groups, and the general public. Planning is accomplished through an annual planning cycle as shown in Figure 2.

Proposed issues to be addressed by the planning process are identified by the Kansas Water Office with input from basin advisory committees, other water-related agencies, special interest groups, and the general public. A draft is prepared outlining goals, objectives, and alternative strategies for the issues that have been identified. The Kansas Water Authority reviews the preliminary draft and approves its release for public review. Informal public meetings are held throughout the state, usually in March, to discuss the various issues and options.

Following public meetings, a working draft is developed incorporating specific recommendations based on input received on the preliminary draft. If approved for release by the Kansas Water Authority, the working draft is presented at public hearings where individuals and organizations are given an opportunity to provide formal comment on the proposed recommendations. A final draft document is prepared following the hearings and presented to the Kansas Water Authority for review and approval in July.

The Kansas Water Authority can defer action on any issue at any point in the process if it decides additional study is warranted.

Plan Implementation

Implementation of the Kansas Water Plan is accomplished by the passage of legislation or through funding of specific programs or projects. Creation of the State Water Plan Fund in 1989 provided a dedicated source of revenue. This fund provides about $16 million annually and is composed of State general revenues, economic development initiative funds (lottery), various water use fees on municipal, industrial and stock water uses, and fees on pesticide and fertilizer use. Pollution fines, penalties, and sand royalties also contribute to the fund.

In July of each year, and prior to submission of State water-related agencies' budgets, the Kansas Water Authority approves an Annual Implementation Plan, prepared by the Kansas Water Office with input from the basin advisory committees and water-related agencies. This document provides guidelines to the agencies for preparation of budgets to implement the Kansas Water Plan (See Fig. 3).

Following submission of agency budgets in September, the Kansas Water Authority reviews the agencies' requests and prepares recommendations to the Governor and Legislature on appropriations from the State Water Plan Fund. The Governor and Legislature pay considerable attention to the Kansas Water Authority's advice in the appropriations process, and final budgets have generally been consistent with the Kansas Water Authority recommendations.

Agencies report annual expenditures from the State Water Plan Fund to the Kansas Water Authority, which compiles this information and provides an annual summary of fund expenditures.

Table 1. The Kansas Water Authority (May 1996).

Kansas Water Authority Members

	Occupation	Representing	Term Expires
Kent Lamb, Chairman RR 1, Box 69 Macksville, Kansas 67557 316/348-2315	Farmer/Irrigator	Governor	Pleasure
Tom Bogner 10055 Eagle Road Dodge City, Kansas 67801 316/225-4085	President, SW KS GMD #3	GMDs #1, #3, and #4	May 1, 1999
Alan Crane RR 2 Larned, Kansas 67550 316/285-2574	Irrigator	GMDs #2 & #5	May 1, 1998
Douglas O. Cruce 6300 Stateline Rd Shawnee Mission, KS 66208 913/362-9620	City Admin Mission Hills	Ks League of Municipalities	May 1, 1997
Joe Glassman 615 E. 13th Hays, Kansas 67601 913/625-2115	Pres./CEO Glassman Corp	Public	Aug. 31, 1996
William R. Hamm 5122 N.E. 72nd Walton, Kansas 67151 316/284-0707	Insurance/Investments	State Assn. of Kansas Watersheds	May 1, 1998
Ray Haner 3801 S. Wichita, Kansas 67210 316/526-2321	Director of Safety Medical & Environ Affairs, Boeing	Kansas Assn. of Commerce & Industry	May 1, 1999
Byron Johnson P.O. Box 2921 Mission, Kansas 66201 913/722-3000	General Mgr Johnson Co. Water District No. 1	President of the Senate	July 1, 1997
Sheila Leiker-Page RR 1, Box Victoria, Kansas 67671 913/735-9242	Dairy Herd Improvement Assn	Kansas Assn. of Conservation Districts	May 1, 1996
Kenneth Maechtlen 100 N. Main, Suite 600 Wichita, Kansas 67201 316/262-1414	Agriculture and Real Estate	Public	May 1, 1997

Dennis Schwartz 3260 S.E. Tecumseh Rd Tecumseh, Kansas 66542 913/379-5553	Manager Shawnee RWD #8	Kansas Rural Water Association	May 1, 1996
John Spurling RR 5, Box 139 Fort Scott, Kansas 66701 316/362-4232	Newspaper/Farmer	Speaker of the House	July 1, 1997
Judy Willingham, R.S 2030 Tecumseh Manhattan, Kansas 66502 913/776-4779	Environmental Health Sanitarian, Riley Co Health Dept.	Environmental Interests	Oct. 26, 1996

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Secretary, Kansas Department of Agriculture
901 S.W. Kansas Ave.
Topeka, Kansas 66612
913/296-3558

Dr. Lee Gerhard
Director, Kansas Geological Survey
1930 Constant Ave, University of Kansas
Lawrence, Kansas 66045
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Director, Division of Environment
Kansas Department of Health and Environment
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Manhattan, Kansas 66506
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Tim McKee
Chairman, Kansas Corporation Commission
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913/271-3100

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Topeka, Kansas 66612
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Tracy Streeter
Executive Director, State Conservation Commission
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Topeka, Kansas 66612
913/296-3600

Steve Williams
Secretary, Kansas Department of Wildlife and Parks
900 S.W. Jackson, Suite 502
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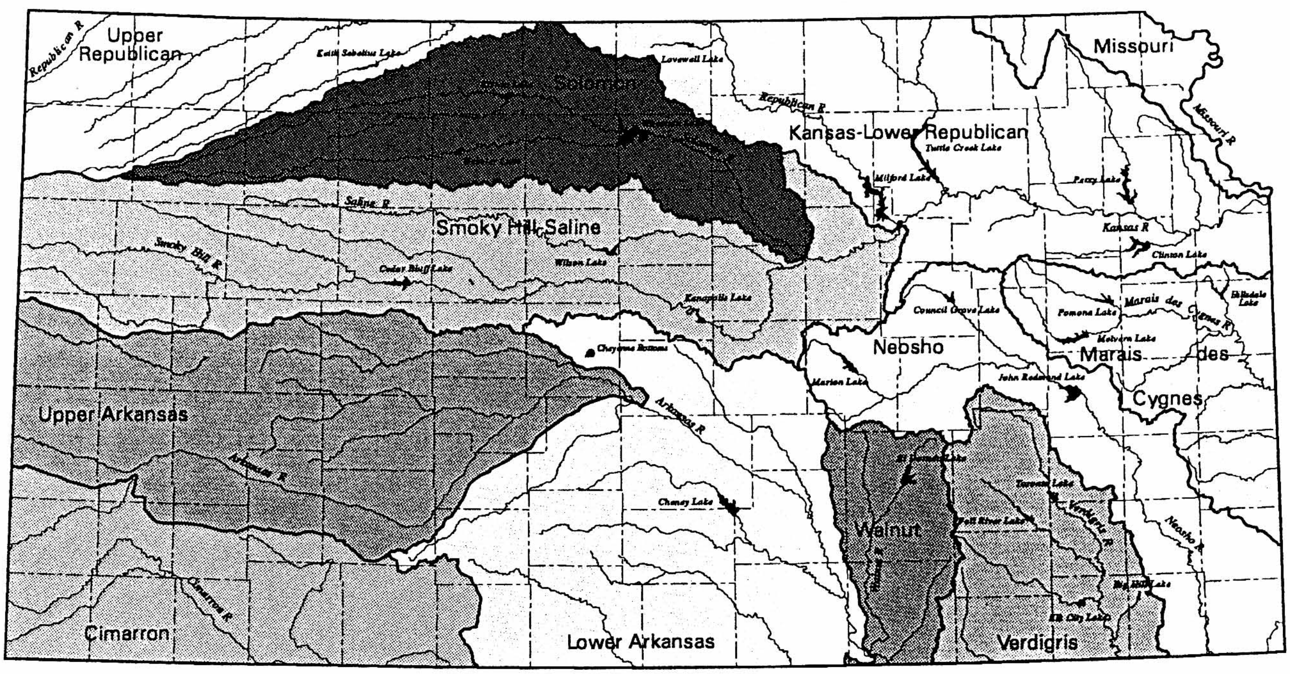
913/296-2281

Kansas River Basins and Federal Lakes



Kansas Water Office

May 1996

Figure 1. Kansas River Basins and Federal Lakes.

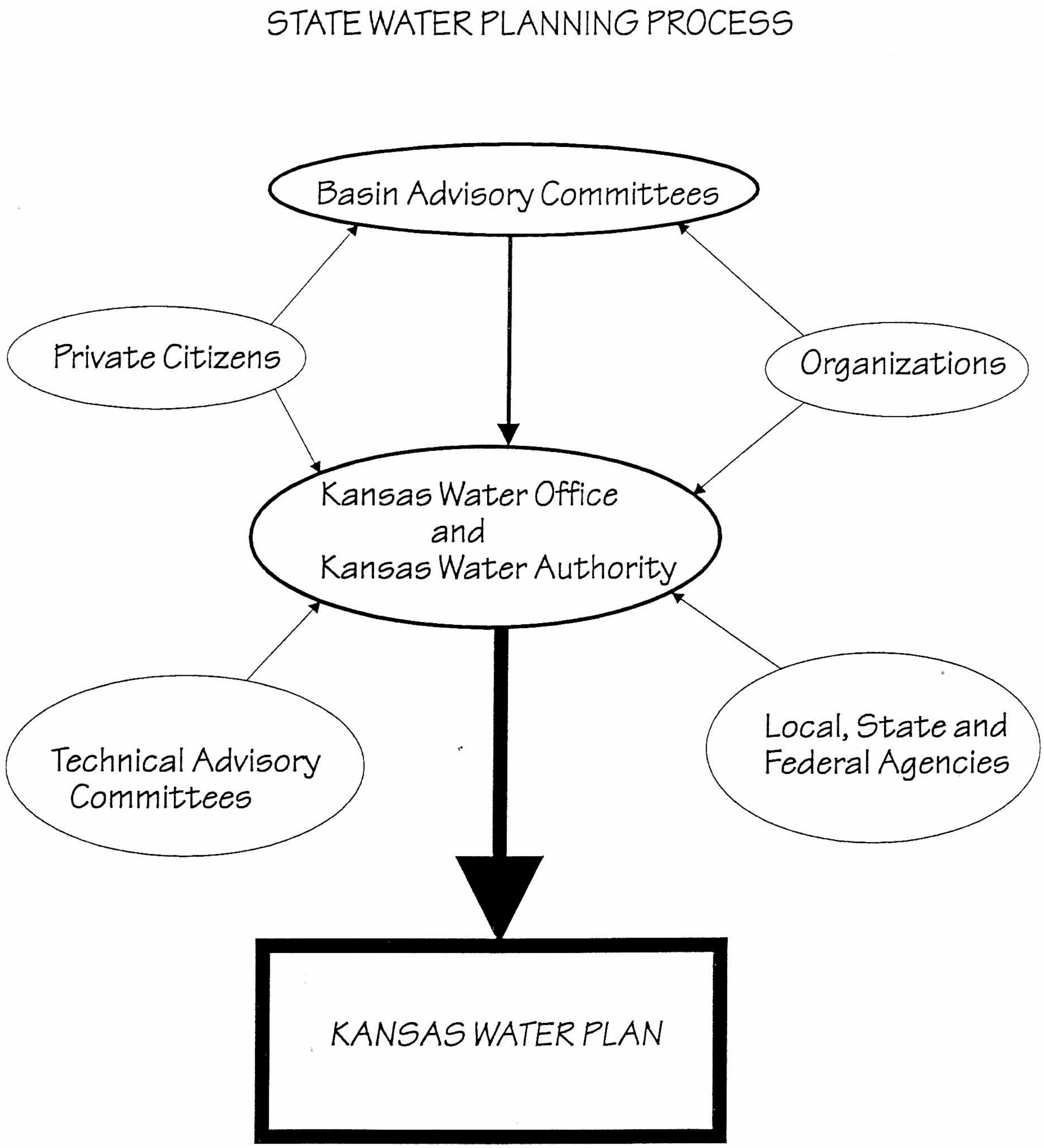


Figure 2. State Water Planning Process.

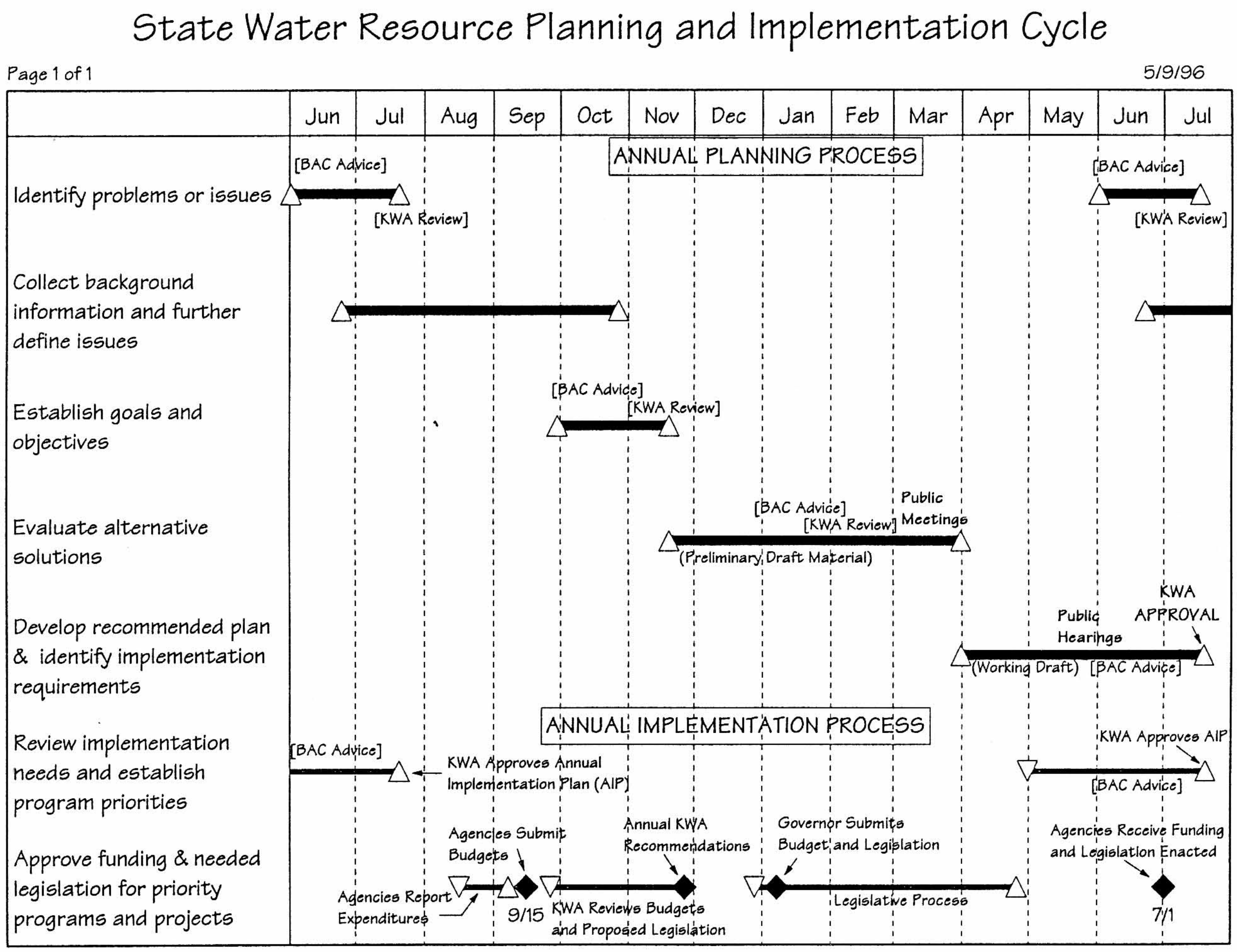


Figure 3. State Water Resource Planning and Implementation Cycle.

The State of Kansas

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Kansas Geological Survey

Public Information Circular 2

June 1995

Proper management of ground water reduces, and frequently avoids, intrusion of saltwater into freshwater supplies

Salt Contamination of Ground Water in South-central Kansas

Robert W. Buddemeier, Geohydrology Section, Kansas Geological Survey
Robert S. Sawin, Geology Extension, Kansas Geological Survey
Donald O. Whittemore, Geohydrology Section, Kansas Geological Survey
David P. Young, Geohydrology Section, Kansas Geological Survey

Introduction

The natural contamination of fresh ground water by saltwater is an important water-quality issue in many areas of Kansas. This saltwater comes from naturally occurring salt minerals in the subsurface. Proper management of ground water reduces, and frequently avoids, intrusion of saltwater into freshwater supplies. This circular provides water users and public officials with a basic explanation of how saltwater enters water supplies, and outlines methods that might diminish or prevent natural salt contamination of freshwater aquifers. South-central Kansas, the focus of this publication, contains unconsolidated (uncemented) sand and gravel aquifers of the Great Bend Prairie, the Equus Beds, and the Arkansas River valley. Many of the same explanations and methods apply in other parts of Kansas where natural salt contamination is a problem.

Areas of south-central Kansas where salt contamination of freshwater aquifers might occur are illustrated in fig. 1. South-central Kansas is shown in detail because of the high occurrence of salt-contamination problems in this region. "Natural" sources of saltwater contamination of freshwater aquifers are the focus of this circular. Locations of "unnatural" salt contamination also have been included in fig. 1.

Terms printed in ***italicized boldface type*** are defined in the glossary at the end of the circular.

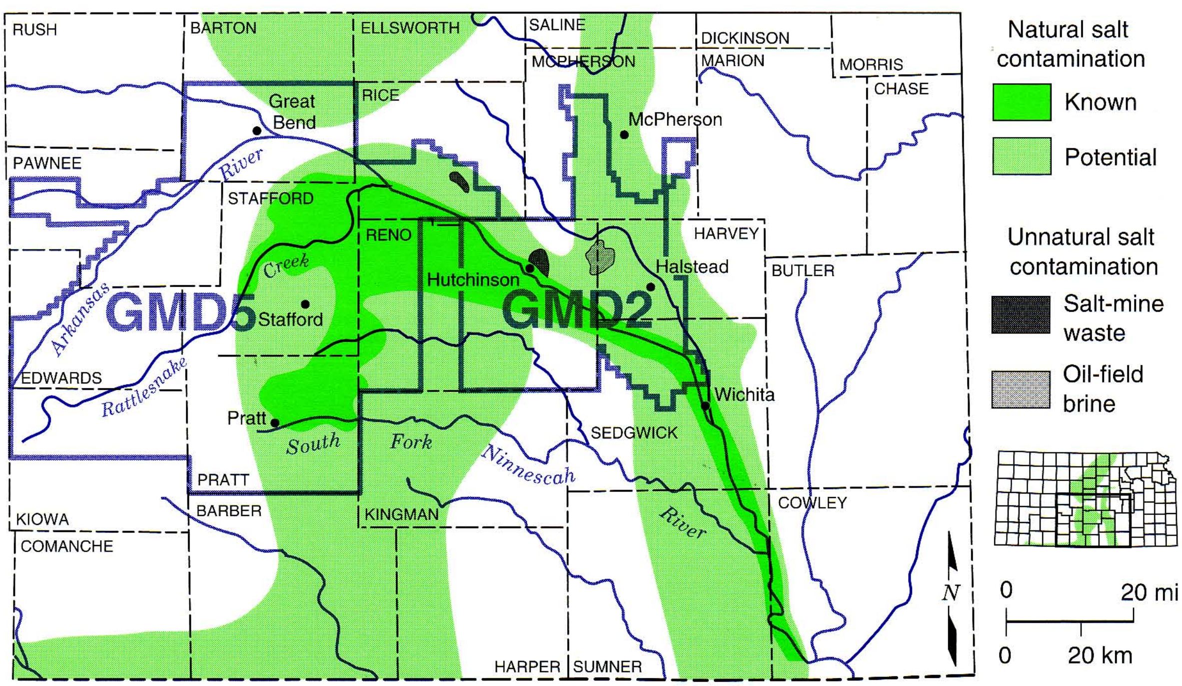

FIGURE 1—Areas with known or potential saltwater contamination in south-central Kansas. Areas identified as "known" natural salt contamination have saltwater within the freshwater aquifer. In the areas labeled "potential" natural salt contamination, subsurface bedrock formations containing salt or saltwater are in contact with the overlying freshwater aquifers. Groundwater Management District boundaries (GMD) 2 and 5 are shown in blue.

Salt

Natural sources of salt contamination of freshwater aquifers include salt- and salt-bearing bedrock formations

When talking about "salt," most people think of table salt or rock salt—sodium chloride—but the term is often used to mean almost any dissolved minerals or inorganic constituents found in water. The salt content of water, also referred to as ***salinity*** or ***total dissolved solids*** (TDS), is an important water-quality factor. Excessive salt content can make water unpleasant, harmful to plants and animals, or uneconomic to use. In addition, high-salinity water contributes to the deterioration of domestic plumbing and water heaters, and municipal and industrial water-works equipment. Table 1 illustrates how salinity limits the use of water for domestic and agricultural uses.

TABLE 1 *(right)—Water-quality threshold indicators for domestic and agricultural uses. Chloride concentration (Cl) is the primary indicator of salinity; corresponding TDS values are approximations for sodium chloride type ground water.*

TDS (mg/L) (ppm)	**Cl** (mg/L) (ppm)		**Water Use Limits**
		>3000	Unsuitable for most domestic/ agricultural purposes
5700	3000	>2200	Poor water for livestock
3900	2000		
		>1500	Poor water for poultry
2100	1000		
		>500	Generally unsuitable for irrigation
1200	500		
		>350	May adversely affect many crops
		140–350	Moderately tolerant plants usually show slight to substantial injury
700	250	**250**	**DRINKING WATER STANDARD**
		70–140	Sensitive plants usually show slight to moderate injury
		<70	Generally safe for most purposes

Sources of Saltwater Contamination

Possible sources of excess salinity in ground water include 1) recharge by irrigation water, 2) contamination of surface water or soil by waste water, road salt, and other sources, 3) contamination by oil-field brine and salt-mine waste, and 4) naturally occurring sources of salt.

Recharge by irrigation water and contaminated surface-water typically cause modest salinity increases in ground water, while contamination by oil-field brines and salt mining can be highly concentrated. Salt contamination associated with oil or mining activities is typically localized.

Natural sources of salt contamination of freshwater aquifers, the emphasis of this publication, include salt- and saltwater-bearing bedrock formations.

Ground-water Behavior and Saltwater Contamination

. . . under natural conditions, ground water flows slowly—usually a few inches or feet per day—through small openings, or pores, in the aquifer

Ground water in Kansas does not flow in rivers or streams as water does on the surface. Instead, under natural conditions, ground water flows slowly—usually a few inches or feet per day—through small openings, or pores, in the aquifer. The mostly horizontal flow is modified by vertical movement—downward in areas of ***recharge*** created by precipitation, and upward with ***discharge*** to creeks, rivers, wetlands, or wells (fig 2). Where recharge is high and freshwater moves downward, aquifers may be flushed of their salt content. By contrast, surface discharge can create circulation patterns that cause saltwater to

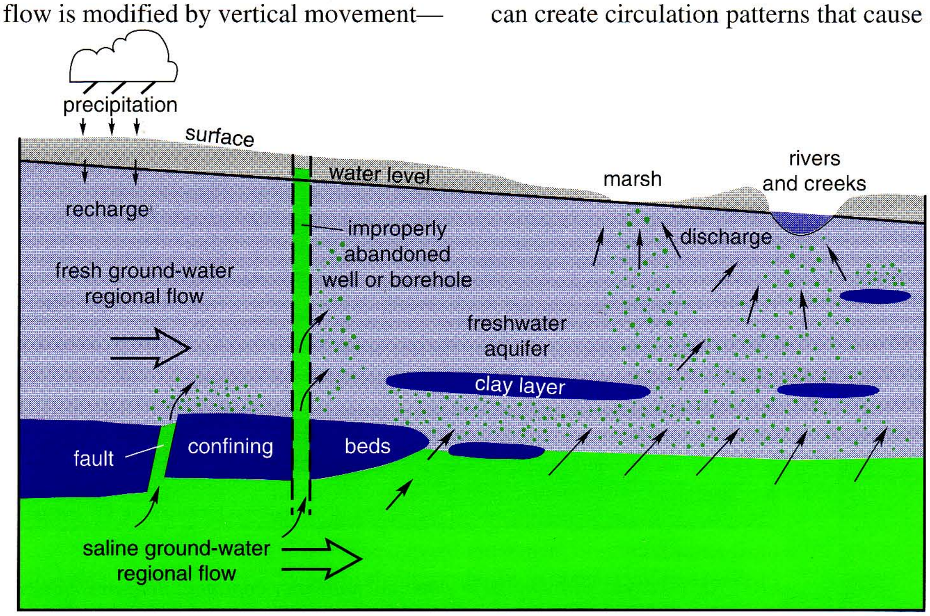

FIGURE 2—Schematic illustration of factors influencing movement of saltwater from a bedrock aquifer to the overlying freshwater aquifer and surface-water discharge areas.

move upward. This is why many of the salt-contamination areas shown in fig. 1 are associated with streams, rivers, and marshes.

Saltwater is found in deep bedrock formations almost everywhere, while freshwater is usually found only near the earth's surface. In most places freshwater aquifers are separated from saltwater-containing aquifers by barriers called ***confining beds***. Confining beds are clay or bedrock layers that slow or prevent the vertical movement of water between aquifers. Where the confining bed is absent or penetrated by natural features such as faults or fractures, or by human-made features such as improperly abandoned wells, saltwater may leak upward and contaminate the freshwater aquifer.

Within an unconsolidated aquifer, thick and extensive clay layers can function as confining beds. Where saltwater has moved above a clay layer, the clay can serve as a ***perching horizon***, maintaining the saltwater higher than would otherwise be expected (fig. 2). Unlike large regional layers of confining bedrock, these clay layers are variable and unpredictable in their size and distribution.

Because saltwater is denser than freshwater, it remains near the bottom of aquifers and flows ***downgradient*** unless it is drawn upward by natural discharge or pumping. In some areas, the aquifer may contain substantial amounts of saltwater near its base, but the freshwater in the uppermost part of the aquifer may not be affected.

In south-central Kansas, bedrock formations containing saltwater and salt layers are in contact with the overlying freshwater aquifer. In these areas, confining beds can be thin, discontinuous, or absent (fig. 2), and freshwater aquifers are potentially vulnerable to natural salt contamination.

Once an area is contaminated, remediation by human modification is difficult, and natural processes are slow

Predicting Saltwater Contamination

Many factors affect the nature, development, and predictability of natural salt contamination. Understanding the hydrology and geology of aquifers is important. Uncertainties in water use and management are caused by variations in the distribution of natural features (clay layers, faults, fractures, salt- and saltwater-bearing formations, ground-water flow patterns) and human-induced problems (improperly abandoned wells, bore holes).

Groundwater Management Districts 2 and 5 have established ground-water-quality monitoring networks and data bases to provide basic information to ground-water users. Additional information is available from other local, state, and federal agencies.

Pumping Wells in Areas Vulnerable to Saltwater Contamination

Pumping a well too hard can cause ***upconing*** of saltwater into the freshwater aquifer. Figure 3A illustrates a situation in which saltwater at the base of the freshwater aquifer does not rise much above the level of a partially confining clay layer. High-capacity wells in fig. 3B, however, create ground-water flow that pulls saltwater up through openings in the confining bed. Eventually, saltwater moves along the top of the clay layer and enters the well.

High-capacity irrigation or municipal-supply wells have zones of influence that may extend more than a mile from the well. These wells can dramatically alter water-table elevations and ground-water-flow directions. Because ground water moves relatively slowly, it may take several years for an underground source of salt contamination to be diverted to the well or nearby wells. Once an area is contaminated, remediation by human modification is difficult, and natural processes are slow.

Severe drought can lead to salt-contamination problems not observed during normal or excess precipitation. During periods of little or no recharge, ground water continues to discharge naturally from freshwater aquifers, decreasing the thickness of the freshwater zone overlying the saltwater. Regional pumping is likely to be greater during droughts and can further decrease the thickness of the freshwater aquifer. Thus, upconing of saltwater can be more severe during extended droughts.

Severe drought can lead to salt-contamination problems not observed during normal or excess precipitation

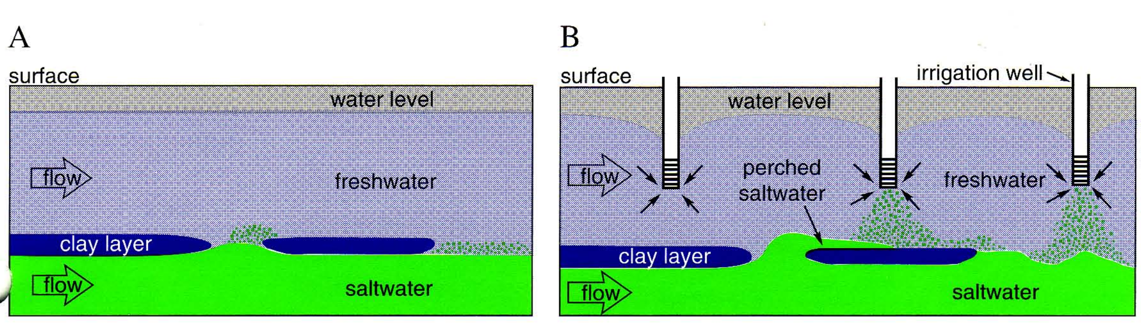

FIGURE 3—A) The undisturbed aquifer contains saltwater at its base, but saltwater does not rise much above the level of the discontinuous clay layer. B) During pumping, saltwater moves toward the discharge points, and upconing beneath the pumping wells occurs.

Precautions and Procedures

How can ground water be used with reasonable safety in potentially vulnerable areas, especially in view of the uncertainties involved in predicting salt contamination? There is no easy answer, but users can take steps to minimize or avoid saltwater problems. Domestic or stock wells are unlikely to have a major impact on water quality, but it is a different story for irrigators and other high-volume users. As has been discussed, high-volume wells can create their own problems. A number of common-sense precautions can be followed:

1) **Assess Well Location and Surrounding Area**—Check with locally knowledgeable people or agencies for saltwater problems in the vicinity of the proposed well. If problems are present, determine whether the source of salt contamination was identified. Investigate a larger area (a few miles) surrounding the proposed well, especially in the ***upgradient*** direction. Learn and comply with any local or state requirements or recommendations.
2) **Install the Well Carefully**—Wells that penetrate a confining bed, encounter saltwater, or are not properly plugged can be major contributors to unnecessary salt contamination. Drilling operations should log wells carefully, monitor water quality, and complete or plug holes according to state requirements for proper well construction and plugging procedures.
3) **Design for Minimum Water-quality Impact**—Screen wells as shallow as practical and pump slowly to minimize upconing. In areas of known salt contamination of the deeper aquifer, safe pumping may require multiple smaller wells rather than a single large well (see fig. 4). If only one well is used, pumping at lower rates for longer periods of time could be advantageous.
4) **Irrigate Conservatively**—Using less water not only preserves the quantity of the resource, it also protects its quality and can prolong the useful life of the well.
5) **Test Water Quality and Keep Records**—Test for salinity at the beginning and end of each season, and more frequently if a saltwater problem is suspected. If water quality deteriorates, early detection allows time to modify operating or crop patterns and minimize loss. If saltwater problems are related to drought, climatic conditions should be a factor in water-use planning.

For information and assistance with saltwater-contamination problems, contact the local Groundwater Management District (GMD2 316/835–2224; GMD5 316/234–5352), the Division of Water Resources (316/234–5311), the Kansas Department of Health and Environment (913/296–1500), the Kansas Ground Water Association (316/548–2669), or the Kansas Geological Survey (913/864–3965). The problems, and the appropriate solutions, depend on the source of the salt contamination. The best defense, however, is to avoid problems in the first place by planning new wells carefully and operating existing wells prudently.

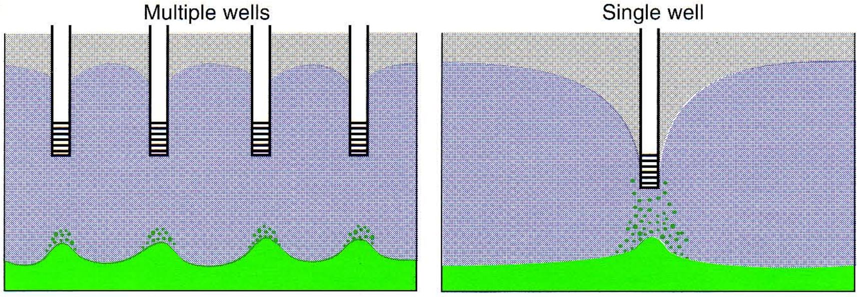

FIGURE 4—Dispersed, low-volume pumping produces less serious salt contamination than does concentrated withdrawal.

Glossary

Confining bed—A layer of relatively impermeable (incapable of transmitting fluids) material overlying an aquifer.

Discharge—Movement of ground water from the subsurface to the land surface, usually from a spring or to a marsh, river, or stream.

Downgradient—In reference to the movement of ground water, the "downstream" direction from a point of reference (a well).

Perching horizon—A relatively impermeable (incapable of transmitting fluids) lens or layer of clay or bedrock in otherwise permeable (capable of transmitting fluids) sediments that slows or prevents the downward movement of water.

Recharge—The addition of water into the aquifer, usually from precipitation percolating into the ground.

Salinity—The total quantity of dissolved salts in water, usually measured by weight in milligrams per liter or parts per million.

Total dissolved solids—The total quantity of all dissolved material in water, usually measured by weight in milligrams per liter or parts per million.

Upconing—The upward movement of ground water from a deeper to shallower position in the aquifer, usually induced by pumping a well or discharge to the surface.

Upgradient—In reference to the movement of ground water, the "upstream" direction from a point of reference (a well).

The mission of the Kansas Geological Survey, operated by The University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geologic hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.

Public Information Circular 2
June 1995

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SCHEDULE & ITINERARY

Thursday June 13, 1996

7:00 am	Breakfast
7:30 am	Bus to Wilson Lake
8:30 am	**SITE 5** - Wilson Lake and Dam *Jody Dvorak*, Park Ranger, US Corps of Engineers
9:00 am	**SITE 6** - Corral Cove - Dakota Formation Outcrop and the Dakota Aquifer *Al Macfarlane*, Kansas Geological Survey
9:30 am	Bus to Hays
10:45 am	**SITE 7** - City of Hays - Water Supply, Conservation, and Contamination *Hannes Zacharias*, City Manager, Hays *Lloyd Dunlap*, Chief, Assessment and Restoration Section, KDHE
12:00 am	Lunch - Tomanek Hall, Fort Hays State University
2:00 pm	Bus to Cedar Bluff Reservoir Western Kansas Weather Modification Program *Darrel Eklund*, Kansas Water Office
2:45 pm	**SITE 8** - Cedar Bluff Reservoir - Storage Acquisition *Tom Stiles*, Kansas Water Office
3:15 pm	Bus to Site 9
4:45 pm	**SITE 9** - Ogallala Formation Outcrop *Jim McCauley*, Kansas Geological Survey
5:15 pm	Bus to Days Inn
6:00 pm	Arrive at the Days Inn, Dodge City
6:30 pm	Cash Bar
7:00 pm	Dinner at the Days Inn
7:30 pm	Evening Session - Ogallala and Upper Arkansas River Aquifers *Don Whittemore*, Chief, Geohydrology Section, Kansas Geological Survey *Wayne Bossert*, Manager, Northwest Kansas Groundwater Management District #4 *Steve Frost*, Manager, Southwest Kansas Groundwater Management District #3 *Keith Lebbin*, Manager, Western Kansas Groundwater Management District #1

Wilson Lake

Wilson Lake was constructed on the Saline River in 1964 by the U. S. Army Corps of Engineers. The lake, named after the town about 10 miles to the south, is located on a drainage area of 1,917 square miles. Because much of that drainage is in native pasture, the water in Wilson Lake is among the clearest of any of the state's reservoirs. However, the water is very slightly saline because of drainage from salt springs and marshes in the Saline River valley and from evaporation from the lake's surface, which concentrates the salts. The lake includes 9,000 acres of water and has about 100 miles of shoreline. It has a total storage capacity of 775,000 acre-feet and a long-range yield of 55 million gallons of water per day.

Wilson Lake is one of nine Kansas lakes operated by the Kansas City district office of the Corps of Engineers (the others are Clinton, Hillsdale, Kanopolis, Melvern, Milford, Perry, Pomona, and Tuttle Creek). The Kansas City district of the Corps is responsible for lakes in the Missouri River drainage basin in Iowa, Missouri, Nebraska, and Kansas. The Tulsa district of the Corps of Engineers handles lakes in the Arkansas River drainage in Kansas.

Wilson Lake is set among sandstones, limestones, and shales deposited during the Cretaceous Period of geologic history, or about 90 million years ago. The red and orange sandstones that crop out in the area are part of the Dakota Formation, probably deposited in the valleys of Cretaceous rivers. Many of those sandstones are heavily crossbedded, showing angled lines where flowing water deposited the grains of sand. While Dakota sandstones crop out throughout the area, they are especially visible on the hiking trail at the Rocktown Natural Area on the lake's north side. One of the sandstone outcrops along the trail is inscribed with a Native American petroglyph.

Sharks' teeth are occasionally collected from Dakota sandstones and shales in the Wilson Lake spillway.

The limestones that crop out around the lake are part of the Greenhorn Limestone and are slightly younger than the Dakota Formation. The Greenhorn includes the well-known Fencepost limestone that was used for construction of bridges, houses, and fenceposts throughout the area. The Fencepost limestone bed is characteristically 10 or 12 inches thick, sometimes marked with a dark iron stain and often containing fossil clams of the variety *Inoceramus*.

Wilson is a popular fishing area and is particularly known for its population of striped bass and wipers. In 1988 it produced the state record for both striped bass (43.5 pounds) and smallmouth bass (5.56 pounds). Both records still stand.

References

Wilson Lake, Kansas, U.S. Army Corps of Engineers Pamphlet.

Lakes in the Kansas City District, U.S. Army Corps of Engineers Pamphlet.

Muilenburg, G., and Swineford, A., 1977, Land of the Post Rock, University Press of Kansas, 207 p.

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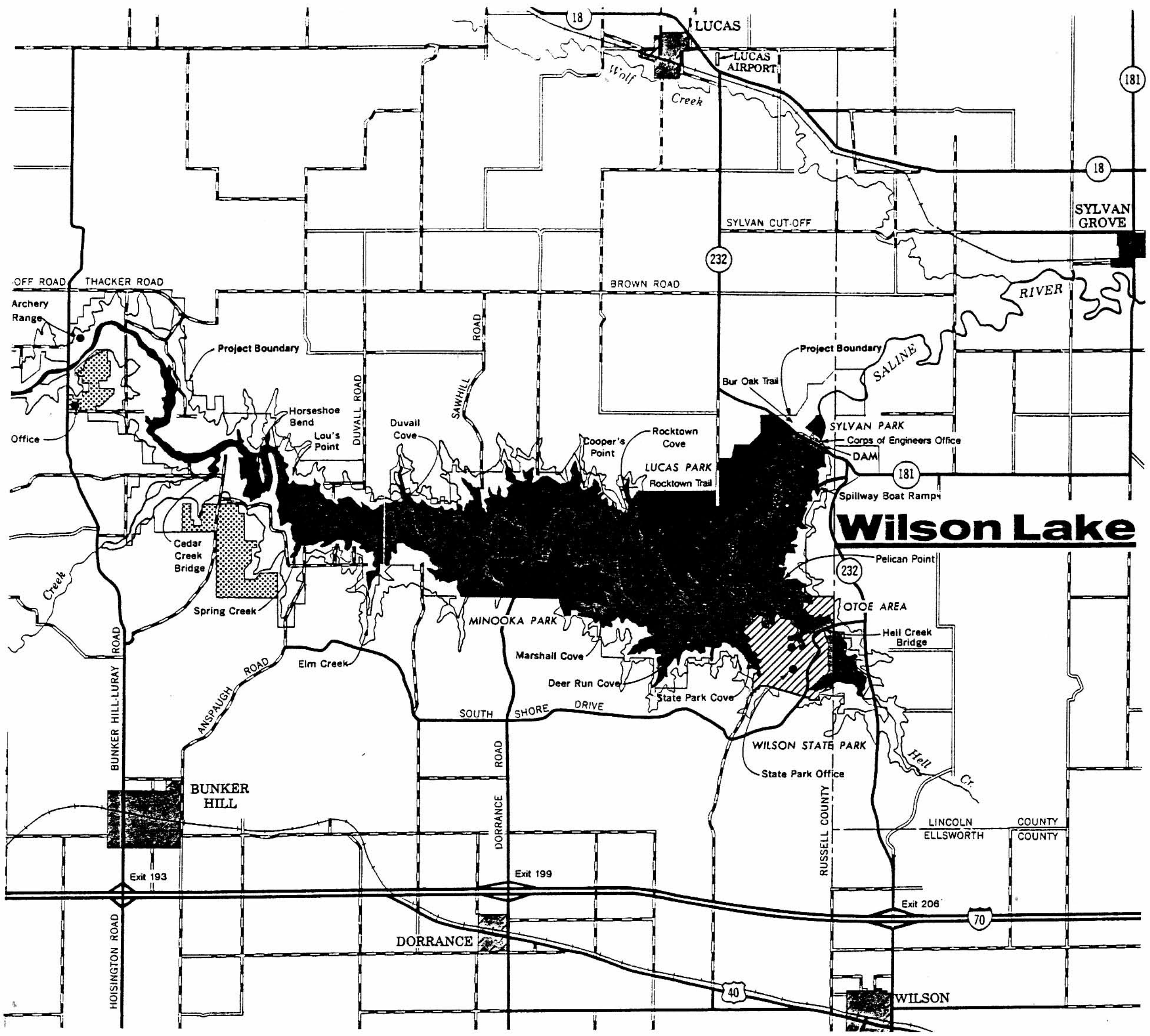

Figure 1. Wilson Lake (illustration from Corps of Engineers).

The Dakota Aquifer of Kansas

P. Allen Macfarlane and D.O. Whittemore
Kansas Geological Survey

Water Resources Issues

The Ogallala and associated shallow aquifers and the river valley systems in western and central Kansas have been major sources of water for agriculture, drinking water, and industrial use. Withdrawal of water in some areas has resulted in substantial decreases in saturated thickness indicating overdevelopment. To control further development, more stringent management policies have been applied by the Division of Water Resources (DWR), Kansas Department of Agriculture, and the groundwater management districts. These policies have effectively eliminated new appropriations of water from these sources to users. However, even with these more stringent policies in place, these once prolific sources of water may become insufficient to meet existing demand in the next few decades. These factors have combined to create interest in using deeper sources of water, such as the Dakota aquifer, to supplement or replace the dwindling shallower sources.

The Dakota aquifer underlies approximately 40,000 square miles of western and central Kansas and is more extensive than the shallower Ogallala aquifer (Fig. 1). Unlike the Ogallala, development is minimal even where the aquifer is relatively shallow in southwestern and central parts of the state. Until recently, the Dakota was less well understood than the Ogallala and other shallow sources because of its geologic complexity, and in some parts of the state, its great depth. Uncertainties with respect to 1) the quantity and quality of ground waters available, 2) the effects of withdrawals, and 3) the potential impact of oil-brine disposal have significantly impeded development of appropriate management policies by State and local agencies. Past management decisions were often made with little or no technical guidance. Well yield, water quality, and the considerable depth to the top of the aquifer have been major factors contributing to the minimal use of this aquifer system as a source of water in Kansas.

Summary of Research Findings and Results

The Dakota aquifer in Kansas is composed of the Dakota Formation, the Kiowa Formation, and the Cheyenne Sandstone. The combined thickness of these units can range up to more than 700 feet in west–central parts of the state. However, not all of the units that constitute the Dakota contain aquifer-grade material that can yield water to wells. The amount of sandstone, considered to be the aquifer material, varies from less than 10% to more than 50% of the total thickness, even over very short lateral distances. Statewide, the average proportion of sandstone is approximately 30% of the entire thickness. The sandstones occur as irregular, discontinuous bodies within relatively impervious shaly strata and generally occur in several, more or less distinct zones within these geologic units. These ribbon-like, irregular bodies of sandstone were deposited during the early part of the Cretaceous Period of geologic history (approximately 90–100 million years ago) in river valleys crossing a coastal plain and in coastal environments along the eastern shoreline of an ancient sea. Typically, these sandstone bodies range in length up to 20 miles, in width up to 1.5 miles, and in thickness up to more than 100 feet. With some exceptions, they tend to be oriented primarily in an east-west direction, parallel to the direction of the ancient drainage. The most permeable part of the aquifer is generally in the river-deposited sandstones in the Dakota Formation and the Cheyenne Sandstone.

The Dakota has been used as a source of water for more than a century in the central Great Plains region that includes Kansas. Flowing wells tapping the Dakota were common in the Arkansas River valley of southeastern Colorado and southwestern Kansas in the late 1800s and early 1900s. Water-level declines in Kansas due to past development are estimated to have been 50 feet. Many of the areas where flowing wells were common have been drastically reduced in size or have disappeared. Measured yields of wells in the Dakota range up to 700 gallons per minute (gpm), but vary widely even over very short distances. Measured yields from wells screened in the Dakota and Ogallala aquifers in southwest Kansas range up to 950 gpm. These yields are less than would be expected from the Ogallala aquifer.

Research results indicate that where the Dakota is overlain (confined) by relatively impervious units, freshwater recharge from overlying sources to the Dakota is negligible (Fig. 1). The Dakota is overlain by these units across most of western and parts of central Kansas. The recharge area for this part of the aquifer is in southeastern Colorado, south of the Arkansas River (Fig. 2). In this region leakage from the overlying Ogallala and infiltrating precipitation enter the aquifer. This water moves very slowly northeastward within the Dakota into western Kansas. Ground waters in this part of the flow system are believed to be greater than 10,000 years old and may exceed 1,000,000 years in age in far northwest Kansas because of the distance from the recharge area and the negligible recharge from overlying sources.

In central Kansas, the Dakota crops out at the surface and is readily recharged by infiltrating precipitation (Fig. 1). Models suggest average recharge rates on the order of 0.2–0.3 in./yr for this part of the aquifer. Ground waters in this part of the system appear to be relatively young with ages generally less than 10,000 years. In comparison, ground waters in the Ogallala aquifer are much younger because they are recharged by precipitation at higher rates. In southwestern Kansas where the Dakota is directly beneath the Ogallala aquifer, model simulations show that the Dakota and the Ogallala behaved largely as a single system prior to development. Work is currently underway to apply a management model of the coupled Dakota/Ogallala aquifer to address local and state concerns. In central Kansas, an additional source of recharge to the Dakota comes from the underlying saltwater-bearing Cedar Hills Sandstone where both aquifers are in hydraulic connection. The Cedar Hills Sandstone is used as a shallow disposal zone for produced oil brines in Kansas and in Oklahoma. Computer simulations show that the amount of saline water contributed to the Dakota aquifer where both aquifers are in contact is small relative to the freshwater recharge entering the upper part of the aquifer.

At the wellfield scale, ground-water flow is influenced primarily by the size and shape of the sandstone bodies and by hydraulic connections between them. The Dakota can be envisaged as a complex natural plumbing system consisting of water-filled sandstone bodies, some of which are hydraulically connected to each other allowing water transmission over long distances to wells. Well-log data reveal a high variability in the frequency and extent of these bodies and their continuity. Our research reveals that the limited extent of these sandstone aquifers "channelizes" the flow to a pumping well (Fig. 3). Consequently, the recharge moving laterally in the aquifer to a single pumping well is limited. At the well, this creates larger drawdowns during pumping than would occur if the same well were withdrawing water from the Ogallala aquifer.

Natural water quality ranges widely in the Dakota aquifer, from very fresh in portions of the outcrop area in central Kansas and in the region where the Dakota directly underlies the High Plains aquifer, to very saline (high sodium and chloride concentrations) in central and northwestern Kansas (Fig. 4). Detailed mapping of the salinity has revealed areas where the water is fresher than previously thought, resulting in the discovery of additional locations of potentially usable waters for future development. Mapping has also shown that salinity is greater than formerly predicted in either area. The expanded area of fresher water delineated is greater than that for the more saline water, and is mainly distributed between northwest and north-central Kansas. Although the actual quality of the additional fresher water discovered is slightly saline, the water could be a valuable resource for the future because much of it lies along the eastern margin of the Ogallala aquifer where water supplies are limited. The research has shown the importance of the flow systems in controlling Dakota aquifer salinity and the presence or absence of overlying and underlying rock units to either contribute natural saltwater or restrict flushing of salinity by fresh recharge.

Maps are also being completed of the distribution of other natural dissolved chemicals that must be considered when assessing the value of aquifer waters for different uses. For example, fluoride concentration in Dakota ground waters is higher than drinking water standards in some fresh or nearly fresh regions of the aquifer. Determination of the mechanisms controlling the high fluoride concentration has allowed improved prediction of fluoride in different regions and at different depths in the aquifer. The water-quality research has included assessment of a variety of major, minor, trace, and naturally radioactive substances. In addition to salinity and fluoride, high dissolved iron, manganese, and sulfate are the main limitations for use as drinking-water supplies. Fresh ground waters in some areas have been naturally softened and have higher sodium concentrations which should be considered for managing the amount of irrigation waters applied to clayey soils.

Contamination of the aquifer by human activities is mainly limited to local sites of high nitrate concentrations primarily from animal waste and fertilizer sources. Most of this contamination occurs in areas where the Dakota rocks are present at or near the land surface. Some of the contamination is related to poor construction or deterioration of older water wells that allow entrance of surface or soil waters along the well bore. Nitrate pollution is less frequent in areas where newer wells have been constructed with better seals between the surface and the water-producing zone. Known locations of saltwater contamination from the oil and gas industry activities are limited to central Kansas where saltwater disposal to relatively shallow bedrock was allowed before and during World War II.

Implications for Management

The major ground-water management issue that will affect the long-term viability of the Dakota as a major resource is its sustainability under increased development. Sustainability implies the establishment of a new equilibrium within the planning horizon between recharge, discharge, and withdrawals by users. The high variability of the deposits that constitute this aquifer system strongly indicate a potential for depletion due to overdevelopment. Also, pumping in areas of marginal water quality near saltwater-freshwater transition zones will need to be at rates that do not induce substantial lateral or vertical encroachment of saline water. The research results indicate that the Dakota will not produce water at the same rate as the Ogallala on a sustained basis. Where the Dakota aquifer is confined by significant thicknesses of relatively impervious strata, increased development will have a pronounced effect if it is not appropriately managed. Because of the low potential for additional recharge induced by pumpage, the goal of safe yield in managing the water resources in the deepest part of the aquifer is untenable. Controls on the spacing between pumping wells and rates of withdrawal are likely to be the most successful management tools. This will reduce the likelihood of water-rights impairment and large-scale depletion as long as the intensity of development remains low. Where the Dakota is a near-surface aquifer in central Kansas, increased development will result in fewer long-term impacts than in the confined area. In southwestern Kansas, the hydraulic connection between the Dakota and the overlying Ogallala suggests that both aquifers should be managed as a single system. Acting on our research results, the Chief Engineer, DWR, has already revised the regulations that address the minimum spacing between pumping wells in the Dakota.

State law mandates the protection of ground water from contamination by human activities. State regulations usually require oil industry drillers to protect near-surface geologic units that may contain usable ground water by installation of additional casing. Substantial portions of the Dakota aquifer in northwest and north-central Kansas have been found to contain unusable ground water that would not need the stringent protection now required. This suggests the need for revision of the minimum surface casing requirements of the Kansas Corporation Commission for the oil and gas industry.

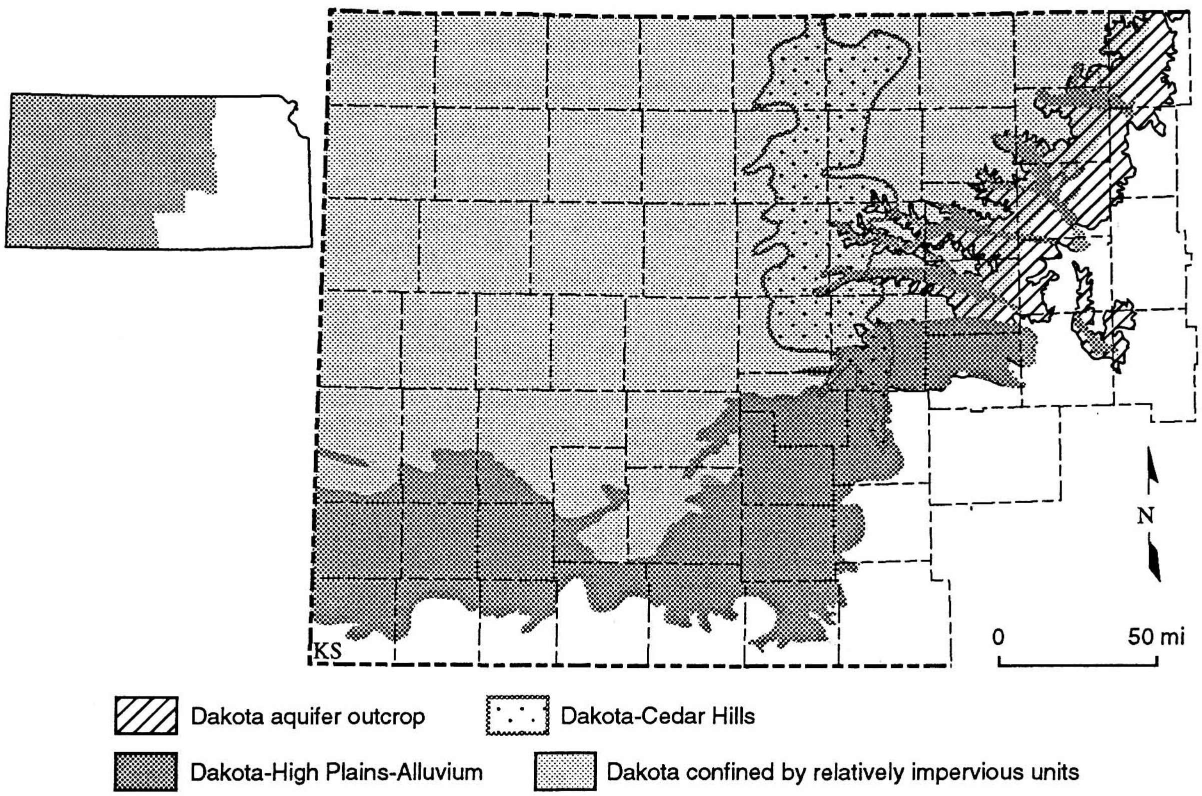

Figure 1. Extent of the Dakota aquifer in Kansas showing regions of hydraulic connection to other aquifers, where the Dakota is a near surface aquifer, and where it is confined by relatively impervious units.

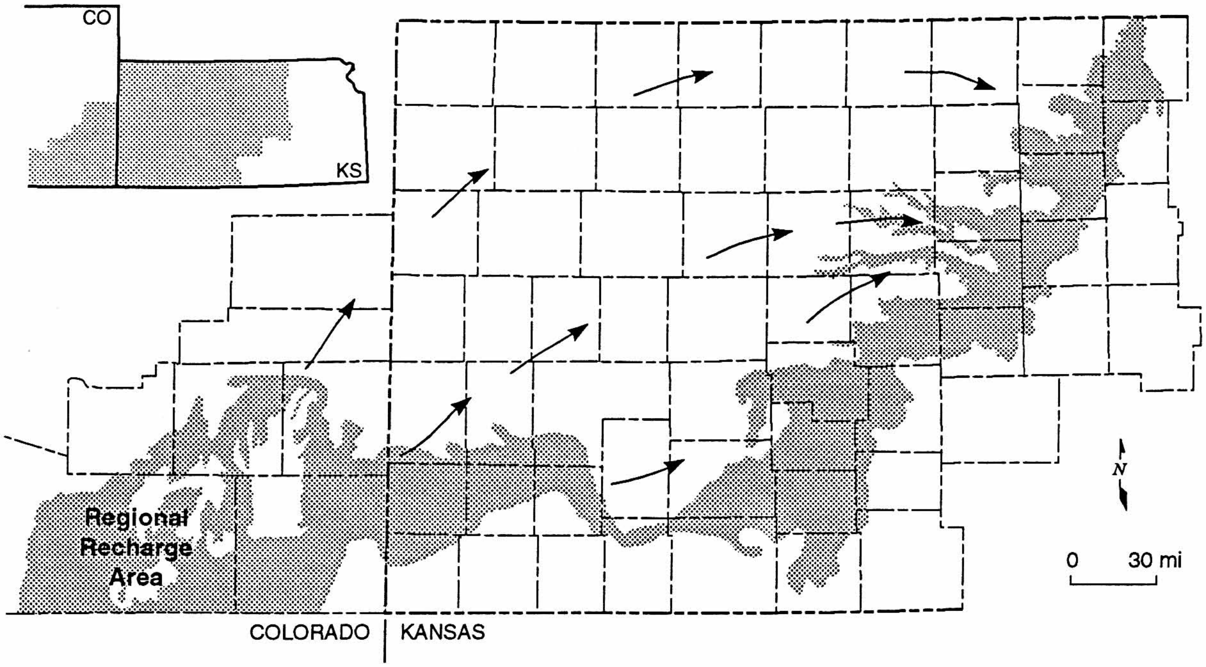

Figure 2. Groundwater flow pattern from the regional recharge area in the part of the Dakota aquifer overlain by relatively impervious units.

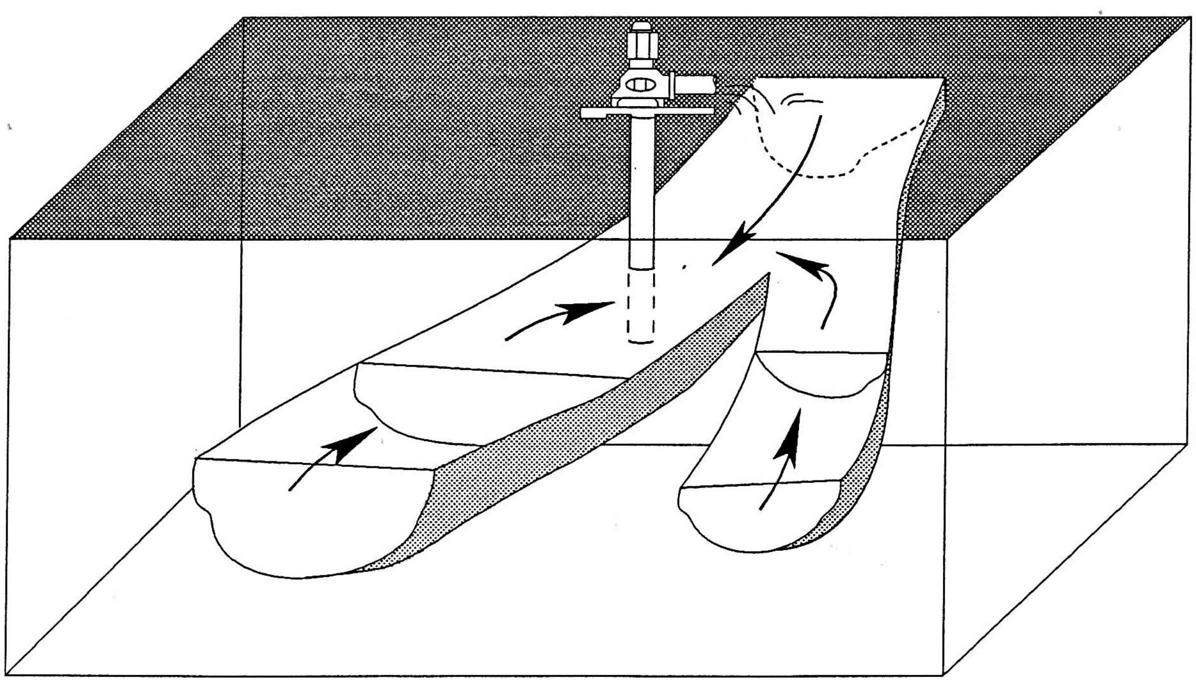

Figure 3. Schematic showing the flow of water to a pumping well screened in a sandstone body. Notice how the flow is "channelized" or restricted and not uniformily distributed as it would be in the Ogallala aquifer.

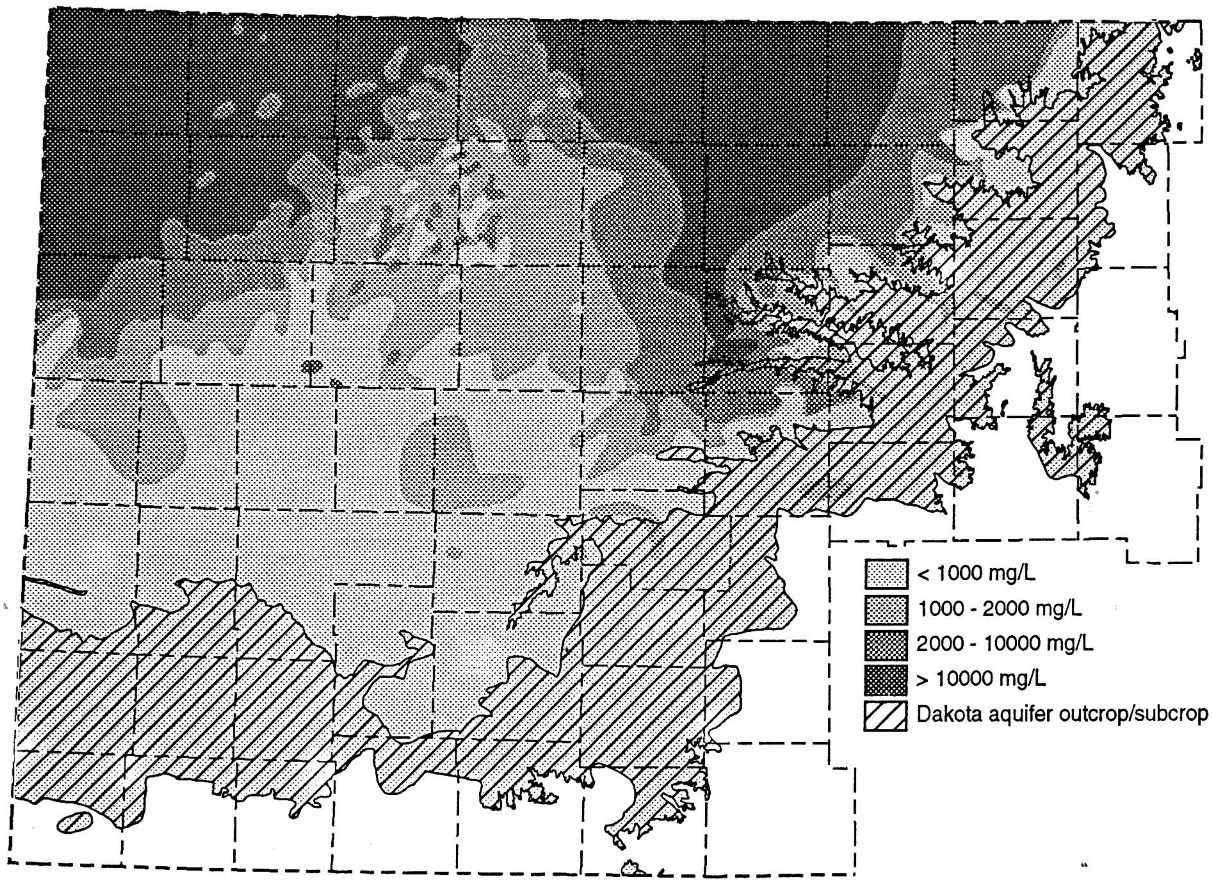

Figure 4. Distribution of total dissolved solids (TDS) concentrations in ground water in the upper Dakota aquifer in western and central Kansas. Water less than 1000 mg/L TDS is defined as fresh. Water with 1000-2000 mg/L TDS is usable for many purposes but is less desirable than freshwater. A concentration of 10,000 mg/L TDS is defined in the state regulations of the Kansas Corporation Commission as the upper limit of usable water; above 10,000 mg/L water is classified as unusable or mineralized.

Water Supply and Conservation Issues
Hays, Kansas

The city of Hays, Kansas, has faced water supply shortages since 1985, when a once-abundant supply of water began to decline. Since then, Hays has searched for additional sources of water and implemented very aggressive conservation measures to reduce demand on the existing supply.

Historically, Hays obtained water from wellfields in the Big Creek and Smoky Hill River aquifers. Big Creek runs through town and the Smoky Hill River is located about 10 miles south of Hays. The Big Creek wellfield has a dependable yield of approximately 1,200 acre-feet per year. The once-dependable yield of the Smoky Hill wellfield has declined over the years from approximately 2,500 acre-feet to 1,000 acre-feet. The decline is a result of reduced streamflow in the Smoky Hill River caused by elimination of releases in 1978 from Cedar Bluff Reservoir located about 22 miles upstream. The Smoky Hill River is the primary source of recharge to the Smoky Hill alluvial aquifer.

Peak water use by Hays was approximately 3,500 acre-feet in 1983. With a dependable yield of only 2,200 acre-feet during drought conditions, the City realized that additional water supplies and conservation measures were needed to meet demands. In 1985, the City began searching for additional water supplies by investigating nearly every source within 90 miles of Hays. At the same time, ordinances were implemented to reduce peak water use in the summer. The original ordinance was tiered with increasing restrictions as drought conditions became more severe. This ordinance reduced the total volume of water used in the City. By 1991, use was reduced to 125 gallons per capita per day (gpcd), while the average use in surrounding counties was 150 gpcd.

Over 1,500 of the City's residents have private wells used primarily for lawn watering. These wells tap the same aquifer that supplies the City's Big Creek wellfield. Restrictions on private wells were needed to insure the Big Creek wellfield would not be jeopardized. Because the City does not have the power to enforce restrictions on private wells, the Division of Water Resources responded to the City's request for help by placing a moratorium on lawn watering from private wells to reduce evaporation and reduce total pumpage.

Other water conservation measures included an aggressive public education program that provides basic information on water conservation, household water saving tips, and a history of the water problems in Hays. Another program reduced losses in the distribution system through testing and replacement of meters and old water mains. Nearly two-thirds of the meters tested and over 25,000 feet of water mains have been replaced since 1985. The City has also started a project that will use wastewater to recharge Big Creek aquifer upstream. This project will provide the City with up to 661 acre-feet of additional water when it is fully implemented.

In 1992, Hays revised its water conservation ordinance to further encourage water savings. Per capita use for 1992 was reduced to approximately 90 gpcd, about 65 percent of the average per capita use. The focus of the new ordinance shifted from outdoor to indoor water use by providing rebates for water-saving appliances such as low-flow toilets and showerheads.

The City utilized a new sales tax to fund development of six wells that tap the deeper Dakota aquifer and provides up to 450 acre-feet of water per year. The Dakota water has to be blended with fresher water because it is slightly saline. In 1994, Hays purchased land and water rights to the R-9 (Circle K) Ranch in Edwards County, Kansas. This acquisition will more than double current water resources when the project is developed.

Reference

Henson, J.W., and Zacharias, H., 1993, Conservation comes to a Kansas community; *in*, Proceedings from Conserve 93 - The new water agenda: American Water Works Association, p. 1661-1670.

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Ground Water Contamination Projects
Hays, Kansas

Kansas Department of Health and Environment

Perchloroethylene Contamination From Drycleaning Operations

In 1989, the Division of Environmental Remediation, Kansas Department of Health and Environment (KDHE), conducted an initial investigation in response to contamination of several public water supply wells in Hays. The purpose of the investigation was to assess the local geohydrology and identify the nature and extent of the contamination. Within the contaminated area, there are at least two former drycleaning operations, and 20 historical and recent underground storage tank (UST) sites.

Six public and several private water supply wells exist in the area of contamination. Some of these, contaminated with perchloroethylene (PCE) from drycleaning operations and petroleum hydrocarbons from underground storage tanks, have been taken out of service. Since potable water is at a premium in Hays, it was important to insure a consistent supply. The initial intent of the KDHE study was to 1) identify the major contaminators, 2) construct a "stop gap" ground-water containment system to control plume migration, and 3) aggressively address the contamination sources. The Hays project is unique in that a regional approach is taken rather than studying each site individually. This helps 1) address the numerous sources of contamination in a cost- and time-efficient manner, and 2) maintain a safe water supply for the City of Hays.

The investigation identified a commingled plume from drycleaning and petroleum hydrocarbon sources. Wastewater from the drycleaning operations was probably discharged into the sanitary sewer or onto the ground surface. Once a normal practice, this method of disposing of waste water is now known to contaminate soil and ground water with PCE. PCE has migrated south from one or more of the drycleaning operations at Vine and Centennial streets to a public water supply well about nine blocks away.

Assessment of the lateral migration of the PCE plume is nearly complete. The southern extent of the plume probably extends as far south as 11th Street, about 15 blocks from the former drycleaning facilities. Currently, pilot tests are being designed to remediate the north area near the former drycleaners and another remediation system is being considered near the southern end of the PCE contamination.

South Hays Project

A second contamination area is on the south edge of Hays hear Vine Street and Old Highway 40. The primary contributor of petroleum hydrocarbon contamination appears to be an oil field service company, with additional contamination from a convenience store, a gasoline service station, and other historic sources. The oil field service company, located at 1102 E. 8th Street, stored gasoline, diesel, and xylene at the site. Petroleum hydrocarbon contamination was identified at the convenience store, located at 7th and Vine streets, where three gasoline tanks were removed. Both sites are regulated by KDHE's program and were admitted to the underground storage tank trustfund.

Remedial efforts for petroleum hydrocarbon contamination are ongoing. Remediation began by installing a ground-water treatment system downgradient from the heart of the plume. Four recovery wells were placed within the plume, three in a line perpendicular to ground-water flow just south of the oil field service company source, and one well downgradient on the leading edge of the plume. The location and spacing of the wells was designed to contain the plume from further migration toward a public water supply well. The three perpendicular wells address the two source areas, the convenience store and the oil field service company site, and act as a hydrologic containment for any contamination from the north. The downgradient well acts as an interceptor for contamination that has already moved past the containment.

Water from this remediation system, approximately 200 gallons per minute, is treated and distributed back into the City's public water system. The system became fully operational in January 1995. In March 1996, operation of the system was turned over to the City.

After installation of the water treatment system, additional information was gathered at the two largest contamination sites. A private contractor was hired to design remedial systems near the source areas. The KDHE Trustfund Remedial

Section and the KDHE Northwest District Office are overseeing the project. A Soil Vapor Extraction (SVE) system will be installed for cleanup of the soil at the source areas. The SVE system removes volatile petroleum vapors from the soil by applying a large vacuum underground. Vapors are withdrawn through piping and then run through a thermal oxidizer before being released into the atmosphere as carbon dioxide and water.

Other possible sources of contamination are now being investigated. After the initial investigation, these sources will be cleaned up or placed into KDHE's monitoring program, depending on the severity of the problems and their proximity to the public water wells. The Storage Tank Section of Bureau of Environmental Remediation has been coordinating the activities of the South Hays Project with KDHE's Northwest District Office, the Bureau of Water, the City of Hays, the Division of Water Resources, private contractors, and the owners and operators of each facility. A cooperative effort from all of these entities has contributed to the success of this project.

Contamination of Public Water Supply Well #20

Public Water Supply Well #20 (PWS #20), located near 17th and Vine streets, was shut down in 1989 because of petroleum contamination. KDHE also identified PCE from an unknown source. PWS #20 is located directly south of a gasoline service station. Underground storage tanks were removed from this station in 1990 and excessive levels of petroleum contamination were discovered. A follow-up site investigation determined the lateral extent of contamination and identified several additional sources of contamination. Petroleum product was discovered in the monitoring wells and an extensive plume, approximately 100 feet in diameter and up to 4 feet thick, was identified north of PWS #20.

Because of the emergency nature of the contamination, KDHE hired a private contractor to conduct removal activities until a remediation system could be designed for the site. Approximately 1,500 gallons of gasoline were removed from the ground water during a two-year period.

A permanent remediation system that is configured similar to the South Hays Project is now being designed. Two pumping wells will be used to draw the water table below the contamination trapped in the soil pores. The cone of depression created by the pumping wells will act as a catch basin. A Soil Vapor Extraction (SVE) system will be installed to remove the vapors trapped in the soil as the water table is lowered. The vapors will then be burned in a catalytic oxidizer. Water from the two pumping wells will be piped to an air stripping system located at the City's Water Softening Plant, treated to remove the contamination, and then discharged into the City's Water Plant. City personnel will be trained to take over operation and maintenance of the system. The treated water will provide an additional 250 gallons per minute to the City's water supply.

Another gasoline service station, located directly north of this site, has recently been identified as an additional source of contamination. This site will also be incorporated into the remedial system.

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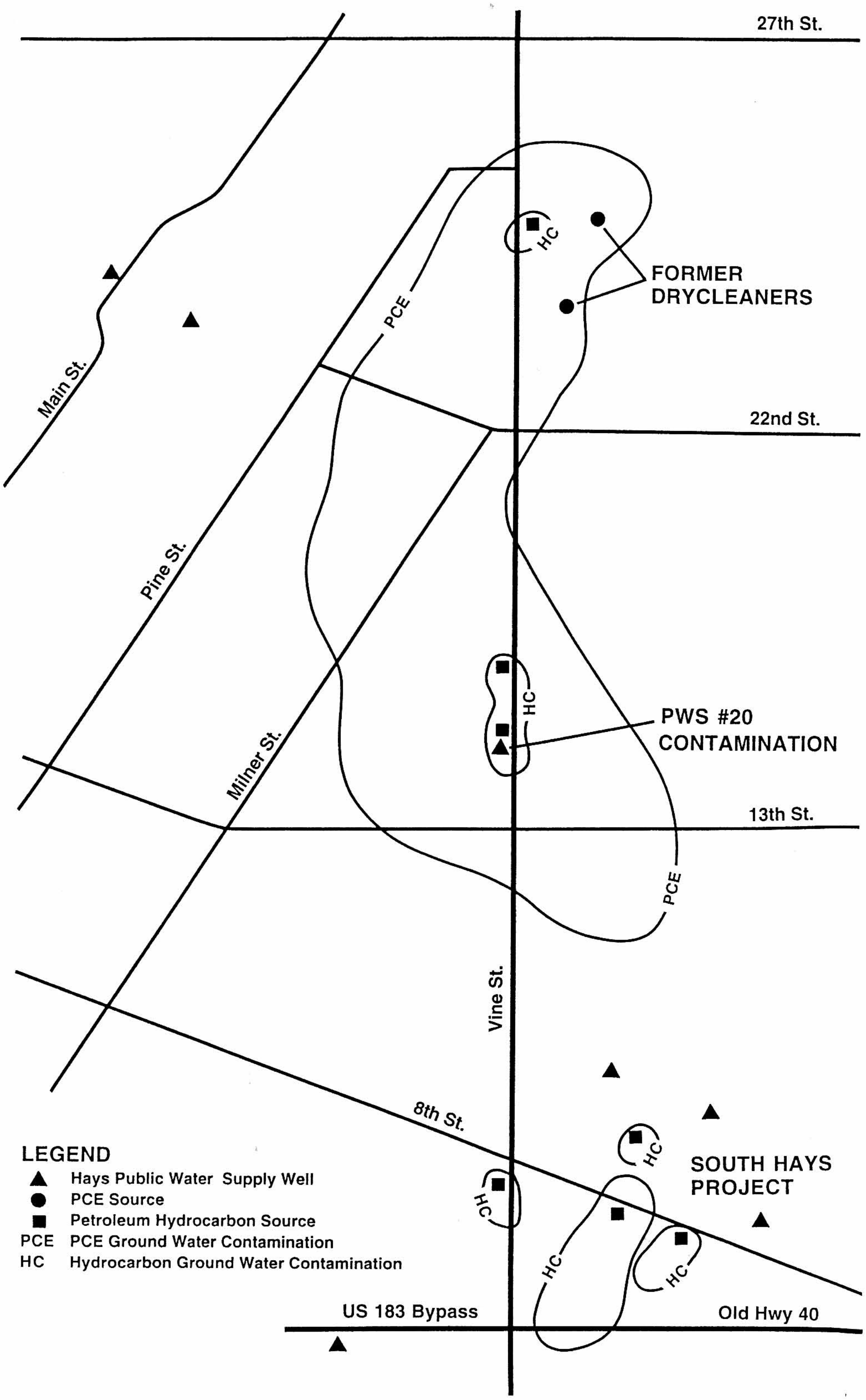

Figure 1. Map of the City of Hays showing approximate extent of contamination plumes.

The Western Kansas Weather Modification Program

Darrel Eklund
Kansas Water Office

Weather modification activities began in western Kansas in 1972 and several cloud seeding operations were conducted from 1972 through 1978. The centerpiece of weather modification activities in Kansas is represented by the Western Kansas Weather Modification Program, which has operated from 1975 to the present under the leadership of the Western Kansas Groundwater Management District No. 1. Seeding for hail suppression has always been the major thrust of the Program due to funding limitations and the amount of loss that can occur with a severe hail storm. Whenever possible, efforts have also been made to increase precipitation.

Seeding for hail suppression is based on the prevailing hypothesis that hailstones grow to large sizes because too few ice crystals form naturally in clouds during vigorous thunderstorm growth, thereby allowing relatively abundant supercooled water to collect upon relatively fewer numbers of ice particles or other hail embryos. Often, those particles grow into hailstones too large to melt before hitting the earth's surface. The introduction of dry ice or silver iodide into clouds results in vastly increasing the ice crystal concentration within these ice crystal-deficient clouds, hence hailstones will be prevented from growing large enough to damage crops and property through strong competition for the available cloud water. Crop type, stage of crop growth, and hail size all play an important role in determining crop damage severity.

Before 1995, the Western Kansas Weather Modification Program was locally funded with financial support typically ranging between $150,000 and $250,000 per year. State support for the Program was limited to the annual issuance of a permit to operate the Program by the Kansas Water Office.

Evaluation

In late 1993 and early 1994, Keith Lebbin and Wayne Bossert, Managers of Western Kansas Groundwater Management District No. 1 and Northwest Kansas Groundwater Management District No. 4, respectively, called upon the Kansas Water Office to evaluate the effectiveness of this Program in order to increase the likelihood that State support might be provided to enhance and/or enlarge the Program. The Kansas Water Office prepared a new subsection of the State Water Plan entitled "The State Role in Weather Modification" and was directed by the Kansas Water Authority to proceed with an evaluation of the Program. This new subsection indicated that State support for the Program would depend upon a favorable outcome to the evaluation.

For evaluation purposes, a six-county target area was chosen. Each of these six counties participated in the Program each year from 1979 to 1993. An eight-county control in northwest Kansas was chosen to represent an area where no cloud seeding was done (Figure 1). A review of hail damage statistics from 1948-1970, before any cloud seeding was done, showed little difference in hail damage between the target and control areas.

The Kansas Water Office evaluation of the Hail Suppression Component of the Program was very positive. The estimated percentage decrease in hail damage to crops in the target area was 27 percent, resulting in an estimated benefit of approximately $60,000,000 to the six-county target area for 1979-1993, or $4,000,000 per year, after the expenses to operate the Program were deducted. These figures were based on reduced hail damage to crops and did not include any estimate of the savings due to reduction in hail damage to dwellings, personal property, wildlife, or other natural resources.

Hail losses within the state can be both variable and staggering. In 1993, the state of Kansas sustained $43,418,000 of insured crop-hail damage, its greatest dollar loss of insured crops due to hail damage since 1948. Because not all farmers insure their crops for hail damage, the total dollar loss for crop-hail damage was, of course, much greater than $43,418,000. Although 1993 was also the worst year for crop-hail damage to the Western Kansas Weather Modification Program target area counties, it should be noted that the insured crop-hail damage loss for Sheridan County, a control area county, was $4,542,000 in 1993, which exceeded the total crop-hail damage loss for all six target area counties.

Figure 2 shows the average amount of crop hail damage per harvested acre. For the 1992-1994 time period, the average crop hail damage per harvested acre exceeded $30.00 in Morton and Sheridan counties or more than $4,800 for a quarter section of harvested acres. Both of these counties lie outside of the target area. Although hail damage tends to be more severe in extreme western Kansas, it should be noted that the target area counties of Wichita, Scott, and Haskell all received less than $10.00 damage per harvested area. An experience this favorable was not found in any county this far west that did not participate in the Program.

From the outset the original designers of the Western Kansas Weather Modification Program knew the Program could never eliminate all crophail damage and they never claimed to be able to do so. Originally, the Program was designed around the best use of the available funding, a concept that has allowed it to expand or contract each year depending on the number of participating counties. Despite Program funding limitations, the Kansas Water Office has concluded that the dollar value of the crop-hail damage reduction, to date, has been very significant.

As a result of this evaluation, the Kansas Water Office provided $120,000 of State Water Plan funds in Fiscal Year 1996 to match Western Kansas county participation in hail suppression weather modification activities at $10,000 per participating county. Two additional counties (Stevens and Wallace) have joined the Western Kansas Weather Modification Program for the 1996 operational season.

Resource Contact

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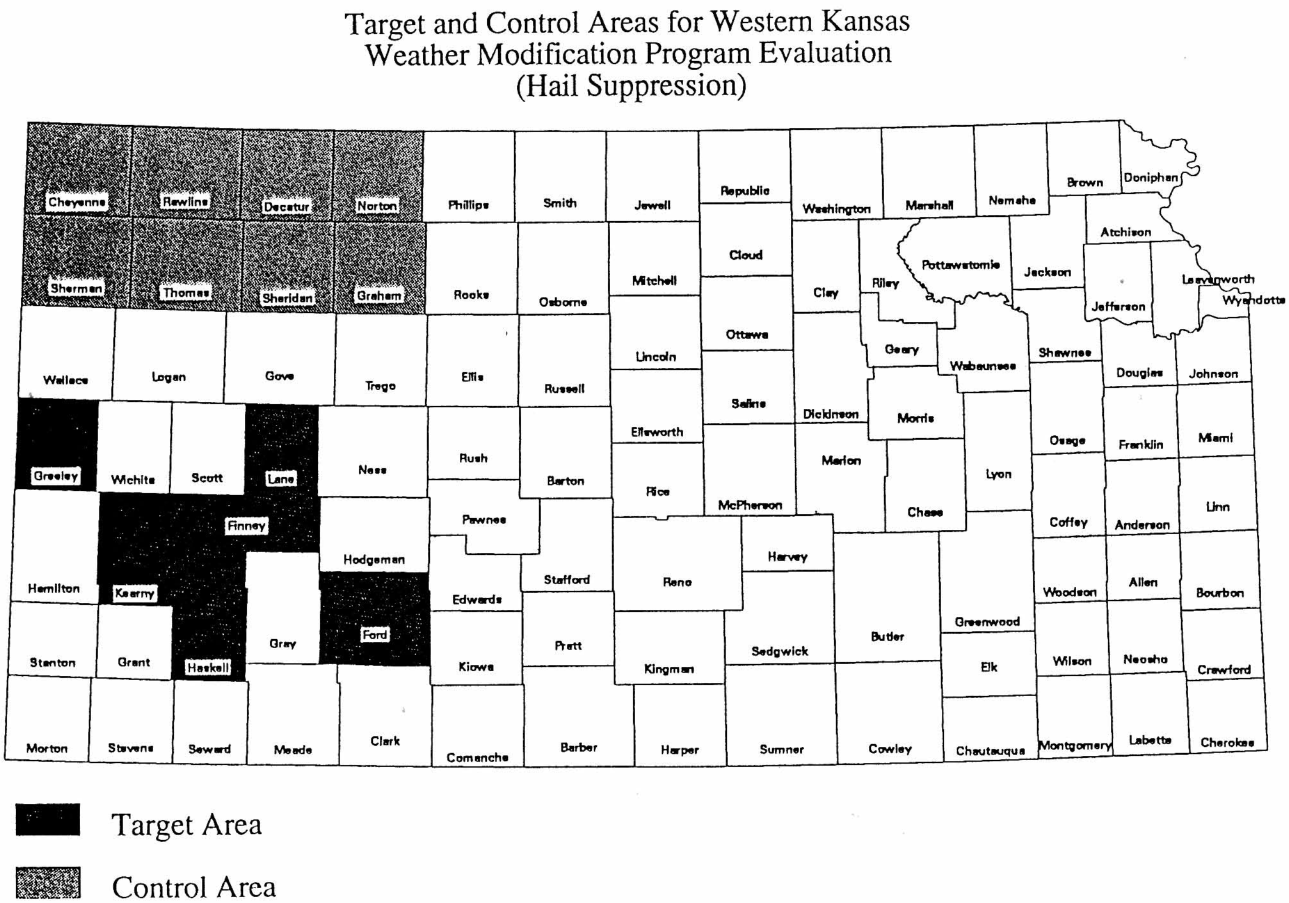

Figure 1. Target and control areas for Western Kansas Weather Modification Program evaluation (hail suppression).

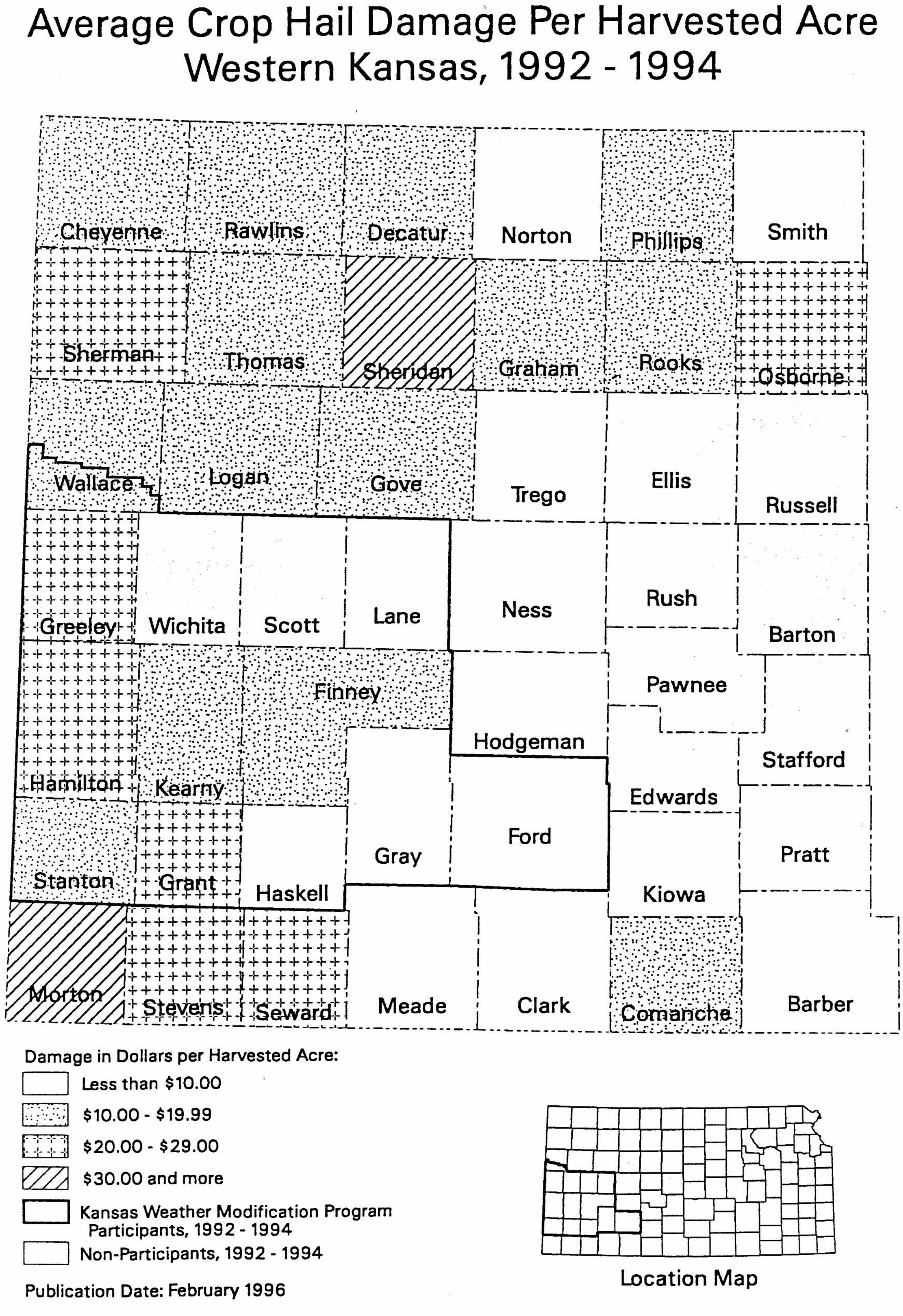

Figure 2. Average crop hail damage per harvested acre in western Kansas, 1992-1994.

Cedar Bluff Dam and Reservoir

Cedar Bluff Reservoir, located in Trego County, captures drainage from the Smoky Hill and a couple of its major tributaries, Ladder Creek and Hackberry Creek. Cedar Bluff's drainage basin covers about 5,200 square miles and stretches as far west as the area around Cheyenne Wells, Colorado. The dam and lake are named after a series of high bluffs, composed of thick layers of the Fort Hays Limestone, overlooking the Smoky Hill River on the southwest side of the lake. Cedar Bluff is operated by the Bureau of Reclamation, one of six Bureau projects in the Kansas River basin in Kansas (the others are Webster Reservoir in Rooks County, Keith Sebelius Lake in Norton County, Kirwin Reservoir in Phillips County, Waconda Lake in Mitchell County, and Lovewell Reservoir in Jewell County).

Cedar Bluff Dam rises 134 feet above the streambed and is 12,560 feet long. It was constructed in 1951 to provide flood control, water for irrigation and municipal use, and water for a fish hatchery below the dam, operated by the U.S. Fish and Wildlife Service. It also provides recreation and habitat for fish and wildlife. The Cedar Bluff Irrigation District, created in 1958, used the Cedar Bluff Canal, which originates at the reservoir outlet and extends eastward on the north side of the Smoky Hill River. The canal is 18 miles long and the laterals total more than 24 miles in length. It was designed to serve 6,200 acres of irrigated land by gravity and an additional 400 acres by private canal-side pumps.

Cedar Bluff filled in the 1950s because of heavy spring rains in 1951 and 1957. Inflow into the reservoir has decreased substantially since 1965 and, according to John Ratzlaff at Ft. Hays State University, "since 1980, contents of the reservoir have averaged about 13 percent of the designed level" (Cedar Bluff is not alone in this regard. Ratzlaff notes that the four Bureau reservoirs in northwestern Kansas "each . . . experienced, and continues to suffer from, substantial decline in content following relatively brief periods of operation at its designed capacity").

Releases of water from Cedar Bluff to entities with water rights stopped in 1979. Because of the lack of flow in the Smoky Hill from Cedar Bluff Reservoir, the Smoky Hill River valley below the lake (from Cedar Bluff to the confluence of the Smoky Hill and Big Creek in western Russell County) was declared an intensive ground-water use control area (or IGUCA) by the State engineer in 1984. Heavy rains in 1993 raised water levels in Cedar Bluff, though they did not fill the lake. According to Ratzlaff, ". . . the chances that Cedar Bluff Reservoir will ever fill are extremely small."

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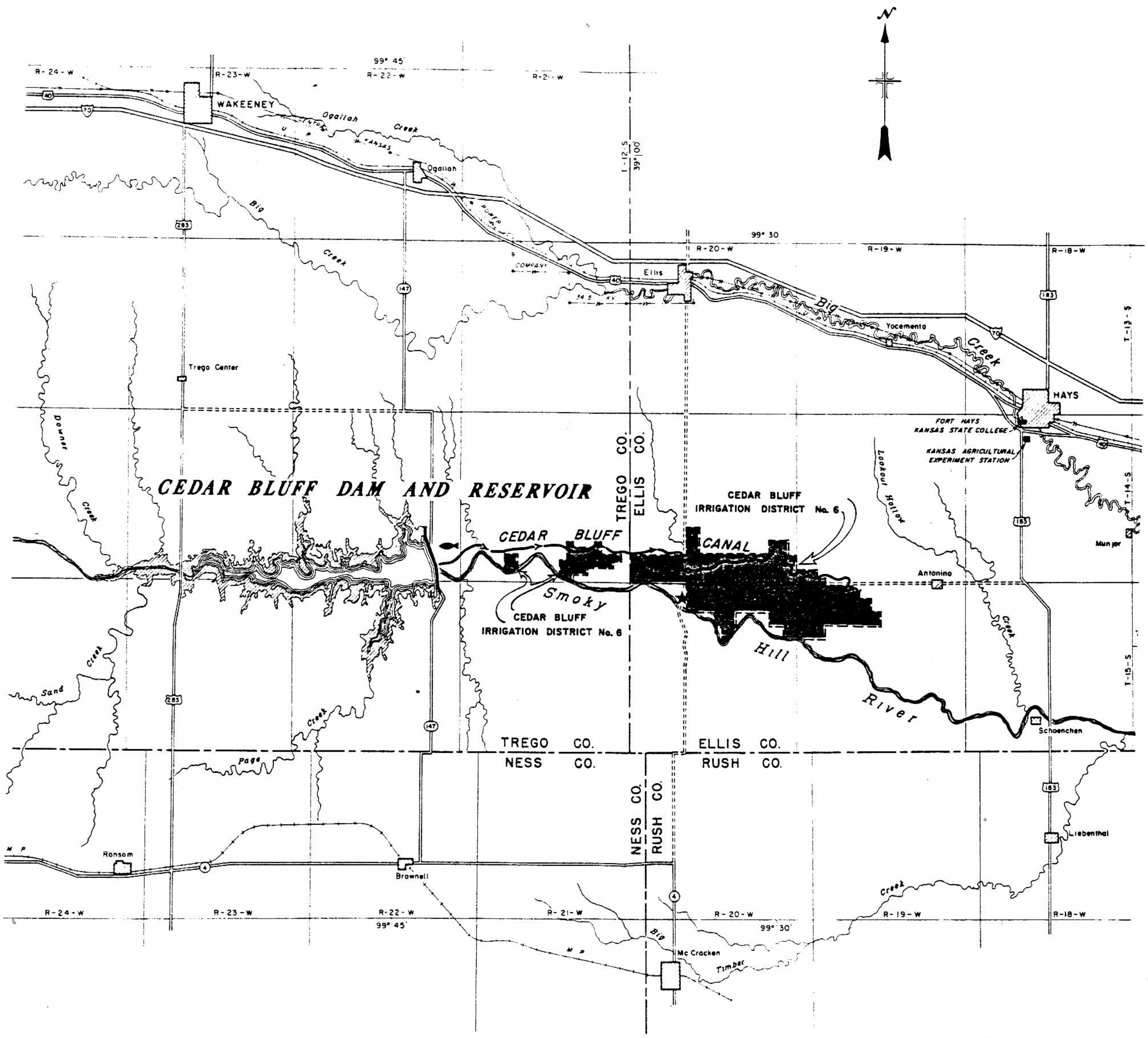

Figure 1. Cedar Bluff Unit (illustration from Bureau of Reclamation).

Reservoir Storage Acquisition

Tom Stiles
Kansas Water Office

Prior to 1985, Kansas controlled about 740,000 acre-feet of storage in nine reservoirs operated by the Corps of Engineers in the eastern third of the state. That storage had been acquired through contractual arrangements between the State and the Federal government in the 1970s and culminated a massive capital improvement project that originated in the 1950's drought. The Federal government had accelerated its program of flood control through dam construction after the 1951 flood. The state, having endured six years of drought from 1952-57, altered federal law (Water Supply Act of 1958), modified its constitution to allow financing over time for reservoir construction, and signed assurances with the Federal government to be financially responsible for conservation storage added on to flood control projects so that water supply benefits could be realized.

With the completion of Hillsdale Lake, the initial plan for reservoir water supply was complete. The State had made assurances for water supply storage that cost close to $69 million. Some of that storage was split into current and future use allocations with state payments on the future portion deferred until that storage was called into service. About $55 million was financed by the Federal government under the terms of the 1958 Water Supply Act and repaid with interest by Kansas for storage put into immediate use.

The State developed its marketing program to provide a vehicle for selling water from storage to cities, rural water districts, and industries, and to begin recouping the State's investment in this capital venture. By 1985 there were 22 contracts made to users for storage in all lakes but Perry.

Through the State water planning process, a new idea emerged that joined the concepts of water rights, which was the predominant form of water supply in the state, with those of streamflow support by reservoir storage. By 1985, it was well established that water right holders below Federal reservoirs enjoyed a benefit of enhanced flows available for diversion during dry times. These benefits were enjoyed without compensation. However, as had been previously seen in the Verdigris in 1983, the benefiting users could not guarantee those benefits into the future since they had no legal claim to dictate release policy.

The Water Assurance Program was created to rectify the situation through securing the benefits of low flow releases through appropriate compensation by the beneficiaries. One fact that surfaced as this program was developed was the discontinuity in which the State controlled storage in the basins. In some cases, there was a surplus of State-owned supply relative to use; in others, the State owned no storage where users were relying on reservoir releases.

This triggered a second round of storage acquisition. The guiding document was a Memorandum of Understanding between the State and the Corps to acquire the storage. The Corps would determine how much storage was available for reallocation to water supply in nine reservoirs and price that storage as if it were originally authorized for that purpose. This was a major policy since it deviated from current Corps philosophy to price reallocated storage as if the reservoir were built today. The updated cost of storage could exceed the original cost by six-fold. The State, in turn, would establish assurance programs to use the reallocated storage, protect inflows and releases deemed to serve a water quality purpose within the stream (no diversion of those releases), and would pay for the storage on a lump sum cash basis rather than through Federal financing. The agreement was to run from 1986 to 1996.

The first six years saw only two reallocations, one for the Kansas River Assurance Program, using Tuttle Creek storage, and a very small amount of storage in Melvern Reservoir to meet the short-term needs of some nearby communities. After 1991, the State water planning process again examined the issue of storage acquisition that led to the recommendation to fully acquire all available storage in seven of those lakes. Ironically, storage in Toronto and Fall River reservoirs in the Verdigris basin had brought the issue to a head in 1983, and were found, through the reallocation process, to be authorized for water supply releases without compensation. Consequently, users in the Verdigris chose not to form a water assurance district.

The 1993 Legislature called upon the Kansas Water Authority to provide a set of recommendations on how to finance acquisition of the storage. After much deliberation across the state, the Authority recommended use of a temporary sales tax or the State General Fund to pay for the storage, with a fallback position of using bonds. The Authority did not wish to dedicate large portions of the State Water Plan Fund to pay for the storage.

The 1994 Legislature appropriated $13.6 million to acquire storage. The next two years were spent trying to determine the amount of storage that would be available in the four lakes operated by the Tulsa District of the Corps of Engineers, as well as how much storage was to be contracted in Melvern and Pomona by the Marais des Cygnes Water Assurance District.

Currently, about 178,000 acre feet of storage is being acquired in the seven lakes. This acquisition is being financed through the $13.6 million appropriation as well as a $2.1 million loan from the Pooled Money Investment Board. The State Water Plan Fund will repay the loan as well as pay the operation and maintenance costs associated with the storage. These payments will exceed $600,000 annually.

Additionally, another loan is anticipated to finance the acquisition of 7,000 acre feet of the existing pool at Kanopolis Lake, as well as another 10,000 acre feet available once the pool is raised by 2 feet.

In a separate matter, the State also has acquired control of storage at Cedar Bluff, ostensibly to adjust the use of that depleted lake from irrigation support to securing the recreation potential at the lake. The financial obligations associated with Cedar Bluff mirror its diminished state, only about $35,000 per year.

Future issues regarding storage will center on minimizing sediment that reduces the volume of storage, regional water supply systems centered around these reservoirs, decisions as to when to call future allocations of storage into service (notably at Milford and Perry lakes), and questions of acquisition at Bureau lakes, as has been proposed by the Irrigation Districts. Wilson Lake is scheduled to undergo an analysis of its potential availability this fall. With the completion of storage acquisition, the State finds itself in a very strong position to support water supply for generations to come.

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Ogallala Formation

No discussion of irrigation on the High Plains is complete without mention of the Ogallala Formation. Stretching 800 miles from the Badlands of South Dakota to the tall buildings of Midland, Texas, and spanning a width of almost 400 miles in places, the Ogallala underlies that vast area once labeled the "Great American Desert" (Fig. 1). It has provided enough water to towns, industry, and thirsty crops to belie this notion of early explorers and map makers.

The Ogallala Formation was named for outcrops near the former cowtown of Ogallala in western Nebraska, and was deposited during the Pliocene (2-5 million years ago). The Ogallala is a thick deposit of a variety of rock types that were washed onto the Great Plains when the Rocky Mountains to the west were uplifted. Streams flowing eastward quickly lost the energy the steep slopes of the mountains provided and entered the drier climate of the plains, which did little to supplement their flow. As a result, these streams became less able to carry the heavy sediment load they brought out of the mountains, and began to drop this sediment in the valleys. They became aggrading streams--streams that tend to build up their river beds rather than dig them deeper. These early valleys were filled with sediment and the streams spilled out over their divides, eventually joining other streams that were also filling up their valleys. In time, these coalescing and branching streams completely filled in the earlier landscape, creating a vast alluvial plain stretching to the east from the Rockies for hundreds of miles.

The Ogallala is mostly composed of the rock fragments weathered from the Rocky Mountains. The sizes of these fragments range from clays to boulders. Some layers of the Ogallala are cemented with calcareous cement and are referred to as the "mortar beds." Where one of these mortar beds forms a prominent escarpment it is often called the "caprock." Much of the Ogallala is poorly cemented sand and gravel, which makes it an excellent aquifer where it is saturated by ground water.

During much of its history, the Ogallala has been soaking up the small amounts of precipitation that has fallen and percolated down into it. Recharge rates are low -- maybe less than one inch per year -- but with enough time it can accumulate several hundred feet of saturated thickness. It has also soaked up many of the streams that have flowed across it. In this way, it has become an important water resource and the principal geologic unit in what geohydrologists call the High Plains Aquifer.

The Ogallala is found throughout much of the western third of Kansas with outliers occurring as far east as Marion County. It is thickest in southwestern Kansas where it reaches 600 feet in thickness. The upper boundary of the Ogallala is often difficult to determine because younger Pleistocene and Recent sediments, with very similar characteristics, overlie the Ogallala. Water does not discriminate between these two ages of sediment either, and moves freely across this time boundary. Thus, these two ages of rocks are said to be in hydrologic connection. The same can be said of the valley fill deposits of modern streams that have cut down into older deposits. All these sediments -- modern, Quaternary, Ogallala, and even some older rocks that underlie the Ogallala -- constitute one large hydrologically connected ground-water resource known as the High Plains Aquifer.

For the most part, water quality from the Ogallala Formation is good, but water quantity is a much larger issue. The bulk of the water pumped from the Ogallala in Kansas is for irrigation. Flood irrigation, or flooding fields through pipe, began in the early 1900s and was common mid-1900s, when center pivot systems were developed. These systems, in which large sprinklers move around fields, usually a quarter-section, allowed irrigation in areas, such as slightly hilly terrain, that were not suitable for flood irrigation. As a result, irrigation increased rapidly in the 1950s, 1960s, and 1970s.

A 1953, Kansas Geological Survey report on water use from the Ogallala in Sherman County said that, "Ground water is being used to some extent for irrigation, and that this use will increase in the future is probable. At the present rate of withdrawal, the danger of seriously depleting the water supply is slight . . ." Rates of withdrawal increased dramatically, however, and declines in water levels soon became apparent throughout western Kansas. The Kansas Geological Survey, the Division of Water Resources of the State Dept. of Agriculture, and the U.S. Geological Survey now make annual measurements of ground-water levels in the High Plains aquifer, measuring approximately 1,500 water wells in western and central Kansas in January of each year, once water levels have stabilized from the previous season's pumping. The Kansas Geological Survey publishes these water-level change data annually.

These measurements show that declines in the High Plains aquifer in southwestern Kansas have been pronounced. Some parts of Grant County have seen declines of as much as 150 feet from pre-development to the present; that represents about a 50 percent decline in the saturated thickness. Total drawdowns have been somewhat less in west-central Kansas, where the saturated thickness is less. Parts of Wichita and Greeley counties have experienced declines of 25 to 50 feet since pre-development; again, that is about a 50 percent decline in the saturated thickness. Declines in northwestern Kansas have been most substantial in Sherman and Sheridan counties, where they have been as much as 50 to 75 feet since pre-development, or 25 to 50 percent decline in saturated thickness. Absolute and percentage declines have been substantially less in south-central Kansas, where precipitation and recharge are greater. More detailed information on specific wells is contained in the annual water level report published by the Kansas Geological Survey.

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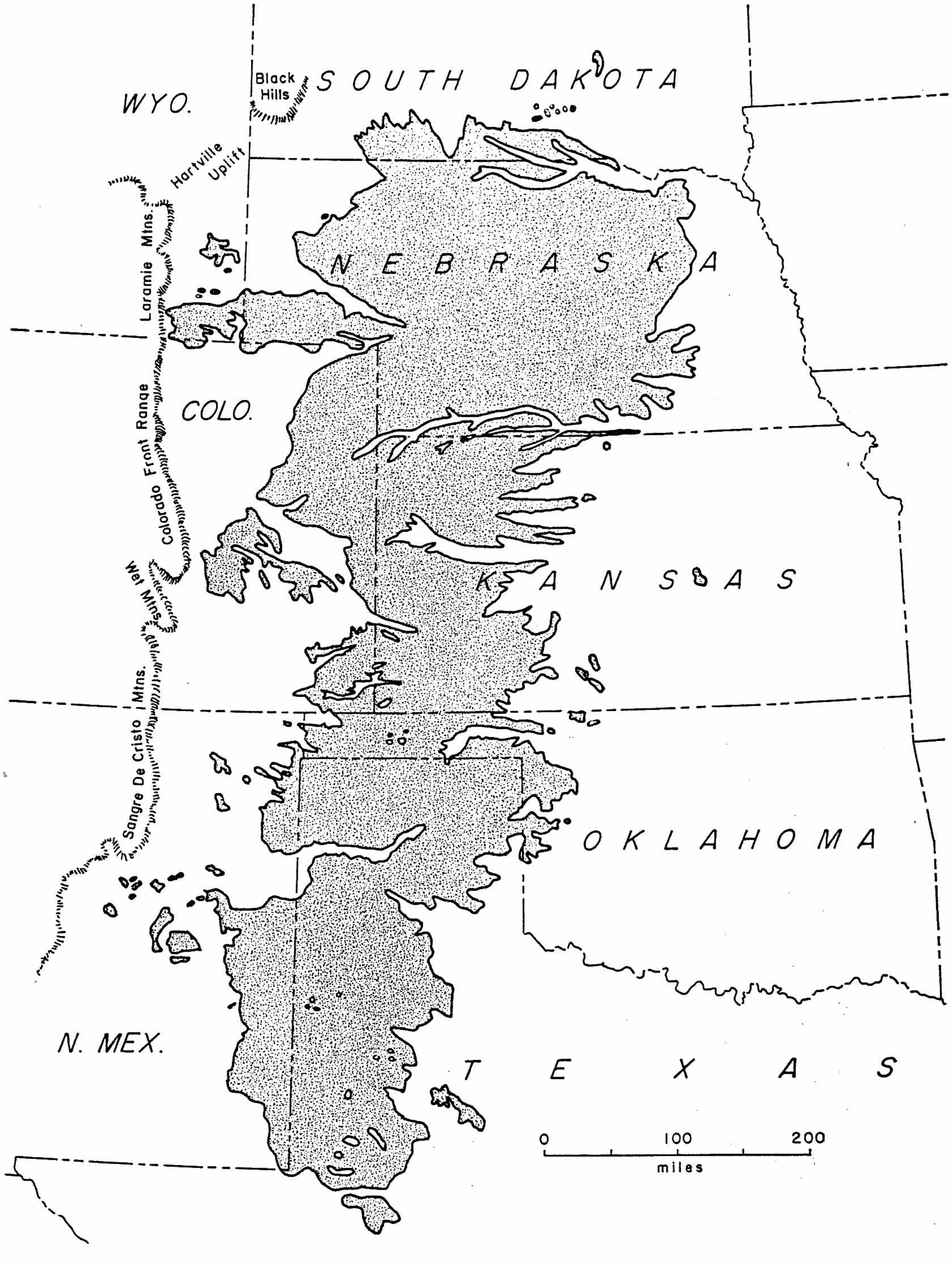

Figure 1. Distribution of the Ogallala Formation in the Great Plains (from Merriam, 1963).

The Arkansas River

The Arkansas River drains much of the southern half of the state and, together with the Kansas River watershed to the north, forms one of the two major drainages in the state. Unlike the Kansas, which drains into the Missouri River, the Arkansas flows to the south and joins the Mississippi River in southeastern Arkansas. At 1,459 miles, the Arkansas is the third longest river in the continental U.S.; it drains more than 160,000 square miles. The river gets its start in Lake County, Colorado, near the town of Leadville, and passes through the Royal Gorge at Canon City. It enters Kansas near Coolidge in Hamilton County and drains generally southeast. In Ford County it heads northeast before making the big loop at Great Bend and moving generally southeast again before leaving the state in Cowley County.

The elevation at the river's edge at Dodge City is 2,483 feet, well above other major rivers in southwestern Kansas. At Garden City, the Ark's elevation is 2,830 feet, or about 200 feet higher than the Smoky Hill River, to the north, or the Cimarron River, to the south, in spite of the fact that the Arkansas enters Kansas at a lower elevation than the other two rivers. That means that the Arkansas has a much less steep course than the other streams. Because the Ark receives little additional flow as it moves onto the High Plains, it drops the load of sediment that it carried out of the mountains, becoming an aggrading stream, which builds up its river bed, instead of a degrading stream, one that is cutting into its channel.

In southwestern Kansas, the Arkansas has been used for irrigation since the 1880s, when ditches were constructed to take water from the river. In addition, a number of wells were dug that took water out of the alluvial aquifer, or the water-bearing sand and gravel deposits that are adjacent to the river. In a 1913 report, Erasmus Haworth, then director of the Kansas Geological Survey, wrote that "the water table throughout the valley is so near the surface an inexhaustible amount of water is available, and therefore there is no practical need of being concerned as to the actual amount of water-bearing sand, for the water will never become exhausted by pumping."

But water is a problem in the Ark River valley. In Kansas, flow in the river decreased throughout the 20th century, until, by the late 1960s and early 1970s, it ceased flowing completely through the state altogether. Except for extremely wet years or times of heavy snow-melt in the Rockies (as occurred in 1995), the river is usually dry from about western Finney County until it begins to flow again near Great Bend. That lack of streamflow is caused by a combination of factors. Increased irrigation in eastern Colorado and southwestern Kansas has lowered water tables in the alluvial and Ogallala aquifers, so that less water is available to flow from the aquifers back into the river during times of low streamflow. In addition, the use of water for irrigation and construction of several large reservoirs in eastern Colorado has increased evaporation and made less water available for streamflow to Kansas.

Today a small amount of water (usually 100-200 cubic feet per second) flows in the Arkansas River across the state line. It is released from John Martin Reservoir, just across the border in eastern Colorado, into the Arkansas. That flow begins to disappear around Lakin, in Kearny County, because irrigation ditches divert the water onto fields. That remaining water soaks into the alluvial aquifer. The lack of water in the river led to a well-known court case that began in 1985 when Kansas filed suit against Colorado for failing to live up to terms of an interstate compact between the two states concerning water in the river. In May 1995, the U.S. Supreme Court ruled in Kansas' favor when it determined that wells in eastern Colorado were pumping too much water from the alluvial aquifer and causing the lessened streamflows. The court is now determining remedies for the problem, which may eventually lead to increased flows in the Arkansas.

The quantity of water in the river is not the only issue, however. Recent research has shown that the quality of Ark River water is also a problem. When it enters Kansas, water in the river is slightly salty because much of the streamflow is made up of return flow, or water that was used for irrigation. As the water moves over fields and back into the river, evaporation concentrates salts in the water. The large reservoirs that were built on the Arkansas in Colorado also contribute to evaporation and cause increased salinity. That slightly salty water is a problem because it moves from the river, into the alluvial aquifer. Salinity levels are not extremely high (total dissolved solids concentrations are typically 2,000-4,000 mg/L). The water can still be used for irrigation because it is usually used with fresh ground water on fields, but it is a problem in situations where high-quality ground water is necessary for manufacturing, for meat packing, and for domestic uses. However, as the saline water moves into the underlying aquifer and slowly increases its salinity, it may cause difficulties in irrigation. Additional releases of water from Colorado may help dilute the river salinity in the future, but salinity will probably continue to be a problem.

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Ground-Water Quality Issues for the High Plains

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Aquifers in the High Plains of Kansas yield large amounts of high-quality freshwater for a variety of uses. The main limitation on the quantity of ground water is salinity. Although most of the water in the High Plains aquifer is fresh, natural saltwater intrudes from underlying Permian bedrock to the Quaternary aquifer in parts of the eastern Great Bend Prairie and western Equus Beds areas, and to the Ogallala aquifer in southeastern Seward and southwestern Meade counties. Saltwater, also from the underlying Permian rocks, renders large areas of the Dakota aquifer unusable in northwestern and north-central Kansas.

The most prevalent water-quality problem caused by human intervention in the High Plains is also salinity. Vertical and lateral movement of natural salinity is enhanced in south-central Kansas, where ground-water withdrawals have changed hydraulic heads. Evapotranspiration concentration of freshwater or slightly saline water, primarily by irrigation use, has produced saline return flow and infiltration. This is the main cause of salinity in the Arkansas River in Colorado. This flow enters southwestern Kansas, infiltrates to the alluvium, and is migrating to the Ogallala aquifer as a result of declining water tables. Salinity increases also occur in shallow ground water from direct recharge of irrigation water concentrated by evapotranspiration. As shallow ground water migrates deeper into the aquifer, or as deep naturally saline water is drawn upward by pumping wells, salinity increases as a result of recycling and mixing. Other sources of salinity from human activities are more local and include oil-field brine contamination and dissolved salt used in water softeners.

Another ground-water quality concern is elevated nitrate concentration derived primarily from agricultural activities and human waste. The main agricultural nitrate sources are fertilizer, animal waste, and oxidation of nitrogen in soil organic matter after the soil has been disturbed. Nitrate contamination occurs more commonly in rural areas, beneath cultivated fields or livestock concentrations, and near homes and farms. Nitrate levels are often higher in alluvial valleys where water tables are shallow. Poor well construction in the past and open abandoned water wells have often led to local nitrate contamination from the surface or shallow subsurface.

Pollution by organic compounds is less widespread, but of greater economic importance, than elevated nitrate concentrations. Petroleum products and synthetic organic chemicals, especially halogenated hydrocarbons, have entered some aquifers from waste disposal, leaks, and spills and rendered public supplies of ground water unusable. These problems are generally located in urban areas and costs for remediation, or replacement supplies, are usually great. Pesticides are present in detectable concentrations in isolated locations of the High Plains aquifer with shallow water tables, but currently do not appear to be a major problem.

Future water-quality issues include increases in salinity from continued consumptive losses of water that concentrate existing dissolved solids, and migration of saline waters into freshwater aquifers due to water-level declines. The latter will be exacerbated during extended droughts because of decreased recharge and increased pumping withdrawals. Slow increases in nitrate levels may also occur unless fertilizer use is managed to prevent leaching below the root zone. It is unknown whether pesticides or toxic degradation products persist long enough in the shallow ground water and unsaturated zone to reach the aquifer depths pumped by wells.

Kansas Geological Survey

Public Information Circular 1

April 1995

A User's Guide to Well-spacing Requirements for the Dakota Aquifer in Kansas

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Introduction

This publication provides current and potential users of water from the Dakota aquifer in Kansas with a summary of the 1994 well-spacing requirements adopted by the Chief Engineer of the Division of Water Resources, Kansas Department of Agriculture, and explains the basis for these new requirements.

The Kansas Geological Survey provides information on the Dakota aquifer to Kansans interested in developing water supplies or in learning more about the aquifer. The Survey also advises State and local agencies on issues related to the Dakota aquifer and other water resources in the state. The Dakota Aquifer Program is a long-term project being conducted by the Kansas Geological Survey to assess the water-resource potential and planning needs of the Dakota aquifer.

Further information on the topics covered in this pamphlet can be found in the publication *Kansas Ground Water* (Kansas Geological Survey, Educational Series 10), compiled by Rex Buchanan and Robert Buddemeier. Additional information on the Dakota aquifer can be obtained by contacting the Geohydrology Section at the Kansas Geological Survey.

Characteristics of the Dakota Aquifer

The Dakota aquifer underlies most of the western two-thirds of Kansas (figure 1). The geologic units that collectively form the Dakota aquifer belong to the Dakota Formation, the Kiowa Formation, and the Cheyenne Sandstone (figure 2). Not all of these units are present throughout the aquifer's extent. The combined thickness of these units may be more than 700 feet (210 m) in west-central parts of the state. Not all of the units that constitute the Dakota aquifer contain aquifer-grade material (usually sandstone)

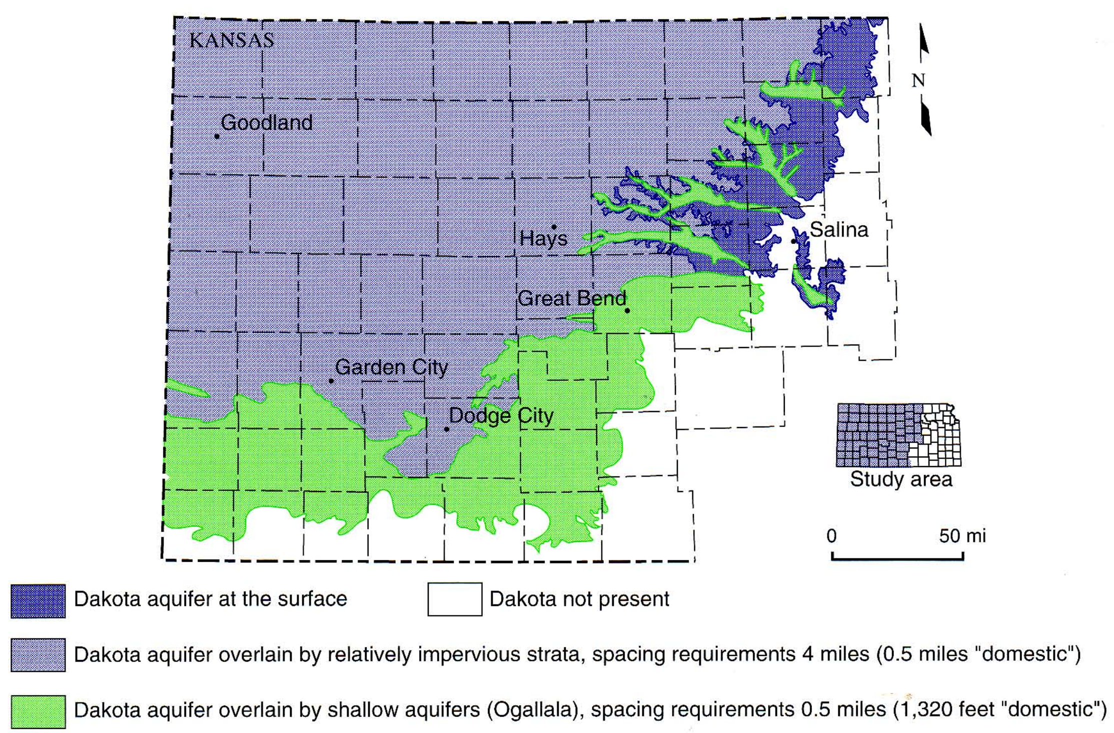

Figure 1—The Dakota aquifer in Kansas.

Further information can be found in the publication *Kansas Ground Water* (Kansas Geological Survey, Educational Series 10), compiled by Rex Buchanan and Robert Buddemeier

The amount of sandstone in the Dakota aquifer varies from less than 70 feet to more than 350 feet of the total thickness

In northwestern Kansas, recharge from precipitation in this part of the Dakota aquifer is negligible, except where the impervious layer is very thin near its eastern and southern extents

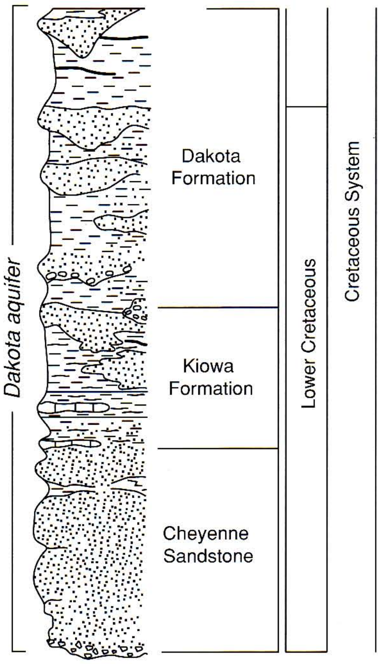

Figure 2—Geologic units of the Dakota aquifer.

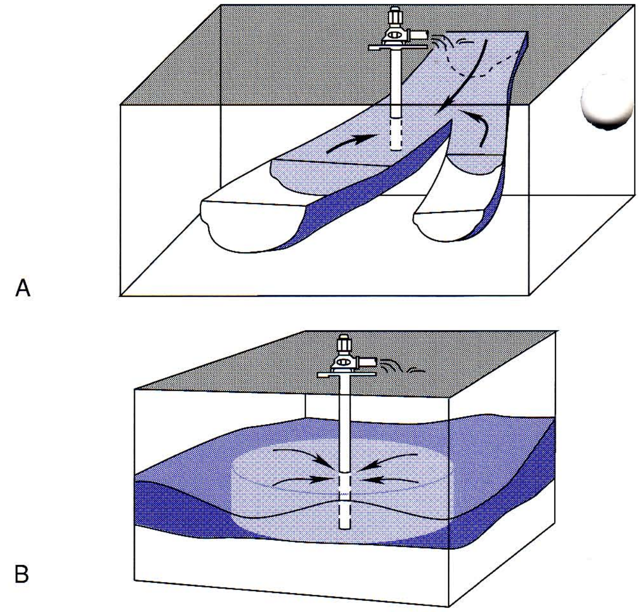

Figure 3—Irregular sandstone bodies. A) river-deposited sandstones, B) shoreline sandstones. Arrows represent flow toward the well. Lighter shading represents the volume affected by pumping a single well.

that can yield water to wells. The amount of sandstone in the Dakota aquifer varies from less than 70 feet (21m) to more than 350 feet (107m) of the total thickness. Variations in thickness can change over very short lateral distances. Statewide, the average amount of sandstone is about one-third of the entire thickness. The sandstones occur as irregular, discontinuous bodies within relatively *impervious* (incapable of transmitting fluids) shaly strata and generally occur in several, more or less distinct zones within the geologic units (figure 2).

These irregular sandstone bodies were deposited during the early part of the Cretaceous Period of geologic history (approximately 90–100 million years ago) in river valleys and along ancient shorelines. Seas eventually covered most of what is now Kansas and the exposed land surfaces laid to the east. The river-deposited sandstone bodies occur in the lower two-thirds of the Dakota Formation and the Cheyenne Sandstone. They are ribbonlike in shape (figure 3A) and are up to 20 miles (32 km) in length, 1.5 miles (2.4 km) wide, and can be over 100 feet (30 m) thick. With some exceptions, these sandstone bodies are oriented in an east-west direction, parallel to the drainage direction. The shoreline sandstone bodies occur in the upper Dakota Formation and the Kiowa Formation. They are usually thin and sheetlike (figure 3B), typically up to 50 feet (15 m) thick and covering several square miles. The long axes of these sandstone bodies tend to be oriented in a north-south direction, parallel to the orientation of the ancient shorelines. In central Kansas, river-deposited sandstones dominate the upper part of the Dakota aquifer, but in western Kansas near the Kansas–Colorado border, shoreline sandstones are more dominant in the upper part of the aquifer. Both river-deposited and shoreline sandstones occur in the lower part of the Dakota aquifer throughout its extent.

Sources of Freshwater Recharge for the Dakota Aquifer

Figure 1 illustrates the areal extent of the Dakota aquifer in Kansas. At its eastern extent in central Kansas, the Dakota is a shallow aquifer that is at or near the surface. In this area, precipitation enters the aquifer directly, adding *recharge* (replenishment of the aquifer with water, usually a direct or indirect result of precipitation). In parts of southwestern and south-central Kansas, the Dakota aquifer is directly beneath the water-saturated Ogallala aquifer (figure 4A). Research shows that both aquifers behaved largely as a single system prior to water-well development. Near the Kansas–Colorado border in areas unaffected by pumping, the Dakota aquifer recharges the Ogallala aquifer, but farther to the east, the Ogallala recharges the Dakota. In northwestern Kansas, the Dakota aquifer is overlain by a sequence of relatively impervious shales and chalks that are up to 2,000 feet (600 m) thick in the northwest corner of the state. Recharge from precipitation in this part of the aquifer is negligible, except where this impervious layer is very thin near its eastern and southern extents (figure 4B).

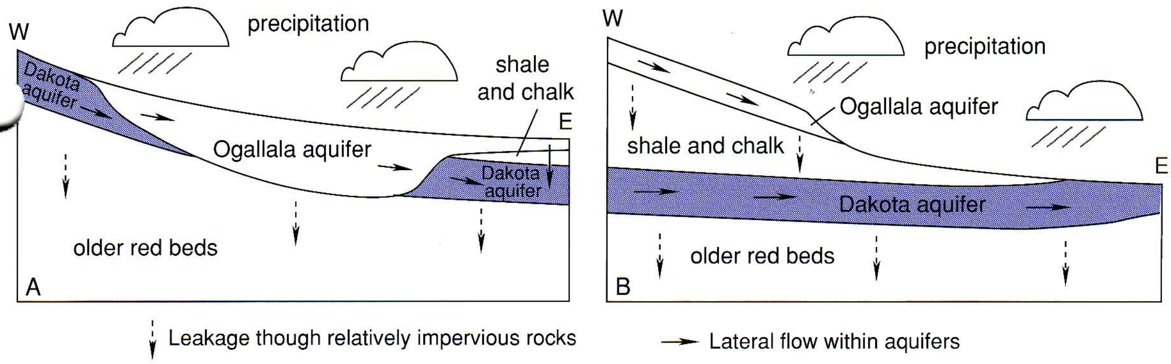

Figure 4—Ground-water flow. Diagrams not to scale.

The size of the cone of depression and the amount of drawdown depend on the pumping rate and the ability of the aquifer's material to transmit water to the pumping well

New Well-spacing Requirements for the Dakota Aquifer in Kansas

In 1994, the Division of Water Resources of the Kansas Department of Agriculture, the State agency that regulates water-well development, modified the existing well-spacing requirements for the Dakota aquifer based on research results from the Dakota Aquifer Program. Well-spacing requirements are based on the aquifer's recharge capabilities and flow rates.

- *Where the Dakota aquifer is at the surface or beneath the Ogallala aquifer (generally areas of rapid recharge), the new-well spacing is 0.5 mile (0.8 km) for all wells other than domestic, and 1,320 feet (396 m) for domestic wells.*

- *The new-well spacing where the Dakota aquifer is overlain by impervious rock units (generally very slow recharge) is 4 miles (6.4 km) for all wells other than domestic, and 0.5 mile (0.8 km) for domestic wells.*

What Happens When the Pump Is Turned On?

When the pump is turned on, the water level drops in the well and in the aquifer adjacent to the well being produced. The *drawdown* is the decline of water level observed in wells screened in the aquifer being pumped. The amount of drawdown is at a maximum at the pumping well and diminishes to zero some distance away. The region affected by drawdown from pumping is called the *cone of depression* (figure 5). The size of the cone of depression and the drawdown will increase until there is a balance between the pumping rate and the flow into the well from the surrounding aquifer. Once the pump is turned off, the cone of depression diminishes in size and water levels will recover to near pre-pumping levels as flow continues to move into that portion of the aquifer affected by drawdown.

The size of the cone of depression and the amount of drawdown depend on the pumping rate and the ability of the aquifer's material to transmit water to the pumping well. The aquifer's ability to transmit water to the well is directly related to its *permeability* (the capacity of a porous material for transmitting a fluid) and total thickness. Aquifer materials that are more permeable and have greater thicknesses allow larger volumes of water to flow toward the pumping well.

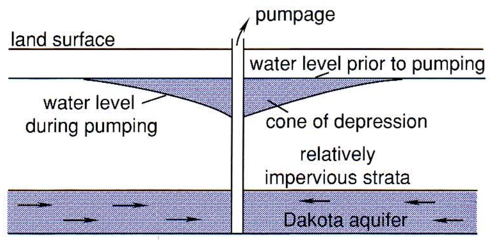

Figure 5—Cone of depression resulting from drawdown from pumping.

Sandstones of the Dakota aquifer in the far western part of the state are 50–100 times less permeable to the flow of water than the uncemented, coarser sands and gravels in shallower aquifers such as the Ogallala

What Happens in the Dakota Aquifer When the Pump Is Turned On?

Sandstones of the Dakota aquifer in the western part of the state consist of cemented, fine to very fine sand grains. In general, this aquifer material is 50–100 times less permeable to the flow of water than the uncemented, coarser sands and gravels in shallower aquifers such as the Ogallala. These permeability differences indicate that a pumping well in the Dakota aquifer will produce a significantly greater amount of drawdown than would a well in the shallower Ogallala aquifers being pumped at the same rate. In some parts of central Kansas, the permeability of the thicker river-deposited sandstones of the Dakota aquifer may approach the permeability of these shallower aquifers.

Sandstone aquifers in the Dakota are also much smaller in extent and thickness than the Ogallala aquifer. The Dakota aquifer can be thought of as a complex natural plumbing system consisting of sandstone bodies, some of which are connected to each other and which transmit water for considerable distances. If all the sandstone bodies in a local area are connected, then water flows from all these bodies toward the well (figure 3A).

The shape of the cone of depression depends on the shape of the sandstone bodies that are connected to the well. Depending on the rate and duration of pumping, the cone of depression of a river-deposited sandstone can extend along the length of the sandstone body for several miles and may extend into other sandstone bodies (figure 3A). This exaggeration of the cone of depression along the sandstone body occurs because the relatively impervious shaly rock surrounding it contributes no water to the pumping well. The result is a cone of depression with a linear or irregular shape. In the sheetlike shoreline sandstone bodies, the shape of the cone of depression is usually more circular (figure 3B).

The Dakota aquifer can be thought of as a complex natural plumbing system consisting of sandstone bodies, some of which are connected to each other and which transmit water for considerable distances.

Effect of Pumping Multiple Wells on the Dakota Aquifer

If multiple wells in the Dakota aquifer are withdrawing water from the same sandstone body, their cones of depression will probably overlap and coalesce (figure 6). This is because of the relatively small size of the sandstone bodies. If multiple wells operate simultaneously for some time, the aquifer may not be able to adequately replace the withdrawn water with recharge, resulting in water-level declines.

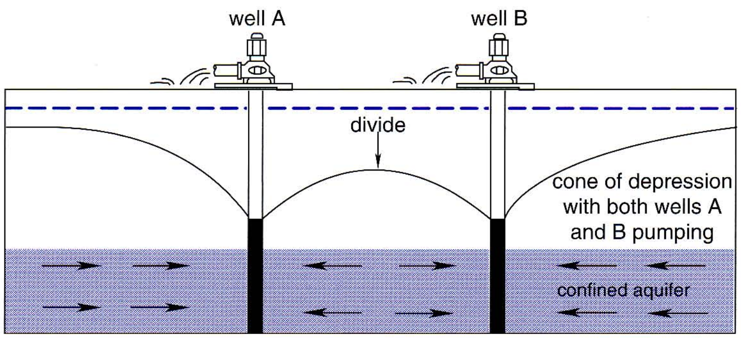

Figure 6—When two nearby wells are pumping, they each create a cone of depression, which overlaps. Note the flow moving in both directions between the pumping wells.

Rationale for Well-spacing Requirements

The water resources of Kansas are managed by the Division of Water Resources using the concept of safe yield. *Safe yield* is the long-term sustainable yield of the source of supply including hydraulically connected surface water and ground water. Thus, the total amount of water pumped from an aquifer should be less than the net recharge so as not to deplete the aquifer. The purpose of well-spacing requirements is to ensure that additional wells using the Dakota aquifer as a source of supply do not impair the supply of water to existing wells.

Impairment can also result from over-development of the entire aquifer. The Dakota aquifer is susceptible to over-development unless the spacing between wells is adequate to avoid overlap in their respective cones of depression. If wells are too close together, they may cause permanent water-level declines and eventual depletion of the aquifer. This is most likely where the Dakota aquifer is overlain by thick, relatively impervious strata. Results from the Dakota Aquifer Program show that there is no significant local freshwater recharge to this part of the aquifer. Consequently, water must come from other parts of the aquifer not affected by pumping. This represents a net loss of water from the aquifer and may cause water-level declines. In areas where the Dakota aquifer is at the surface or is overlain by shallow aquifers, local recharge to the Dakota aquifer from precipitation or from the overlying aquifer is sufficient to justify a denser well spacing.

A denser well spacing for domestic wells is appropriate because they typically operate at low pumping rates and for relatively short periods of time, causing less impact on the aquifer than nondomestic wells pumping at higher rates and for longer periods of time.

The mission of the Kansas Geological Survey, operated by The University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geologic hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.

Public Information Circular 1
April 1995

Kansas Geological Su
Geology Extension
1930 Constant Avenue
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Lawrence, Kansas
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SCHEDULE & ITINERARY

Friday June 14, 1996

7:00 am	Breakfast
7:30 am	Bus to Feed Yards
7:45 am	**SITE 10** - Tour Winter Feed Yard - Feed Yards/Packing Plant Overlook *Ken Winter*, Winter Feed Yard *Al Guernsey,* Kansas Dept. of Health and Environment
8:30 am	Bus to Circle K Ranch
9:15 am	**SITE 11** - Circle K Ranch, Edwards County *Kent Moore*, Water PACK
9:45 am	Bus to Larned
10:30 am	Larned - Rest Stop, Schnack Park
10:45 am	Bus to Walnut Creek
11:15 am	**SITE 12** - Walnut Creek Drainage Basin (no stop) *Bruce Falk,* Division of Water Resources
11:30 am	**SITE 13** - Tour Cheyenne Bottoms Wildlife Area *Karl Grover,* Kansas Department of Wildlife and Parks *Alan Pollom*, State Director, The Nature Conservancy
1:00 pm	Lunch - Cheyenne Bottoms
2:15 pm	Bus to Great Bend
2:30 pm	**Arrive Holiday Inn, Great Bend**

Kansas Livestock Industries

Southwest Kansas provides the climate and resources conducive to development and operation of commercial cattle feedlots, and recently, the development of commercial/corporate hog operations. Low rainfall and humidity, mild winters, abundant ground water, local availability of feed crops such as corn, alfalfa, and milo (many of which depend on irrigation from the Ogallala aquifer), coupled with sparse population, creates the impetus for rapid growth and development of commercial scale operations.

In 1995, according to Kansas Ag Statistics, Kansas ranks first in the number of cattle processed by packers (7.11 million), second in the total number of cattle (6.5 million), and second in fed cattle marketings (5.95 million). Kansas cattle generated $4.24 billion in cash receipts. This figure does not account for feed and other supplies purchased, services, or beef sold.

The major packing plants represented within the southwest portion of the state are Farmland, Excel, Monfort, and IBP, operating facilities within Ford, Finney, and Seward counties. Growth of the packing plant industry (daily kill approximately 24,000 head fat cattle; the Guymon, Oklahoma, Seaboard hog processing plant kills about 5,000 head daily) has also increased growth of the commercial hog and cattle feedlots.

Winter Feed Yard

The Winter Feed Yard opened in 1957. With a capacity of 30,000 head, the feedyard is said to be one of the most modern, highly efficient facilities in the nation. The feedyard and the Kansas Department of Health and Environment work together in efforts to protect the environment. According to the Kansas Livestock Association, the feedyard's waste management system far exceeds State and Federal requirements.

Reference

Pike, A., 1996, Kansas cattle industry an economic powerhouse: Kansas Stockman, May/June, p. 12.

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Walnut Creek Intensive Groundwater Use Control Area

Walnut Creek is one of the two major tributaries of the Arkansas River in the upper Arkansas Basin. Walnut Creek, flowing from west to east, begins in Lane County and empties into the Arkansas River about 5 miles east of Great Bend in Barton County. The drainage area is about 100 miles long and averages 16 miles wide, covering an area of over 1,600 square miles. Walnut Creek is a meandering stream that dominates the hydrologic system in its narrow alluvial valley. The valley is impacted by significant ground-water pumping for irrigation and other uses. The alluvial aquifer is periodically recharged by high flows of short duration.

Land use in the watershed is about 65% cropland and approximately 35% grassland, of which a small portion is urban and roads. Approximately 17,660 acres were irrigated from the alluvial aquifer in 1988. About 23,000 acre-feet of ground water is used each year for irrigation.

Since the early 1960s, the increasing development of ground water in this area has caused serious water resources concerns, such as significant ground-water level fluctuations, diminishing streamflow, and some water quality deterioration. Average annual flow in Walnut Creek went from 60,000 acre feet per year in the early 1960s to about 12,000 in the early 1980s. Ground-water levels in the Walnut Creek valley in Barton and Rush counties declined as much as 18 feet between 1960 and 1982.

In 1992, the decline of ground-water resources and lack of streamflow to satisfy senior surface water rights in the Walnut Creek valley caused the Chief Engineer, Division of Water Resources of the Kansas Department of Agriculture, to declare an Intensive Groundwater Use Control Area (IGUCA) to limit ground-water withdrawals and the affect of those withdrawals on streamflow. The area included within the IGUCA is generally the Walnut Creek valley in Barton, Rush, and Ness counties. That portion in Barton County in the IGUCA is generally north of Dry Walnut Creek and west of the Walnut Creek diversion dam for Cheyenne Bottoms. The total area of the Walnut Creek IGUCA is about 550 square miles.

New appropriation of ground water and surface water has been closed as of 1992, except for domestic use. The IGUCA also enables the Division of Water Resources to intensely manage the water resources in the Walnut Creek watershed. Within the IGUCA, water appropriations have been restricted based upon priority date, and allowable use can be spread over five years, provided the total amount is not exceeded.

The estimated long-term sustainable yield of ground water from the alluvial aquifer was determined to be 22,700 acre-feet per year. The IGUCA order established allocations that restrict the use of ground water under water rights in the IGUCA. Each ground-water right was assigned an allocation of water which covers the five-year period from 1992 to 1996. While a water right may be exercised to its full extent at any time, over the five-year period the allocation defined in the IGUCA order may not be exceeded.

The Kansas Department of Wildlife and Parks holds one of the most senior water rights in the watershed. Wildlife and Parks is allowed to divert up to 19,160 acre-feet of surface water from Walnut Creek each year to supply water to Cheyenne Bottoms Wildlife Area.

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Scherer, M.A., 1996, Walnut Creek Intensive Groundwater Use Control Area Revisited, unpublished abstract.

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Cheyenne Bottoms

Cheyenne Bottoms is a natural basin lying just northeast of Great Bend, and is near the exact geographic center of the state. Rimmed by bedrock on three sides, Cheyenne Bottoms appears like a bullseye on the geologic map of Kansas. It covers 64 square miles; nearly 30 square miles of that is a wildlife management area maintained by the Kansas Department of Wildlife and Parks. Historically, runoff from the natural watershed around Cheyenne Bottoms, about 220 square miles, flows into the lowest areas, creating an intermittent marsh. Because runoff is relatively low and sporadic, the marsh may have been dry about two years in five prior to settlement in the late 1800s. During wet periods, Cheyenne Bottoms probably increased in size to over 40,000 acres.

The State of Kansas began purchasing land in Cheyenne Bottoms following the passage in 1937 of the Pittman-Robertson Act that provided Federal aid to states for wildlife restoration. Much of the work to develop the area was done in the 1950s and Cheyenne Bottoms was dedicated in 1958. The marsh was divided into a series of pools by dikes, and control gates were installed to facilitate water movement into the marsh, between pools, and to the overflow canal. Over the years, canals were dug diverting water from the Arkansas and Walnut rivers into the basin to maintain water levels in the wetlands and secure a habitat for both indigenous waterfowl and the many transient species that stop over during seasonal migrations (Fig. 1).

The International Shorebird Survey, conducted by Manomet Bird Observatory in Massachusetts, concluded that of the 200 wetlands studied, Cheyenne Bottoms is the top shorebird staging area during migration in the 48 contiguous states, attracting almost half of the entire populations of North American shorebirds whose path of migration is east of the Rockies. Some 320 species of birds frequent Cheyenne Bottoms, including the endangered whooping crane, bald eagle, peregrine falcon, least tern, and piping plover.

Geology

The geologic history of Cheyenne Bottoms has been subject to debate among geologists. Eramus Haworth of the early Kansas Geological Survey was the first to speculate in print on the basin's origin, suggesting in 1897 that stream erosion had carved out the elliptical hole in the bedrock. In 1901, W.D. Johnson of the U.S. Geological Survey postulated that dissolution of underground salt beds and subsequent collapse of overlying rocks was the reason for the basin's existence. One author, Bruce Latta of the Kansas Geological Survey, advanced both processes as an explanation for Cheyenne Bottom's current surface expression. Charles Bayne of the KGS, following other studies of salt in central Kansas, studied Cheyenne Bottoms to settle the debate and determine its origin. Bayne interpreted the logs of 230 oil and gas wells in the area and picked the locations where numerous formations in the subsurface came into contact. He then constructed structural contour maps of these surfaces that look much like topographic maps and can be studied to determine the configuration of underground formations. If salt solution were the sole cause of basin formation, only rocks lying above the salt, in this case a layer called the Hutchinson Salt, would be affected. Bayne found that downwarping extends well below the Hutchinson Salt and may extend down to the ancient Precambrian basement rocks.

The youngest rocks affected by the downwarping are outcrops of the Greenhorn Limestone on the northeast rim of Cheyenne Bottoms. These rocks are Late Cretaceous (65-80 million years ago) in age. Channel cutting began in early Pleistocene (2 million years ago). No rocks of intervening age are present to pinpoint the time of basin formation, thus Bayne maintains that structural movement of the rocks occurred sometime between Late Cretaceous and the Pleistocene.

Bayne also points out that molten igneous rocks (kimberlites and lamproites) intruded Permian rocks in Riley County and Pennsylvanian rocks in Woodson County during the Late Cretaceous or sometime later. Subsequent studies around the world have indicated that the end of the Cretaceous and the beginning of the next period, the Tertiary, was a time of cataclysmic change in the earth, including the quick extinction of the dinosaurs. Was formation of Cheyenne Bottoms and the Kansas intrusives somehow related to this cataclysm?

Cheyenne Bottoms Wildlife Management Area

The Kansas Department of Wildlife and Parks operates a 19,857-acre wildlife management area in the southeastern portion of the basin. About 12,000 acres are reliable wetlands. In 1992, Wildlife and Parks began a renovation project to improve the ability to manage water on the state-owned portion of the Bottoms. Renovations and improvements include installation of pumps to facilitate water transfer between pools, dividing pools into smaller units, improving dikes to allow water to be stored in deeper pools, and installing water measurement devices. These improvements are designed to assure some water will be available in storage at all times so that at least 3,000 acres of wetlands can be maintained. With careful management, stored water can be carried over to a second year.

The Nature Conservancy

The Nature Conservancy owns and manages 5,437 acres in the northwest portion of Cheyenne Bottoms. It purchased this part of the marsh in 1990 and 1991. The Conservancy's wetlands management philosophy calls for restoration of the wetland hydrology and native grasslands to their original state for the benefit of the wildlife. The Conservancy recognizes that during most of the year, the marsh is completely dry, and plans to manage the wetlands in the same manner. In contrast, the State's portion of the Bottoms is characterized by deeper pools, managed water levels, and supplementing the natural water supply to the Bottoms with outside water sources. Wildlife and Parks and the Conservancy work closely together at Cheyenne Bottoms. The different management techniques are complementary.

To achieve the Conservancy's restoration goals, three main priorities have been established. First, restore the original hydrology of the area to the extent possible by plugging the drainage systems put in place in the past for agricultural purposes. Second, make the site more accessible to the public, especially for educational purposes. Third, improve the ability to manage the grazing activities necessary to maintain the birds' preferred habitat conditions by mimicking the effect bison had on the habitat. Without grazing to keep the height of the grass down, many of the shorebirds would not use the habitat. Replicating the impact of bison involves flexibility in cattle grazing, so that cattle can be moved on and off the various sections of the preserve as warranted by the conditions of the habitat. This is why, to the surprise of many, The Nature Conservancy is building fences to keep cattle on the preserve, rather than keeping them off.

Another problem that plagues Cheyenne Bottoms is the invasion of non-native plants -- mainly musk thistle, salt cedar, and Russian olive. These plants compete for sunlight, soil, and water resources, to the detriment of native species. The Conservancy believes the most cost-effective and environmentally benign way to remove these invaders is by hand.

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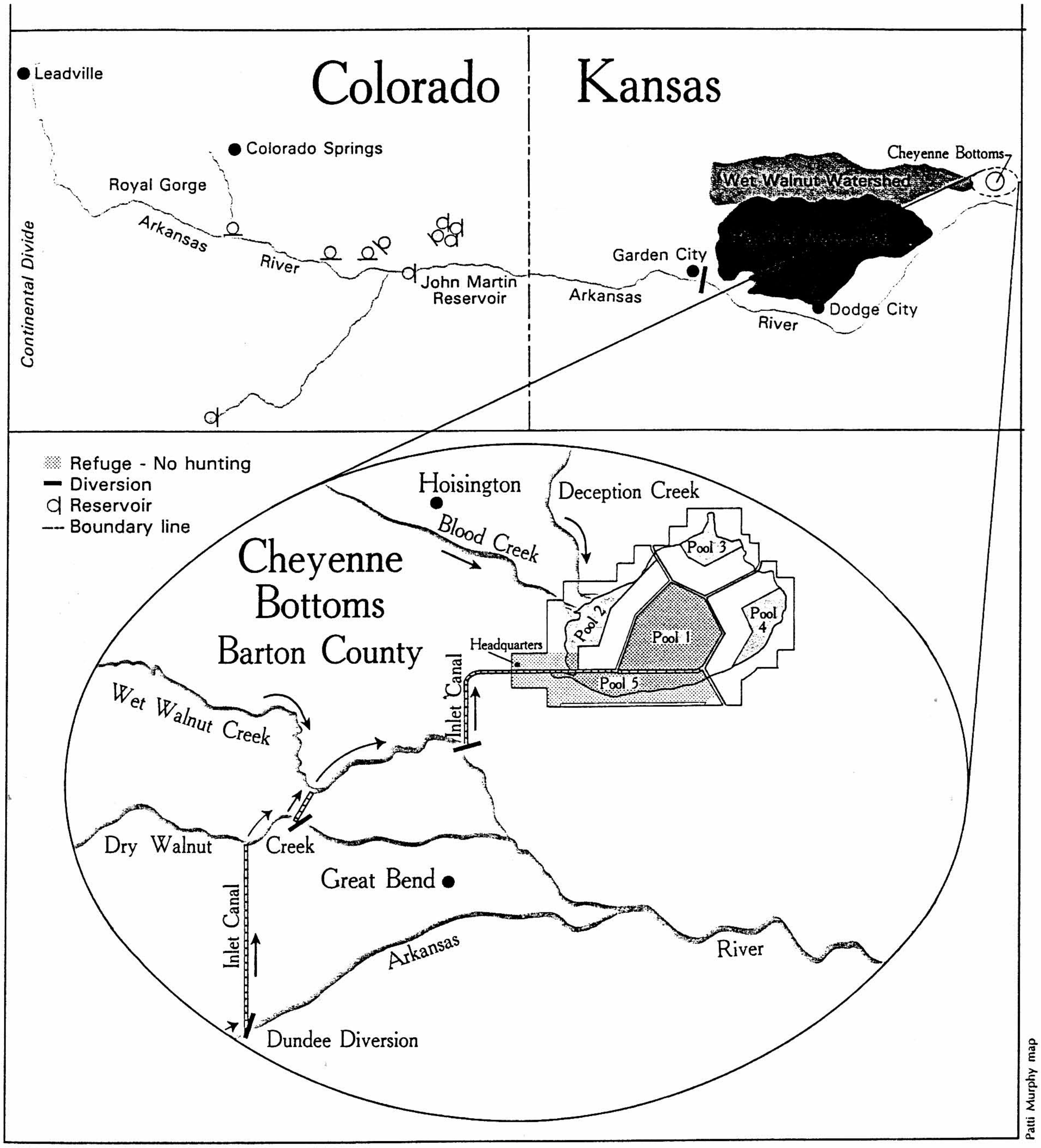

Wildlife & Parks

Figure 1. Cheyenne Bottoms (illustration from Kansas Department of Wildlife and Parks).