UPPER ARKANSAS RIVER CORRIDOR STUDY: PROBLEM IDENTIFICATION, PRELIMINARY RESEARCH, AND FY96 AND FY97 PLANS

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The following text and figures comprise the presentation given at the October 13, 1995 meeting of the Technical Advisory Committee meeting of the Upper Arkansas River Corridor Study. Parts of the presentation were also given at the October board meeting of Southwest Groundwater Management District No. 3 and meetings of the Upper Arkansas River Basin Advisory Committee.

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Figure 1. FY 1995 status of activities. The outline indicates the investigations conducted prior to and during FY 1995 for preparing proposals and work plans for the Upper Arkansas River Corridor Study which started in FY 1996.

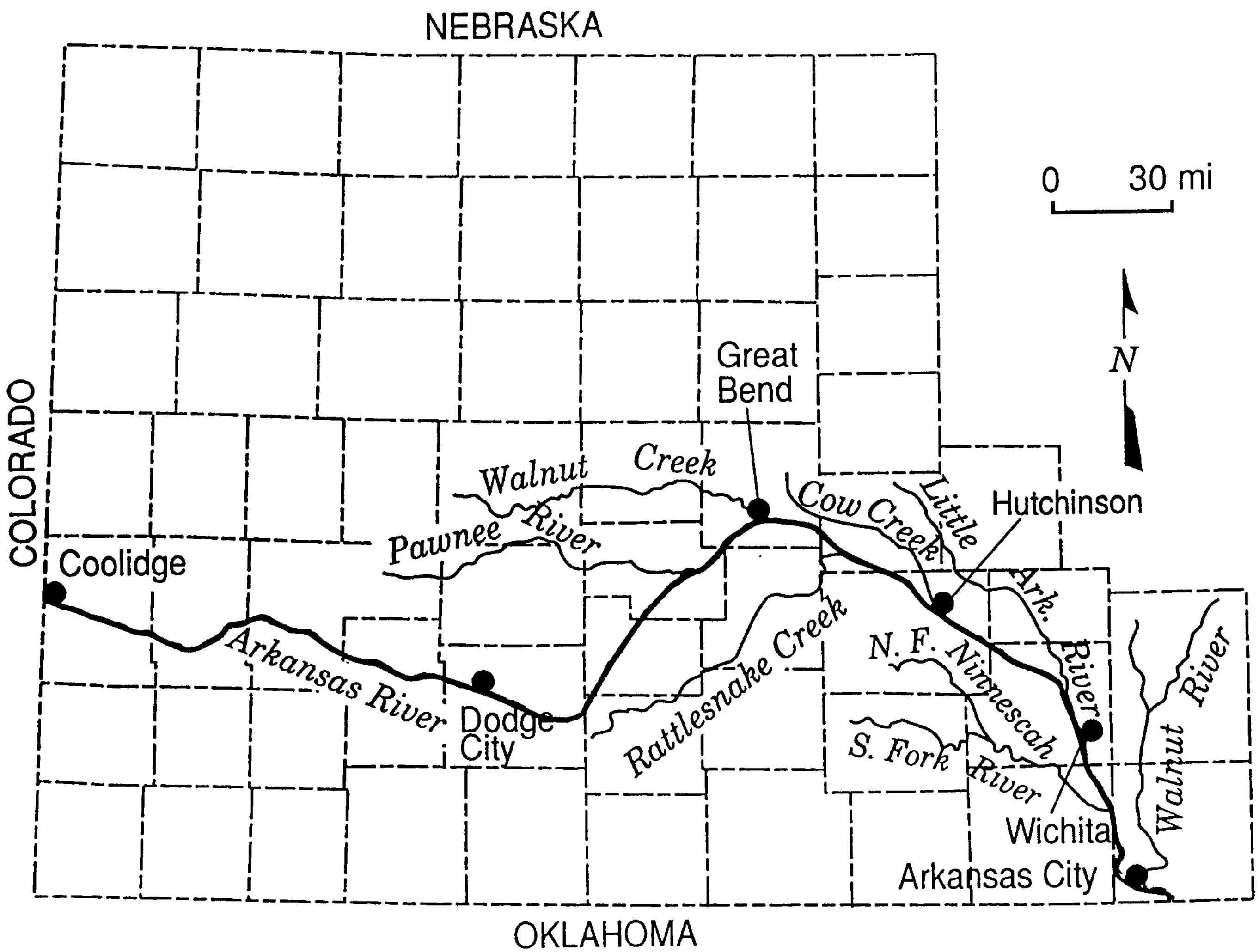
WATER QUALITY AND GROUND-WATER DECLINES IN THE UPPER ARKANSAS RIVER

FY 1995 Status of Activities

1. Identification of problems
    a. Declines in ground-water levels
    b. Decreases in the flow and quality of Arkansas River water
    c. Contamination of corridor aquifer by infiltration and migration of saline river water
    d. Increase in nitrate concentration in corridor aquifer
2. Preliminary work to assist in planning research
    a. Sampling of river waters by Groundwater Management District No. 3
    b. Sampling of irrigation wells by Board of Agriculture
    c. Sample analyses by Kansas Geological Survey
3. Preparation of research plans

Figure 2. Location of the Arkansas River and major tributaries in Kansas.

The Upper Arkansas River Corridor Study involves the valley of the Arkansas River from the Colorado-Kansas state line to just east of Dodge City. The chemistry of the upper Arkansas River is markedly different from that of the lower Arkansas River in Kansas as indicated in Figure 3.



NEBRASKA
COLORADO
OKLAHOMA
0 30 mi
N
Coolidge
Dodge City
Great Bend
Hutchinson
Wichita
Arkansas City
Arkansas River
Walnut Creek
Pawnee River
Rattlesnake Creek
Cow Creek
Little Ark. River
N. F. Ninnescah
S. Fork River
Walnut River

Figure 3. Total dissolved solids concentration and discharge versus Arkansas River miles from Canon City, Colorado for a low-flow period in 1968.

Records for low-flow in 1968 provide information for a period in which the Arkansas River flowed completely through Kansas for the entire year at all locations along the river. The water-quality records are also more complete (exist for a greater number of stations) for 1968 than nearly all prior and post periods. In addition, the flows were relatively stable during this period such that a salinity profile could be represented without large effects from dilution from heavy local rainfall.

Figure 3 indicates the lower discharge and much higher TDS in the Arkansas River in western Kansas in comparison with south-central Kansas. The discharge of the Arkansas River appreciably declined at the John Martin Reservoir, remained relatively constant to Great Bend and substantially increased downstream. The total dissolved solids (TDS) concentration of the river water greatly increased through Colorado, especially from above to just below the John Martin Reservoir, and continued to increase to Coolidge. The main cause of the TDS or salinity increase is the concentration of dissolved constituents by the great loss of water to evapotranspiration. The river water TDS decreased appreciably from Coolidge to Great Bend based on the 1968 records. The greater TDS at Hutchinson than at Great Bend is due to intrusion of natural Permian saltwater, but the increase was much smaller than the increase in TDS in the river water in Colorado. The figure shows how much greater the TDS was in the river in easternmost Colorado and westernmost Kansas than at Hutchinson. The greater flow in the Hutchinson area diluted the effect of the Permian saltwater intrusion. The slightly greater flow at Dodge City and Great Bend than at Coolidge and Syracuse probably resulted from freshwater inputs which diluted the high TDS.

ARKANSAS RIVER IN COLORADO AND KANSAS

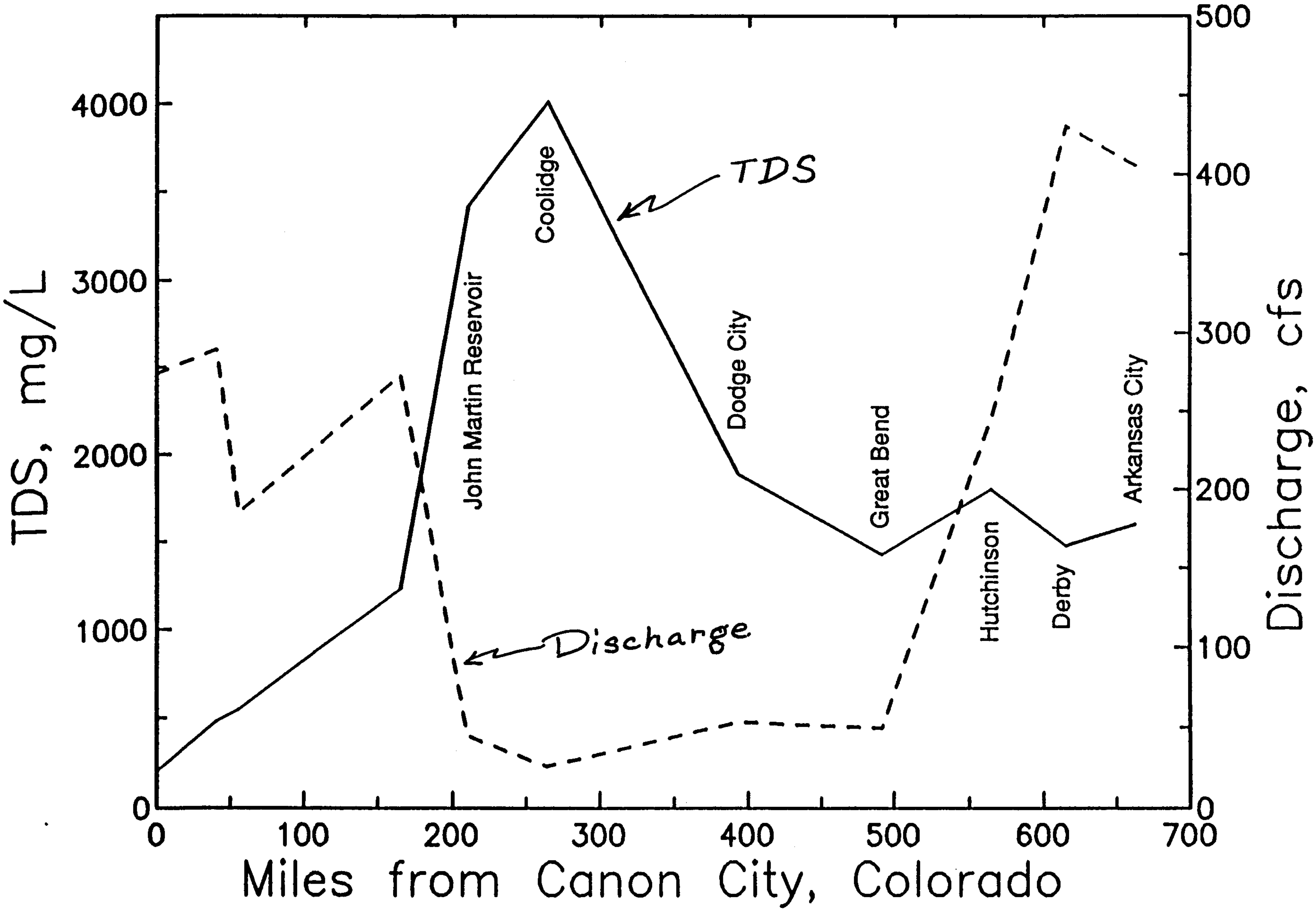


Figure 4. Fate of high total dissolved solids water in current Arkansas River. The text outlines major points important to the current contamination of ground water by saline river water in the upper Arkansas River valley.

WHERE ARE TDS LOADS IN ARKANSAS RIVER GOING?

Inputs from Colorado

Past: Flows increased from Coolidge to Dodge City

Most of TDS load was carried downstream to Oklahoma

Present: Flows usually decrease to zero to Dodge City

Mean annual TDS load at Coolidge is 640,000 metric ton
or 152,000 acre-ft/yr of 3,570 mg/L TDS water
based on water years 1988-1990

Most of TDS load enters and contaminates ground water

Figure 5. Comparison of total annual discharge in the Arkansas River at different gaging stations in western Kansas from 1962 to 1993.

The total annual discharge of the Arkansas River in western Kansas greatly fluctuates depending on the flow from Colorado and local intense rainfall. Peaks in total discharge occurred during 1965 and 1987. A peak for 1995 is also expected based on the comparatively large flows of the summer. The discharges at Coolidge and Syracuse are the same during high and low flows, indicating little loss or gain along the river valley in that section. In comparison, the total annual flows at Garden City and Dodge City are smaller and since 1977 have become negligible except during and immediately following large flow events.

The total annual flows at Dodge City were generally greater than at Garden City for moderate to low total flows in the 1960's but became smaller than at Garden City by the 1980's. By 1975 no flow periods of greater than one month occurred at Dodge City. By 1977 there was essentially no flow in the river at Dodge City for the entire year, except for short periods reflecting heavy local or regional rainfall or parts of 1987-1988 and 1995 when reservoir releases from Colorado provided flow.

The cause of the much lower flows is a combination of smaller amounts of water released by Colorado to Kansas and the effect of the declining water table in the alluvial and Ogallala aquifers to allow increased river-water infiltration. Water now flowing from Colorado passes through the section of the Arkansas River valley from Coolidge to south-central Kearny County without much change due to the restricted size of the alluvial valley cut into bedrock and the absence of the Ogallala Formation. After Kearny County, the flow begins to markedly decrease because ground-water table declines in the Ogallala and alluvial aquifers allow substantial infiltration of river water. As recently as the 1960's, the water-table in the High Plains aquifer along parts of the some river valley may have allowed some ground water to discharge to the river and increased the amount of rainfall runoff appearing as river flow in the valley between Garden City and Dodge City. The opposite occurs now such that most flow passing Garden City infiltrates long before reaching Dodge City.

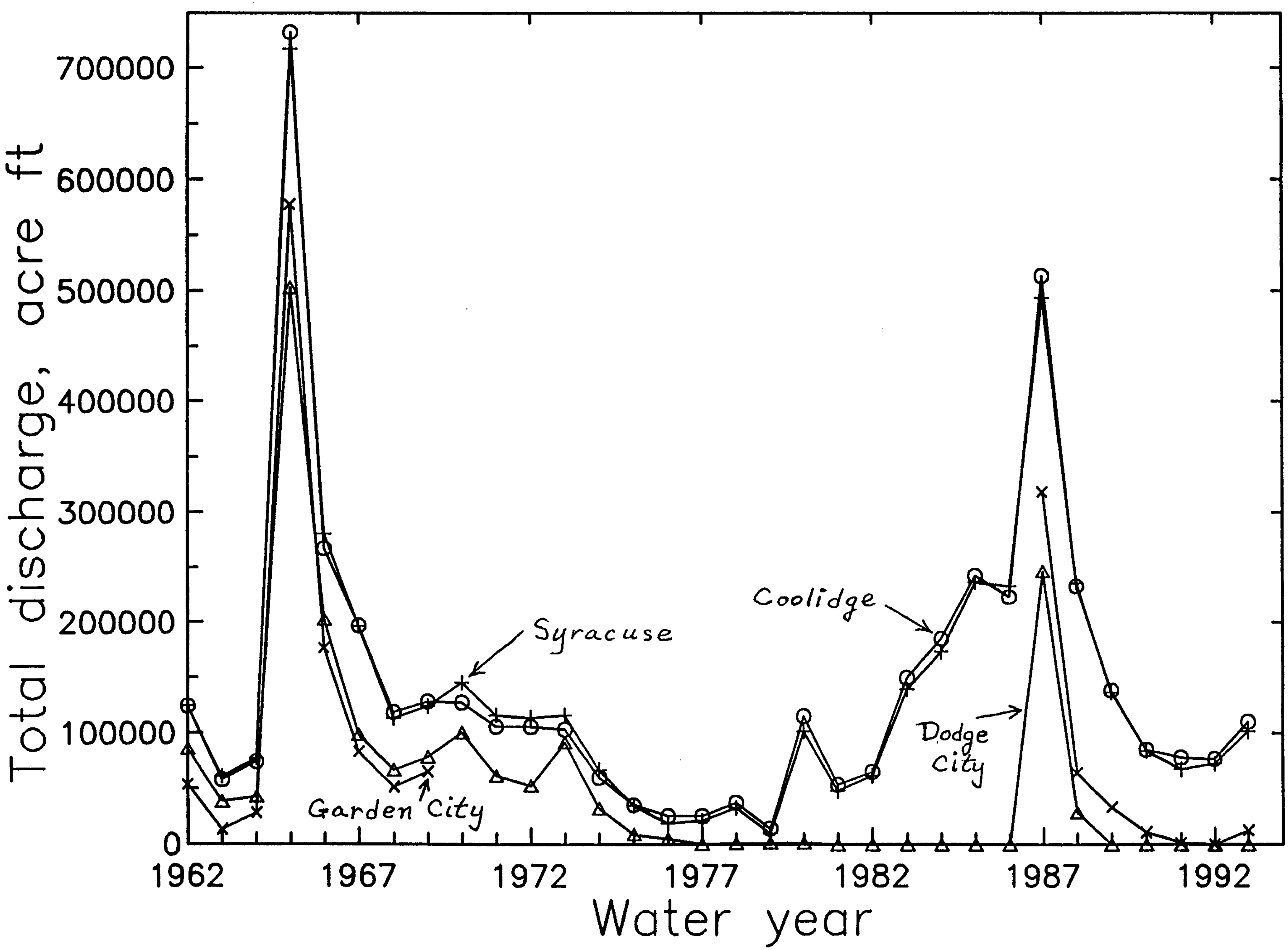

Total discharge, acre ft
700000
600000
500000
400000
300000
200000
100000
0
1962
1967
1972
1977
1982
1987
1992
Water year
Syracuse
Coolidge
Garden City
Dodge City

Figure 6. Increase in total dissolved solids and sulfate concentrations in Arkansas River water at Coolidge from 1906 to 1973 and comparison with concentrations for freshwater limits and uncontaminated ground waters in the Ogallala aquifer.

Historical records of water-quality data for the Arkansas River were examined along with information on discharge to estimate the change in TDS and sulfate concentrations in the river water at Coolidge from 1906 to 1973. The approach involved examination of constituent to discharge ratios at Coolidge and other river sites in order to appropriately compare water quality for similar flow conditions. TDS and sulfate concentrations appear to have doubled during the period. The TDS and sulfate contents of low flows have remained within the same approximate range from 1973 to the present. In the figure, the freshwater value for TDS represents the upper limit at which waters are classified as fresh, and for sulfate indicates the maximum contaminant level proposed by the U.S. government for public supplies of drinking water. The Ogallala aquifer TDS and sulfate values are typical concentrations in the aquifer waters uncontaminated by saline waters of the Arkansas River. The freshwater limits and Ogallala aquifer concentrations show comparatively how saline is Arkansas River water during low flows.

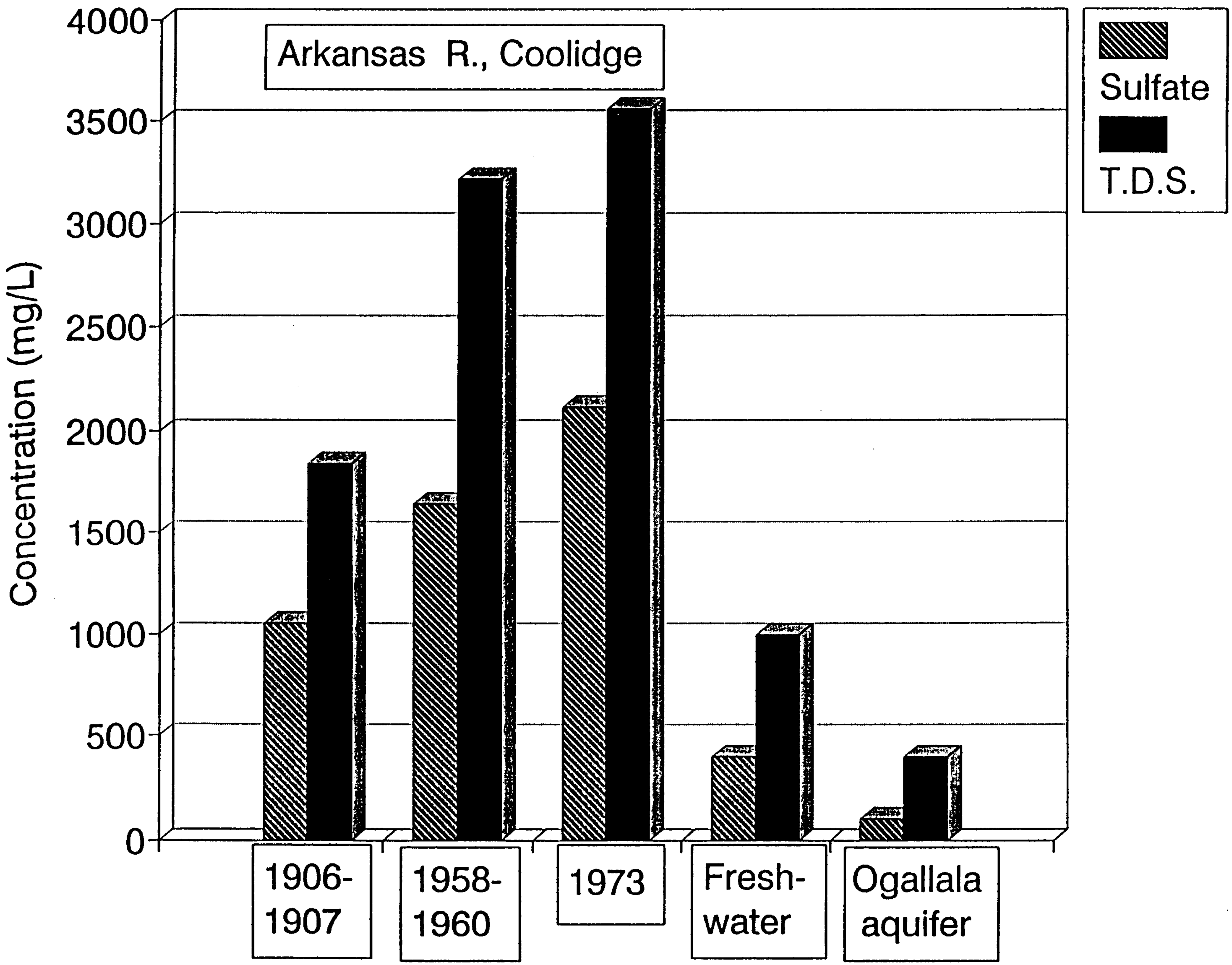
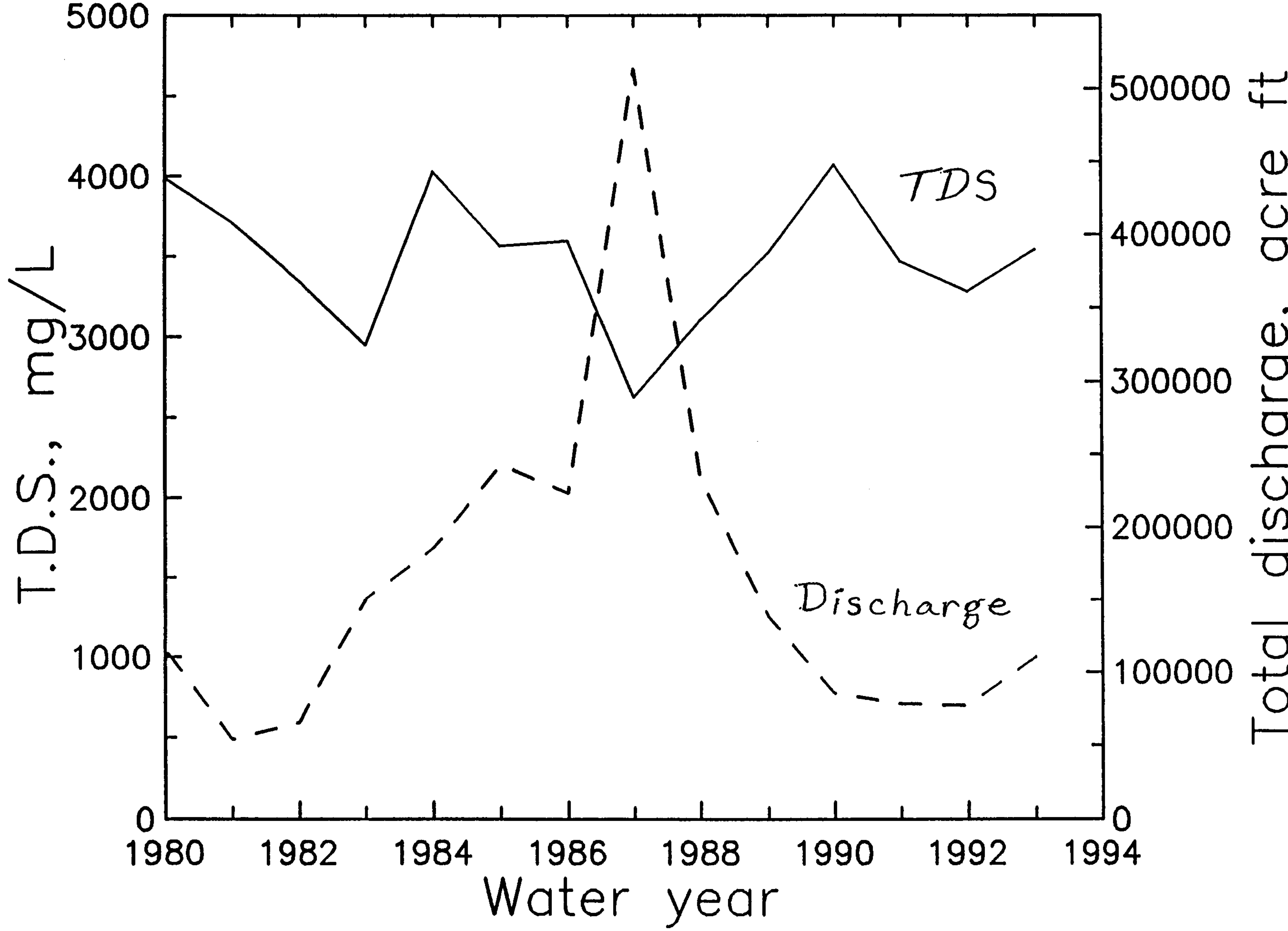

Arkansas R., Coolidge
Sulfate
T.D.S.
Concentration (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
1906-1907
1958-1960
1973
Fresh-water
Ogallala aquifer

Figure 7. Total dissolved solids concentration and total annual discharge for Arkansas River water at Coolidge from 1980 to 1993.

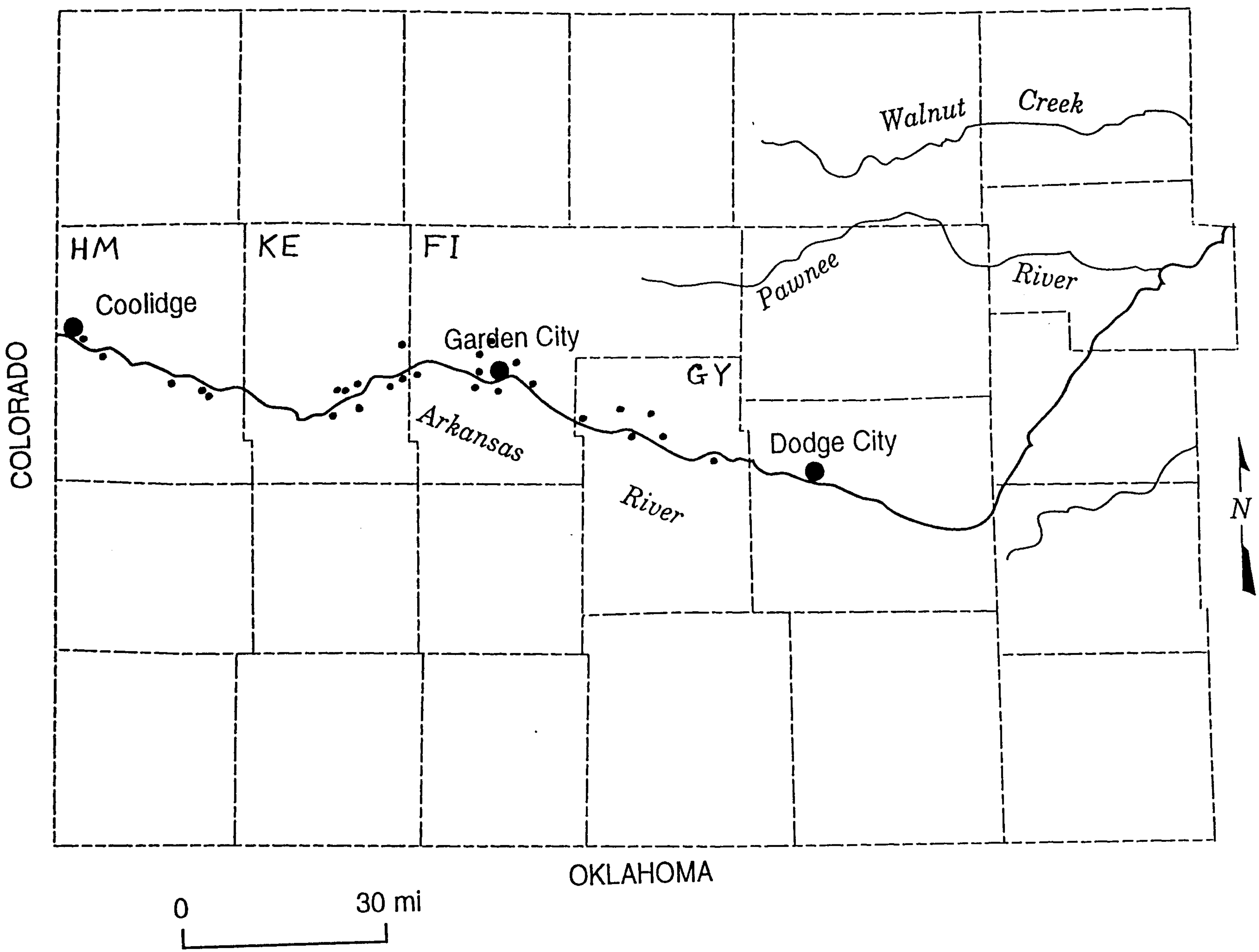
Annual averages of the TDS concentration data for the Arkansas River at Coolidge during 1980-1993 were computed and plotted along with total annual discharge to compare changes in salinity and flow during the period. The figure shows that the average TDS remained high during the recent 14 year span even though total discharge fluctuated over a relatively large range. The peak discharge year of 1987 resulted in a lower river salinity as expected from dilution, but the reduction in salinity was not in proportion to the increase in discharge. The data suggest that there is a large store of salinity in eastern Colorado that keeps TDS values high during higher flows.



5000
4000
3000
2000
1000
0
T.D.S., mg/L
500000
400000
300000
200000
100000
0
Total discharge, acre ft
1980
1982
1984
1986
1988
1990
1992
1994
Water year
TDS
Discharge

Figure 8. Map of the Arkansas River in western Kansas with locations of major cities (large filled circles) and irrigation wells (small filled circles) sampled for investigation of water-quality changes from 1975 to 1994.

In 1994 the Kansas Geological Survey (KGS) conducted a study of changes in ground-water quality in the alluvial valley of the upper Arkansas River as a part of preliminary investigations for the study now funded by the Kansas Water Office. The KGS worked with Georgia Schrauner of the Division of Plant Health (DPH), Kansas Department of Agriculture to identify irrigation wells that the KGS had sampled in 1975 that could be resampled in 1994. The DPH collected water samples from the wells still available to be sampled or wells close to the wells sampled in 1975 and sent the water to the KGS for analysis. The figure shows the location of the wells sampled in 1994 along the Arkansas River valley in Hamilton, Kearny, Finney, and Gray counties.



Walnut
Creek
HM
KE
FI
Coolidge
Garden City
Pawnee
River
GY
Arkansas
River
Dodge City
COLORADO
N
OKLAHOMA
0
30 mi

Figure 9. Changes in sulfate concentration in waters from irrigation wells sampled in 1975 and 1995 in the Arkansas River valley in Hamilton, Kearny, Finney, and Gray counties.

The sulfate concentrations in ground waters sampled in 1994 by the DPH are plotted versus sulfate for water from the same irrigation well or a well very close to an irrigation well sampled in 1975 by the KGS. The dashed line represents the condition in which concentrations were the same for 1994 and 1975. Points above the dashed line indicate an increase in sulfate during the period; points below the line a decrease for the same period. The figure shows that there were both increases and decreases in sulfate contents. The sulfate level at locations with lower to moderate concentrations in 1975 either increased or remained about the same, whereas the levels at locations with high concentrations in 1975 either decreased or remained about the same. The percentage increases in sulfate concentrations tended to be greater than the percentage decreases.

The increases in sulfate concentrations may reflect migration of the saline water-freshwater transition zone within the Arkansas River valley. The substantial decreases in sulfate were generally in one area of Kearny County and might possibly be related to locations with a substantial percentage of land in the Conservation Reserve Program. Causes of the changes will be examined in the current study. The figure also indicates how high sulfate concentrations can be in the ground water in the valley.

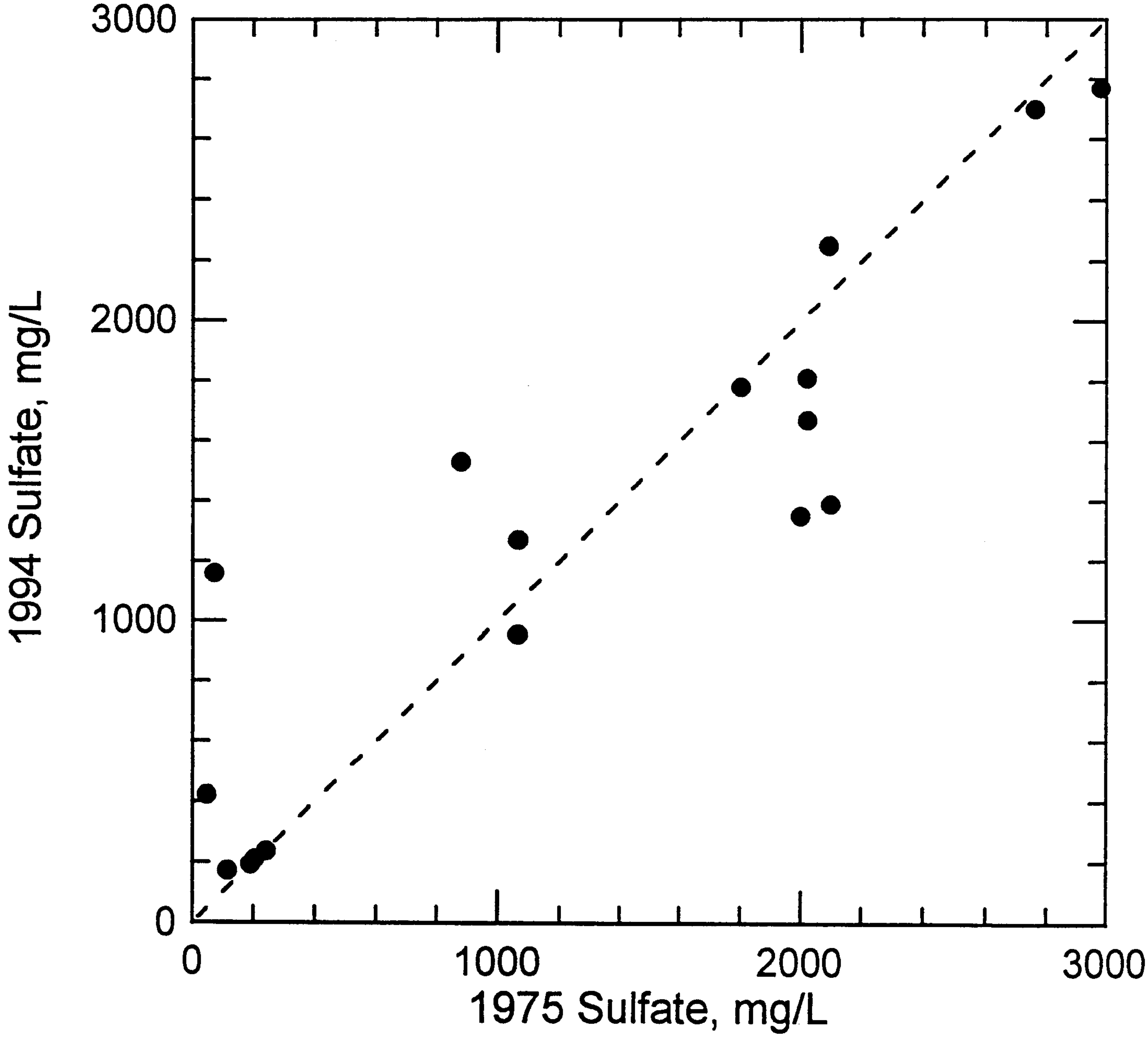
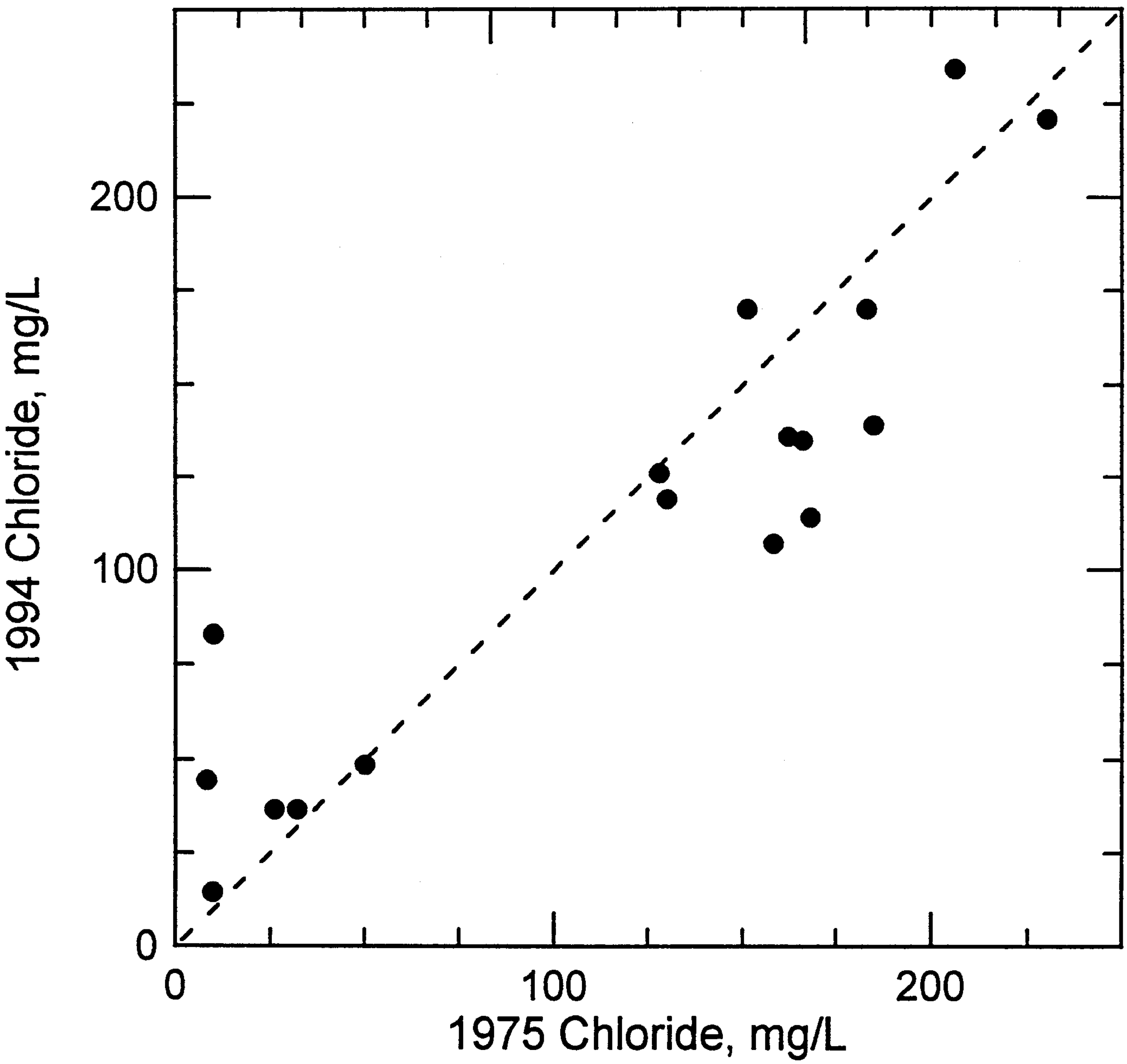

3000
2000
1000
0
1994 Sulfate, mg/L
0
1000
2000
3000
1975 Sulfate, mg/L

Figure 10. Changes in chloride concentration in waters from irrigation wells sampled in 1975 and 1995 in the Arkansas River valley in Hamilton, Kearny, Finney, and Gray counties.

The chloride concentrations in ground waters sampled in 1994 by the DPH are plotted versus sulfate for water from the same irrigation well or a well very close to an irrigation well sampled in 1975 by the KGS. The dashed line represents the condition in which concentrations were the same for 1994 and 1975. Points above the dashed line indicate an increase in chloride during the period; points below the line a decrease for the same period. The figure shows that there were both increases and decreases in chloride contents. The relative changes generally are similar to those for sulfate concentrations in the same wells (Figure 9) and indicate the coherence of sulfate and chloride in the ground waters. The coherence stems from the origin of the high salinity in the water as infiltration of Arkansas River water concentrated by evapotranspiration. The evapotranspiration process concentrates both sulfate and chloride as well as other constituents dissolved in the water.



1994 Chloride, mg/L
200
100
0
0
100
200
1975 Chloride, mg/L

Figure 11. Changes in nitrate concentration in waters from irrigation wells sampled in 1975 and 1995 in the Arkansas River valley in Hamilton, Kearny, Finney, and Gray counties.

The nitrate concentrations in ground waters sampled in 1994 by the DPH are plotted versus nitrate for water from the same irrigation well or a well very close to an irrigation well sampled in 1975 by the KGS. The diagonal dashed line represents the condition in which concentrations were the same for 1994 and 1975. Points above the dashed line indicate an increase in nitrate during the period; points below the line a decrease for the same period. The figure shows that the nitrate concentration increased in 13 of the well waters and decreased in only 3 of the waters. The magnitude of the average increase was larger than the average decrease.

The horizontal and vertical dashed lines represent the maximum contaminant level for nitrate in public drinking-water supplies. One of the well waters was at the standard and another contained nitrate appreciably greater than the standard. The results indicate a problem of nitrate increase. The issue will be examined in more detail in the current study.

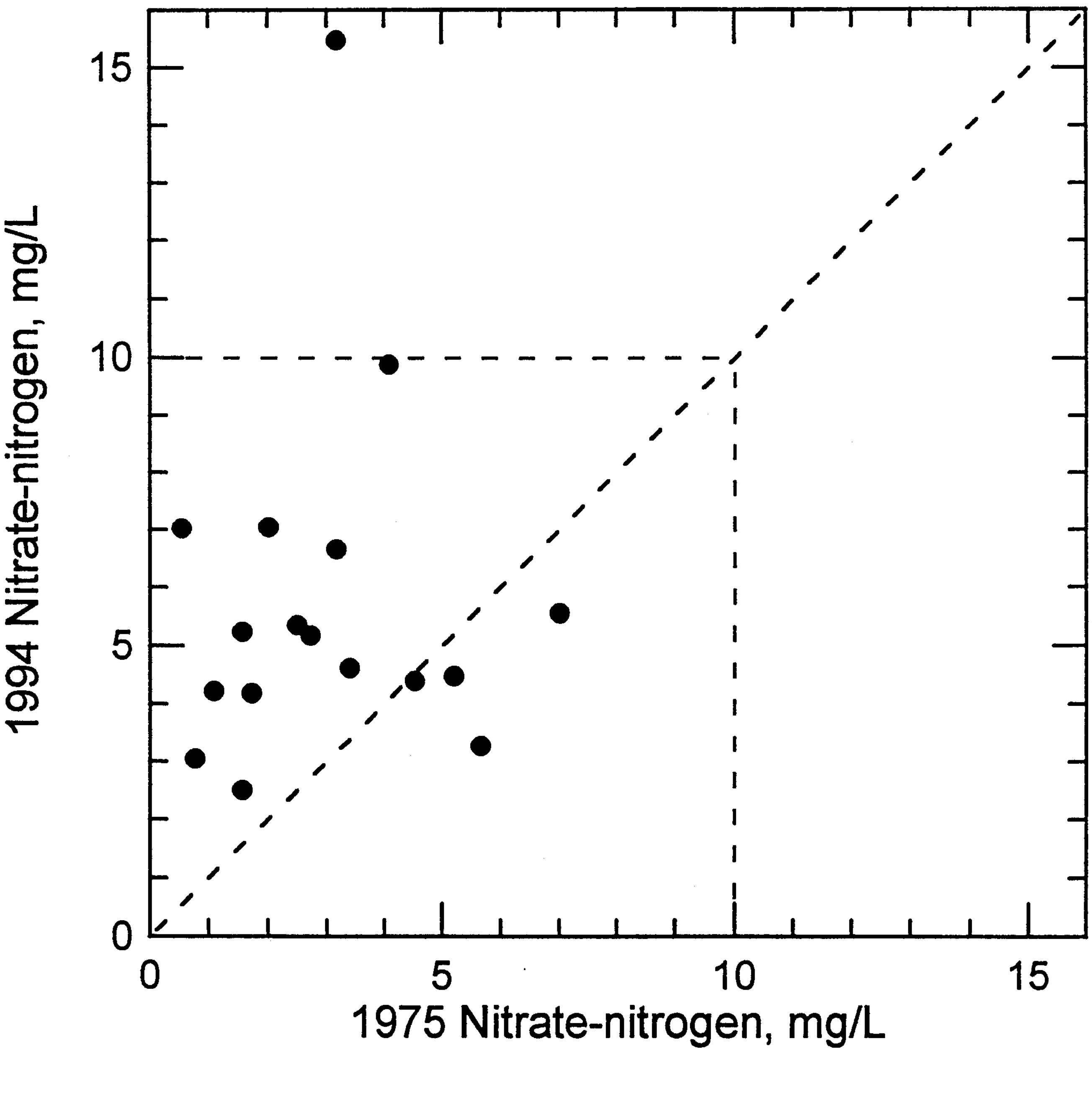

15
10
5
0
0
5
10
15
1994 Nitrate-nitrogen, mg/L
1975 Nitrate-nitrogen, mg/L

Figure 12. Outline of the basic objectives of the FY 1996 program activities.

UPPER ARKANSAS RIVER CORRIDOR STUDY

FY 1996 Program Activities

Basic Objectives

1. Document fate and effects of contaminated Arkansas River flows on the alluvial, Ogallala, and Dakota aquifers in the river valley
2. Establish the links among decreased flow in the Arkansas River, increased levels of water contamination in the alluvial, Ogallala, and Dakota aquifers, and lowered ground-water tables
3. Predict effects of changing water use and environmental factors on salinity migration into freshwater areas
4. Recommend best management and protection strategies to mitigate contamination of freshwaters

Figure 13. Outline of the primary components of the FY 1996 program activities.

UPPER ARKANSAS RIVER CORRIDOR STUDY

FY 1996 Program Activities

Primary components of work plans

1. Appraise existing water-quality and quantity conditions and determine data needs
2. Begin initial data collection to meet required information needs
3. Develop initial conceptual models of water quality and hydrology
4. Select an appropriate quantitative model that could be adapted to simulate current conditions and future changes in water-quality and quantity, as well as effects of possible management and protection plans
5. Establish an Interagency Technical Advisory Committee and cooperative investigation agreements with other state and federal agencies

Figure 14. Upper Arkansas River Corridor Study area.

The figure is a revision of the earlier map of the study area. The map shown in October indicated a general study location outlined around the 5 county area of Hamilton, Kearny, Finney, Gray, and Ford counties. The revision is the more specific study area recently designated.

The actual study area will focus on the Upper Arkansas River Valley IGUCA, the ditch irrigation of Kearny and Finney counties (the Garden City Study Area of the Division of Water Resources), and a buffer zone outside of these two areas that will allow determination of the transition from saline water in the river valley to freshwater in the Ogallala aquifer. The northern and southern borders of the study area are township boundaries such that there is a buffer of at least 6 miles outside the IGUCA and DWR Garden City Study Area. The western border is the Colorado-Kansas state line and the eastern border is that of Ford County.

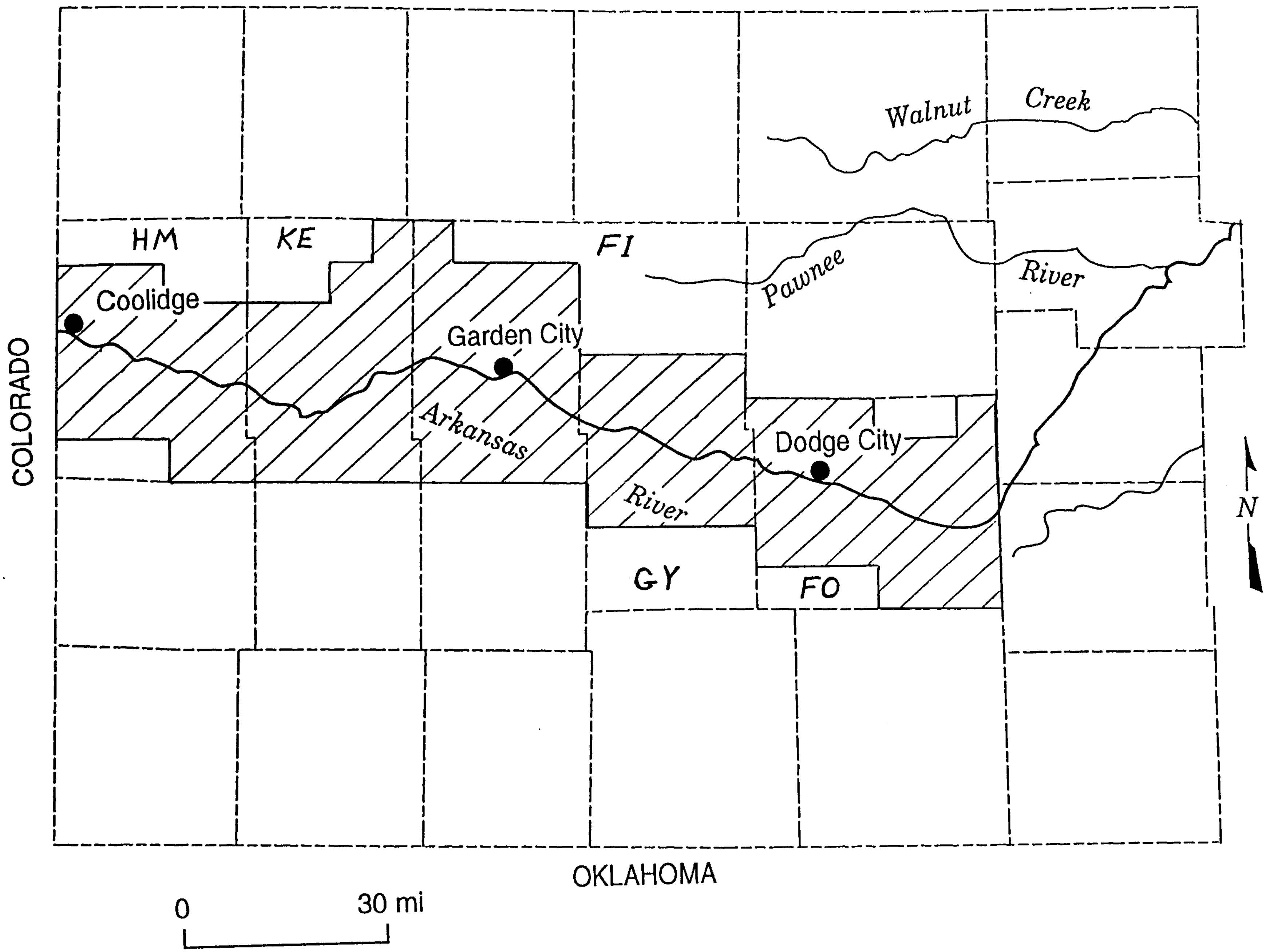

Walnut Creek
HM
KE
FI
Pawnee River
Coolidge
Garden City
COLORADO
Arkansas River
Dodge City
N
GY
FO
OKLAHOMA
0
30 mi

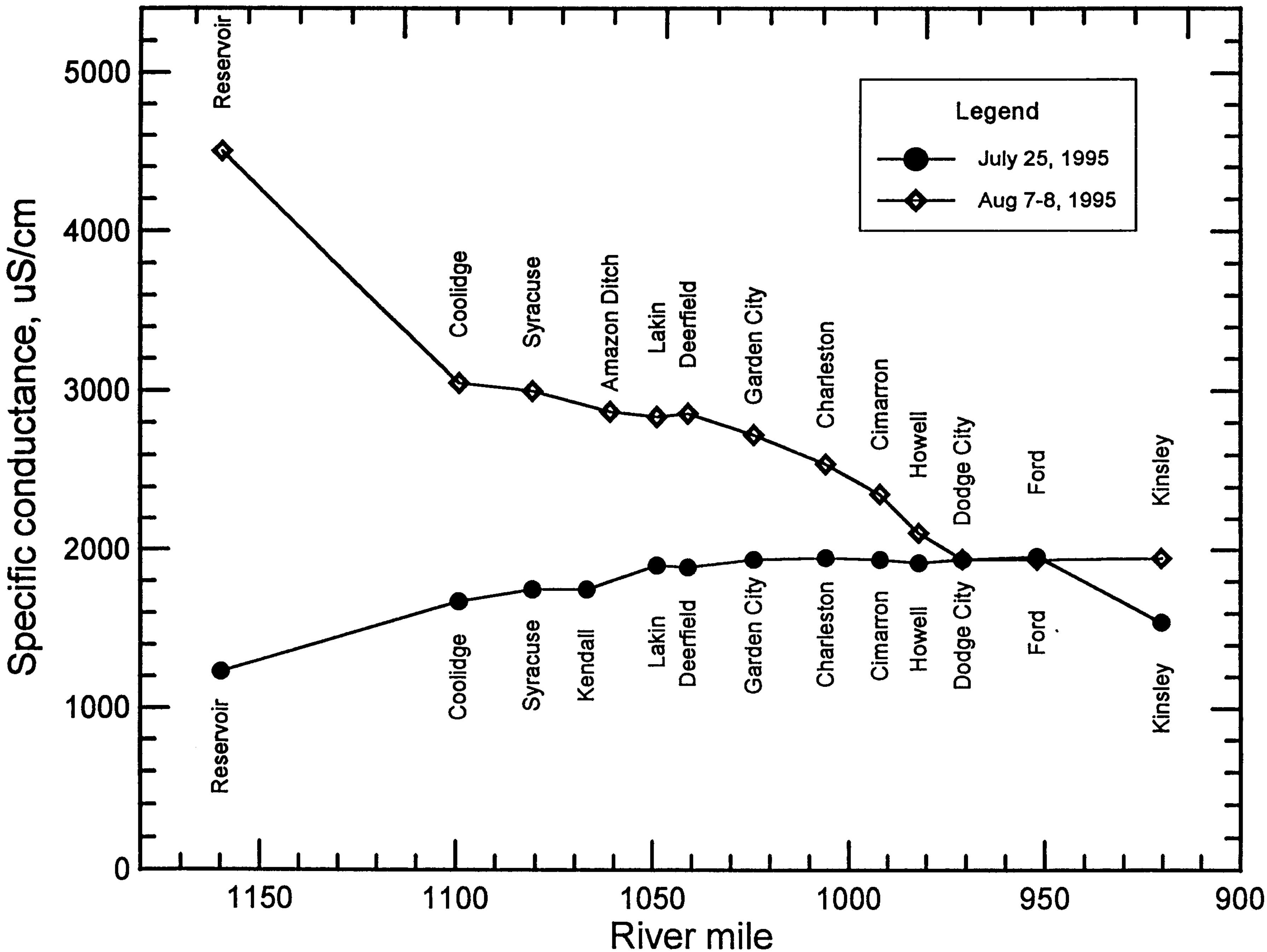
Figure 15. Two profiles of river-water salinity along the upper Arkansas River during the high-flow event of July and August, 1995.

Larger than average snow melt from the Rocky Mountains in central Colorado and much rainfall in eastern Colorado filled the reservoirs of the Arkansas River and tributaries in the early summer of 1995. Colorado began to substantially increase the volume of water released from John Martin Reservoir from about July 1 to the middle of July. The flow was decreased near the end of July until reaching more typical amounts by early August. The increased river flow migrated downstream in the Arkansas River valley in Kansas. However, because large amounts of the flow infiltrated to the dry or nearly dry river bed between Garden City and Larned, the Arkansas River did not flow in substantial amounts completely through to Larned until about the beginning of August. The migration velocity of the flow front in the river bed was a factor of the infiltration rate compared to the rate of flow from upstream. After the reservoir releases to Kansas were substantially decreased, the flow of the Arkansas River rapidly decreased in response to the combined effects of smaller upstream flow and infiltration to the alluvium where ground-water levels in the alluvial corridor were still below the river bed. The flow effectively ceased at Dodge City by the end of the third week in August.

The KGS decided to collect information on this now unusual event as a part of the appraisal of existing water-quality conditions in the river for the Corridor Study. The KGS worked with staff of Southwest Groundwater Management District No. 3, the Kansas Department of Health and Environment in Dodge City, the Kansas Water Office, Big Bend Groundwater Management District No. 5, and the Division of Plant Health, Kansas Department of Agriculture to collect river water samples during the high flow period. The samples were analyzed at the laboratories of the KGS. Figure 15 shows the results for the two most extensive sampling trips for Kansas stations, one by GMD 3 on July 25 and one by the KGS with Gerald Hargadine of the KWO during August 7-8. The latter sampling trip also included collection of Arkansas River waters from just east of Hutchinson to Larned. The values of specific conductance in Arkansas River water just below John Martin Reservoir were obtained from the real-time data available on the USGS surface flow pages for Colorado on the computer internet. The specific conductance was used as a measure of salinity and plotted versus river miles as designated by the USGS for gaging stations. River miles for locations without USGS gaging stations were estimated from maps.

The July 25 salinity profile along the river approximately represents the period of freshest water flowing into Kansas. Four days later (July 29) the discharge rate at Coolidge began to decrease. The increase in salinity along the river on July 25 indicates the lag time for the fresher water to flow downstream. The front of Arkansas River flow had not quite yet reached Kinsley at this date. The Kinsley sample on this date was taken from shallow, nearly stagnant water in the river channel.

The August 7-8 profile indicates the great increase in salinity of the water flowing from the John Martin Reservoir to Kansas once the flow rate was greatly decreased. Similar to the July 25 profile, there is a lag effect for the salinity, only this time the salinity decreased along the profile because more saline water was flowing downstream. It is possible that the water in the Arkansas River from Lakin to Kinsley reached a lower salinity between July 25 and August 7-8. However, the salinity probably did not become as low as that for the Coolidge sample due to mixing with more saline water from shallow stream-aquifer interactions along the river course. The leveling off of the specific conductance from Dodge City to Kinsley during August 7-8 supports this because if the water had been much fresher, a continued slight decrease from Dodge City to Kinsley would have been expected. The minimum conductance for the Arkansas River from Garden City to Kinsley between July 25 and August 7-8 probably was never lower than 1,800 μS/cm.



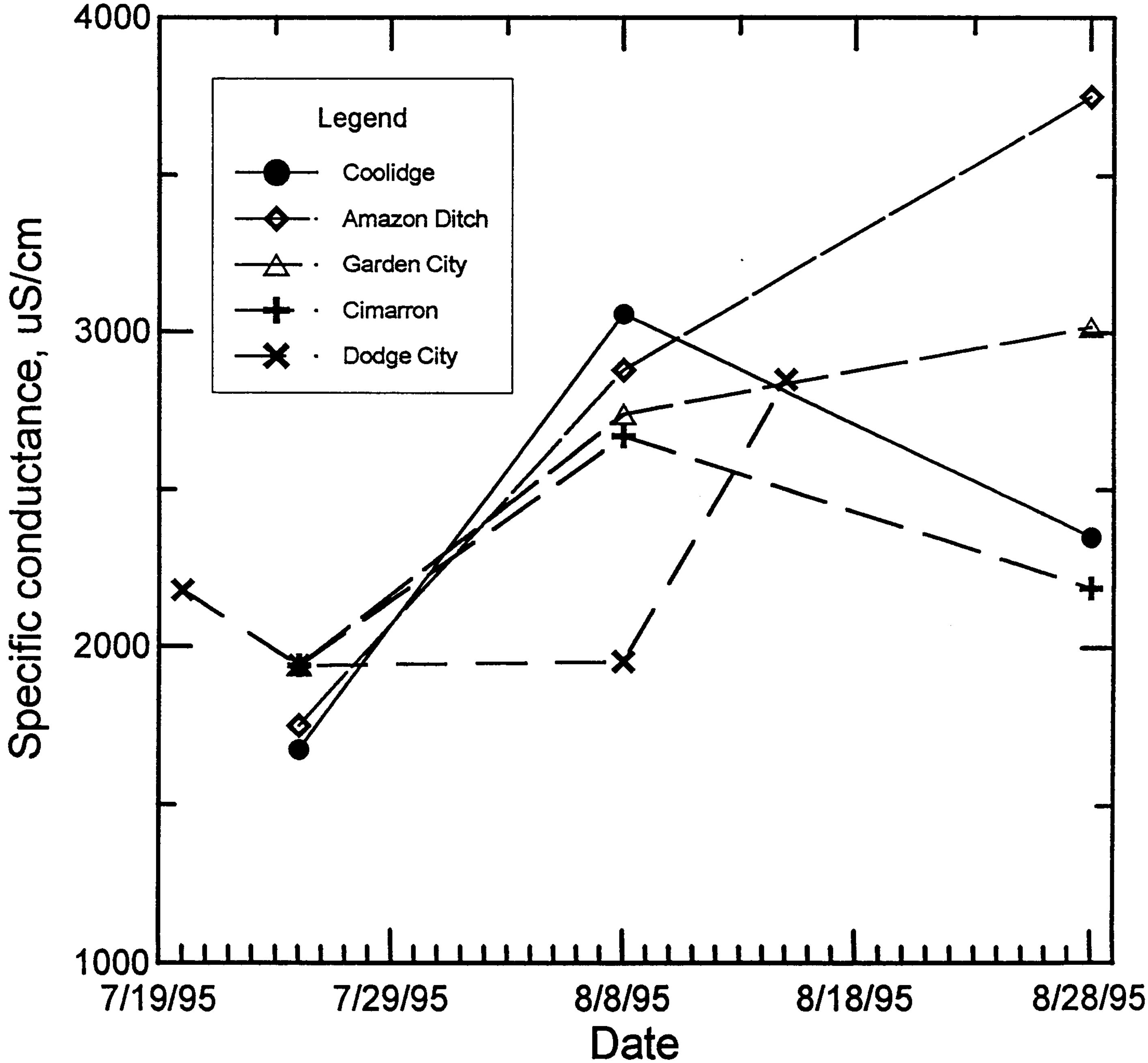
Specific conductance, uS/cm
River mile
Legend
July 25, 1995
Aug 7-8, 1995
0
1000
2000
3000
4000
5000
1150
1100
1050
1000
950
900
Reservoir
Coolidge
Syracuse
Amazon Ditch
Lakin
Deerfield
Garden City
Charleston
Cimarron
Howell
Dodge City
Ford
Kinsley
Reservoir
Coolidge
Syracuse
Kendall
Lakin
Deerfield
Garden City
Charleston
Cimarron
Howell
Dodge City
Ford
Kinsley

Figure 16. Variations in river-water salinity at different sampling stations along the upper Arkansas River during the high-flow event of July and August, 1995.

River-water samples were collected at selected stations on the Arkansas River at times additional to the July 25 and August 7-8 profiles. Figure 16 shows the specific conductance results for these stations versus sampling date.

The first river water collected in the summer was on the east side of Dodge City when the front of the flow was passing though the area. The decrease then increase of the salinity at Dodge City indicates the effect of the wave of fresher water that flowed though the river valley. In general, the samples at the other sites were collected starting from near their freshest point through the increase in salinity that resulted as flows decreased.

The cause for the large range in specific conductance for waters collected on August 28 is unknown at this time. The salinity increased in the river water from August 8 to 28 at the Amazon Ditch and Garden City but decreased at Coolidge and Cimarron. The decrease at Coolidge may indicate changes in the relative amounts of flow released from the John Martin Reservoir and from saline irrigation returns. This pulse of lower salinity water may not have reached the Amazon Ditch by the sample date. The decrease at Cimarron might represent stream-aquifer interactions by which some fresher water that entered the alluvium during the higher flow period discharged back into the river when the flow had appreciably decreased. This might have occurred in stretches of the river underlain by low permeability sediments that restricted the rate of infiltration to the underlying Ogallala aquifer. The other possibility is an effect by local heavy rainfall. The cause for these variations will be further examined.



Legend
Coolidge
Amazon Ditch
Garden City
Cimarron
Dodge City
4000
3000
2000
1000
Specific conductance, uS/cm
7/19/95
7/29/95
8/8/95
8/18/95
8/28/95
Date

Figure 17. Outline of FY 1997 proposed activities.

UPPER ARKANSAS RIVER CORRIDOR STUDY

FY 1997 Proposed Activities

- Establish data-collection network necessary for conceptual and quantitative modeling
- Begin identification of the sources and fate of salinity and other chemical constituents of concern, including nitrate
- Initiate determination of hydrogeology and salinity distribution in areas between existing data and observation network locations
- Revise preliminary chemical distribution maps and cross sections and conceptual models developed in FY 1996
- Begin modeling of water-level declines, aquifer interactions, and water quality for predicting effects of natural and human factors
- Develop possible management, protection, and remediation plans and strategies for research guidance