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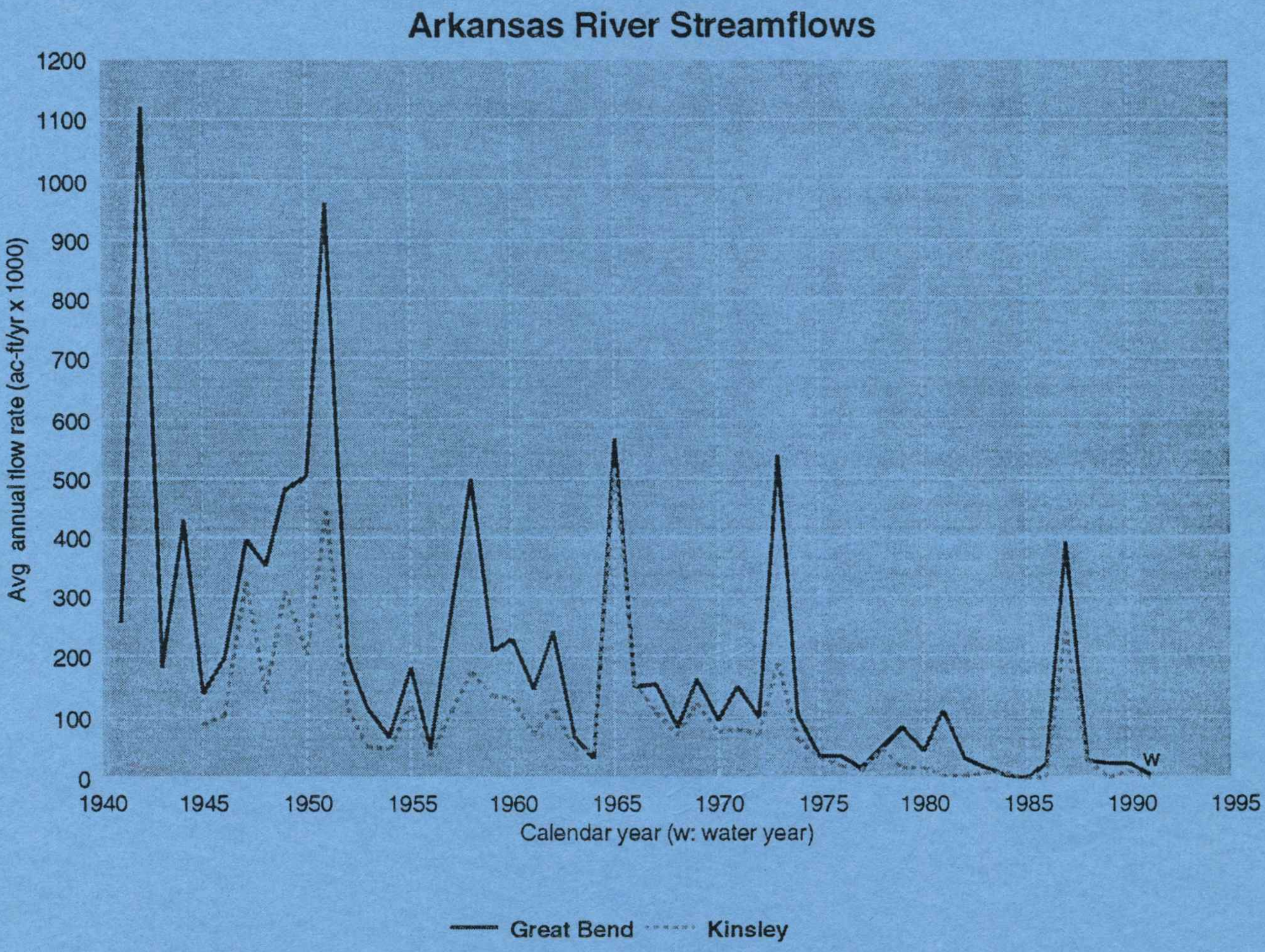
Kansas Geological Survey

Stream-aquifer numerical modeling of the Kinsley to Great Bend reach of the Arkansas River in central Kansas: Final Report



Marios Sophocleous, Samuel P. Perkins,
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Open-File Report 93-~~21~~32

GEOHYDROLOGY

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Abstract

We address the problem of declining streamflows in interconnected stream-aquifer systems and explore possible management options to address the problem for the Kinsley to Great Bend segment of the Arkansas River valley. The approach we followed was to implement, calibrate, and "validate" a stream-aquifer numerical model combined with a parameter estimation package and sensitivity analysis. Hydrologic budgets for both predevelopment and developed conditions indicate significant differences in the hydrologic components of the study areas resulting from development. The predevelopment water budgets give an estimate of induced recharge, indicating that major ground-water development changes the recharge-discharge regime of the model area with time. Such stream-aquifer models link proposed actions to hydrologic effects, as clearly demonstrated by the effects of various management alternatives on the streamflows of the Arkansas River. Thus we show that a possible means of restoring specified streamflows in the area is to implement protective stream corridors with restricted ground-water extraction.

I. Introduction

Statement of the problem

Many regions of western and central Kansas have experienced significant ground-water and streamflow declines, especially during the last two decades (Sophocleous, 1981; Sophocleous and McAllister, 1987, 1990; among others). According to the Kansas Water Office (KWO), extensive ground-water appropriations in the Big Bend Prairie (fig. I1) have contributed to extreme low flows in the Arkansas River and Rattlesnake Creek (Water Research Needs Conference,

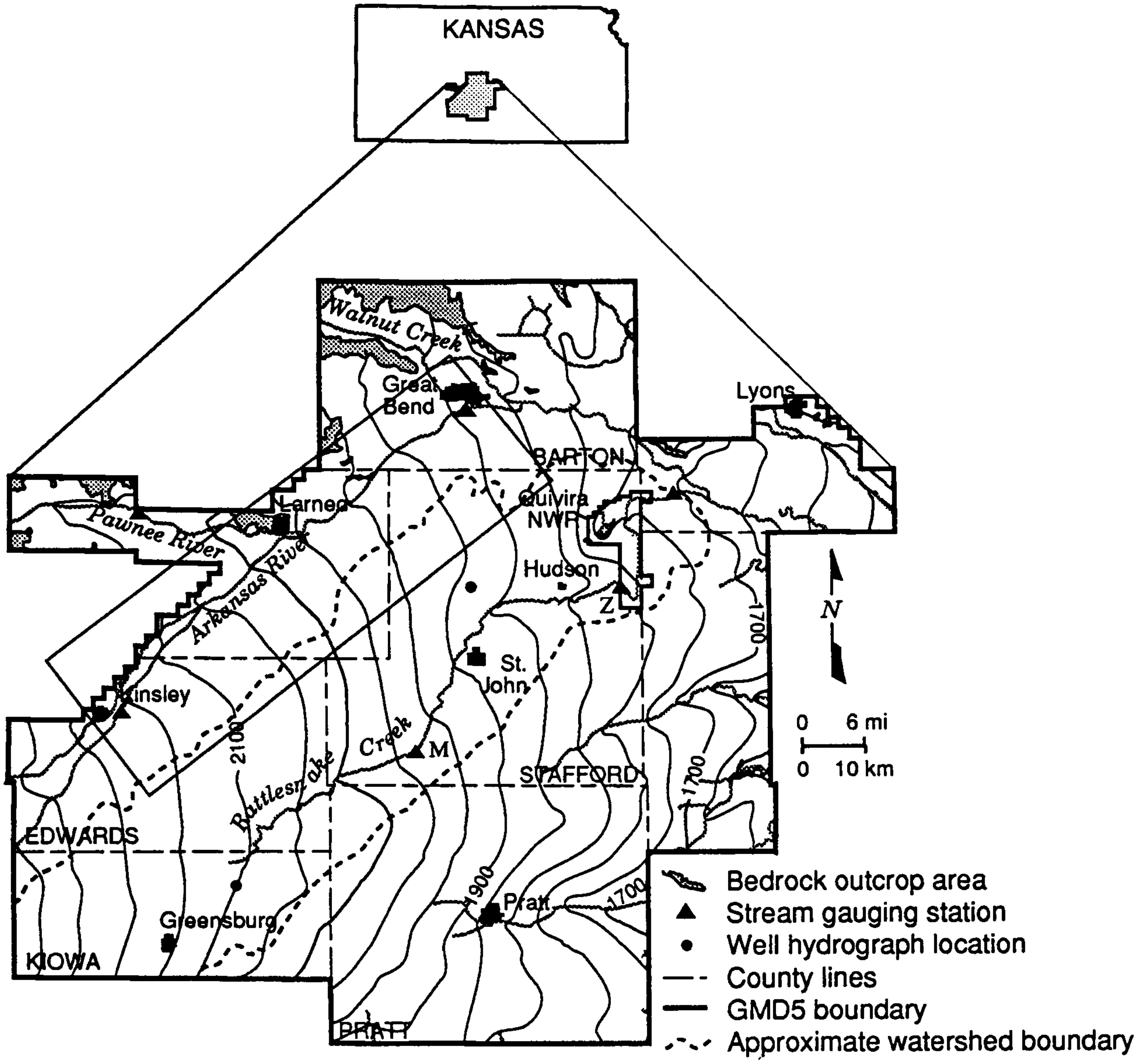

Figure I1. Study area. Diagonal box encompasses the model area. Uppercase letters denote stream-gaging stations.

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).

Figure I2 summarizes the general hydrologic state of the Great Bend Prairie region of Kansas. The figure depicts annual streamflows of the Arkansas River at Great Bend together with annual precipitation in Great Bend (fig. I2a), the number of ground-water rights issued in the Big Bend Groundwater Management District No. 5 (GMD5) over time (fig. I2b), and two long-term ground-water-level obesrvation well hydrographs in the area (fig. I2c). Figure I2 indicates streamflow and ground-water declines with time, with precipitation patterns and amounts showing no corresponding declines while ground-water rights show a dramatic increase over the same period of time.

In 1983 the Kansas legislature passed the minimum instream flow law, which requires that minimum desirable streamflows be maintained in different streams in Kansas, including the Rattlesnake Creek. Implementation of this law certainly requires a better understanding of the stream-aquifer system. According to the Division of Water Resources (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.

Historical perspective

Up to the early 1880's there was such an abundance of water in the Arkansas River that it was considered a navigable stream as far as Fort Mann, a fort formerly located south of Kinsley in Edwards County. In the early 1880's several small craft managed to navigate the river as far as Wichita (Root, 1936).

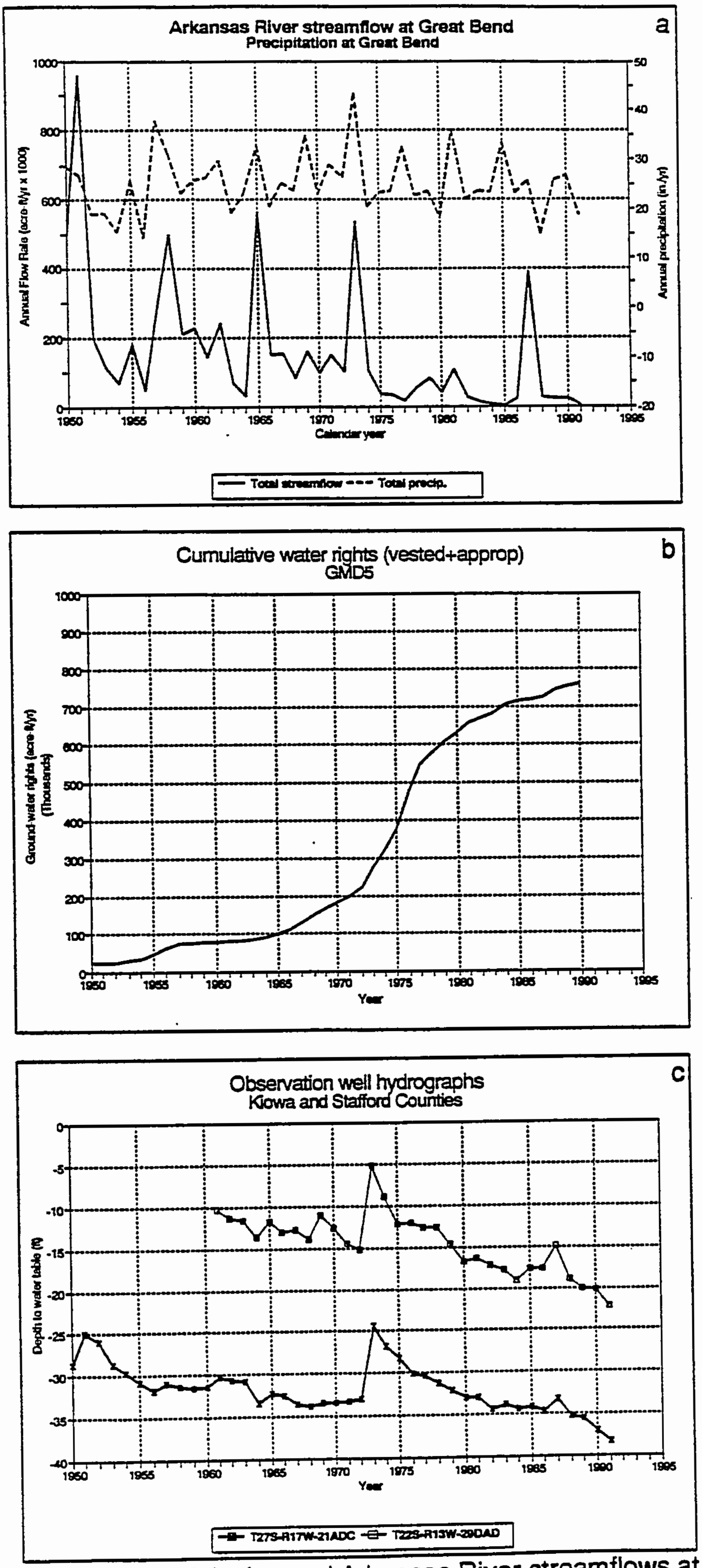

Figure I2. (a) Annual precipitation and Arkansas River streamflows at Great Bend. (b) Appropriated cumulative ground-water rights in GMD5. (c) Two long-term observation well hydrographs in the study area (see fig. I1 for well locations).

However, river discharge and channel morphology along the Arkansas River have changed dramatically during the past century, and these changes are directly related to the withdrawals of surface and ground water (Spray, 1986). Decreases in discharge began with widespread expansion of irrigation ditches in southeast Colorado and southwest Kansas in the late 1800's and early 1900's (Sherow, 1990). These early decreases, coupled with large-scale droughts in the 1890's and 1930's resulted in permanent channel narrowing from 800–1200 ft in 1872, when the original federal land survey was conducted, to less than 40–50 ft today.

With the proliferation of ditch irrigation in the early 1900's, ground-water levels rose in response to percolation of irrigation water downward through cultivated fields. This yielded a good, steady, shallow supply of water, and riparian vegetation, which was practically nonexistent before ditch irrigation, gained a foothold (Sherow, 1990).

When John Martin Reservoir was completed in the late 1940's, maximum flows in the Arkansas River decreased and minimum flows increased because of reservoir regulation, giving the Arkansas a more continuous flow. This decreased flow, however, lessened the ability of the river to rid its channel of debris and vegetation through periodic flooding and resulted in the abandonment of parts of the outer flood channels, which soon became stabilized by the already expanding riparian growth.

Ground-water use did not play an important role in stream discharge changes until after widespread expansion of center-pivot irrigation systems in the 1950's through the 1970's, because few large-capacity irrigation wells were in operation until that time. As a result of the shift from ditch irrigation methods to ground-water-based center-pivot sprinkler irrigation, ground-water levels have dropped significantly in western Kansas (Sherow, 1990). The underlying Ogallala and undifferentiated Pleistocene aquifers in the region are hydraulically connected to the Arkansas River and its alluvium. For this reason, large withdrawals of ground water through pumping resulted in a lowering of the water table and a reduction of ground-water discharge in the Arkansas River as baseflow. These changes, coupled with surface-water removals, have resulted in a substantial to complete loss of flow in the Arkansas River in recent years and in increased mortality of riparian vegetation.

Concerned by such declines, the Kansas legislature passed the minimum desirable streamflow law in 1983. Implementation of this law has resulted in the need to examine the interrelationship of streamflow and ground water in the river alluvium and the associated aquifers that may contribute to water flow in these streams. "Stream-aquifer interaction" was identified in the highest priority category of research needs in the Kansas Water Authority–Kansas Water Office annual research reports for several consecutive years.

To address and manage this stream-aquifer interaction problem, we need to understand the physical processes involved so that we can quantify and model them. Therefore the first phase of this project to study the Kinsley to Great Bend reach of the Arkansas River was a comprehensive stream-aquifer pumping test in the spring of 1986 (Sophocleous et al., 1987, 1988) to demonstrate and quantify the extent and nature of the streamflow–ground-water flow interaction along the Arkansas River in central Kansas. The results of that test indicated that the Arkansas River alluvial aquifer is a prolific aquifer with high transmissivity. As a result, the aquifer readily responds to imposed stresses, such as ground-water pumping. The pumping stress of ~1700 gal/min during the test affected an area with a radius larger than 1 mile, demonstrating that ground-water pumping in the aquifer has a significant area of influence and impact on both ground-water levels and streamflows in nearby streams. For detailed analysis and results of this stream-aquifer testing phase see Sophocleous et al. (1987, 1988).

Objectives

The objectives of this study phase, as outlined in the Kansas Water Office–Kansas Geological Survey cooperative agreement (Kansas Water Office Contract 91-9) are as follows:

1. To define the geologic and hydrologic relationship between ground water and surface water in the reach of the Arkansas River from Kinsley to Great Bend,

2. To evaluate the impacts of ground water management alternatives on streamflows in the river reach,
3. To evaluate recovery of regional ground water in response to increased streamflow in the river reach.

In this report we outline the construction and application of a stream-aquifer numerical model for the Kinsley to Great Bend reach of the Arkansas River and compile the necessary data for this purpose. We also report on the calibration of such a model using parameter optimization techniques and discuss its implementation in evaluating several management alternatives on streamflows in the study reach.

The report is organized into five parts: (1) introduction, including statement of the problem, historical perspective, and study objectives, (2) methodology used and basic data analysis, (3) model implementation and calibration, (4) numerical modeling results and related analyses, and (5) management alternatives. The more technical, mathematical parts on numerical modeling and regression analysis can be skipped without a loss of continuity.

II. Methodology and Data Analysis Results

The methodology we used in this study consists of three approaches: (1) compilation and analysis of existing information, (2) limited field data collection, and (3) numerical modeling based on items 1 and 2. A brief summary of the main components of each approach together with some basic data analysis results follows.

Compilation and analysis of existing information

1. A comprehensive bedrock and predevelopment water-level map for the Great Bend Prairie region (in which the study area belongs) based on all available data accessible and/or known to us has been prepared and documented separately (Sophocleous et al., 1990). A predevelopment water-level map and a bedrock map of the study area are shown in figs. 1 and 2.

Predevelopment water-level contours (ft)

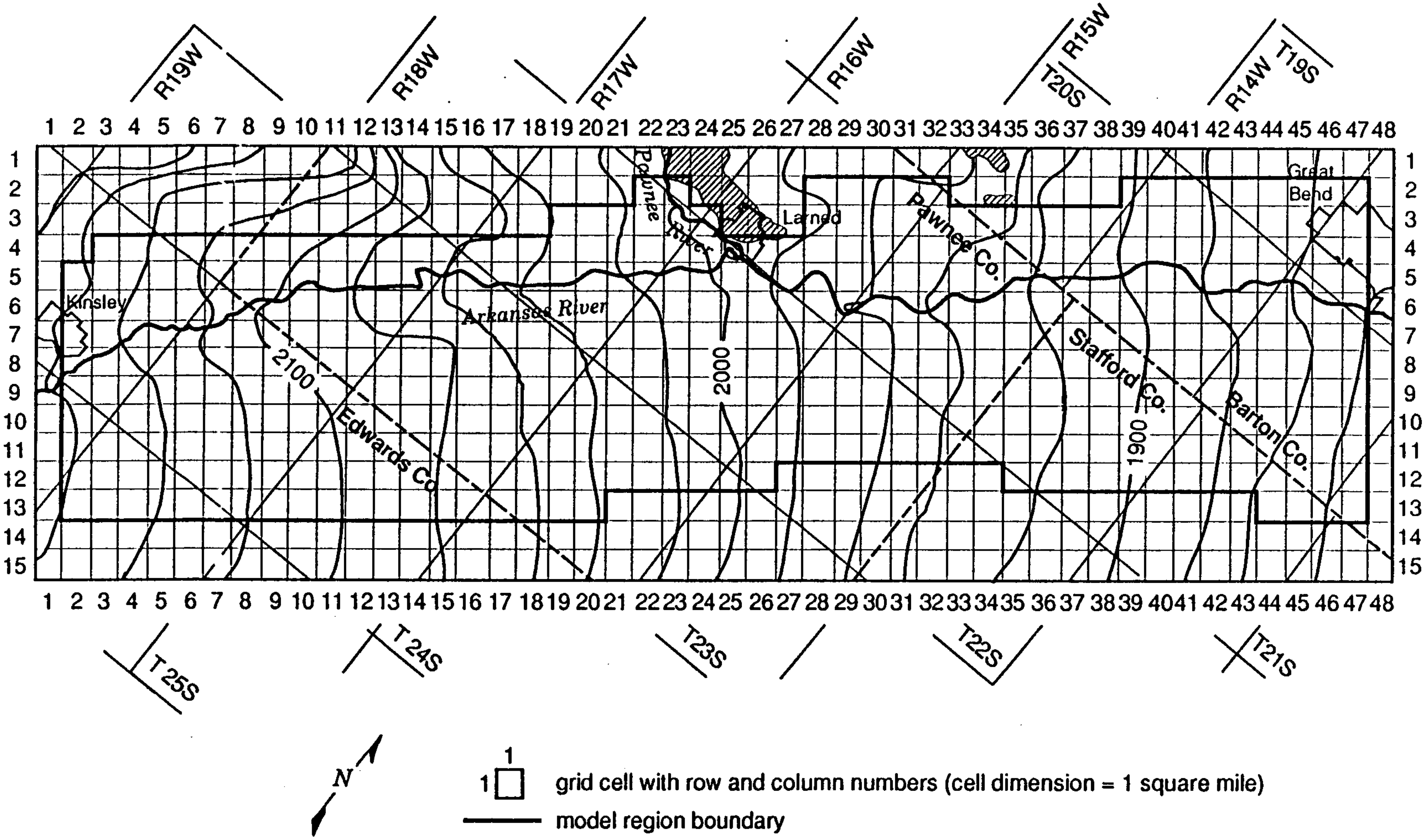

Figure 1. Predevelopment water table map of the study area. Contour interval 20 ft.

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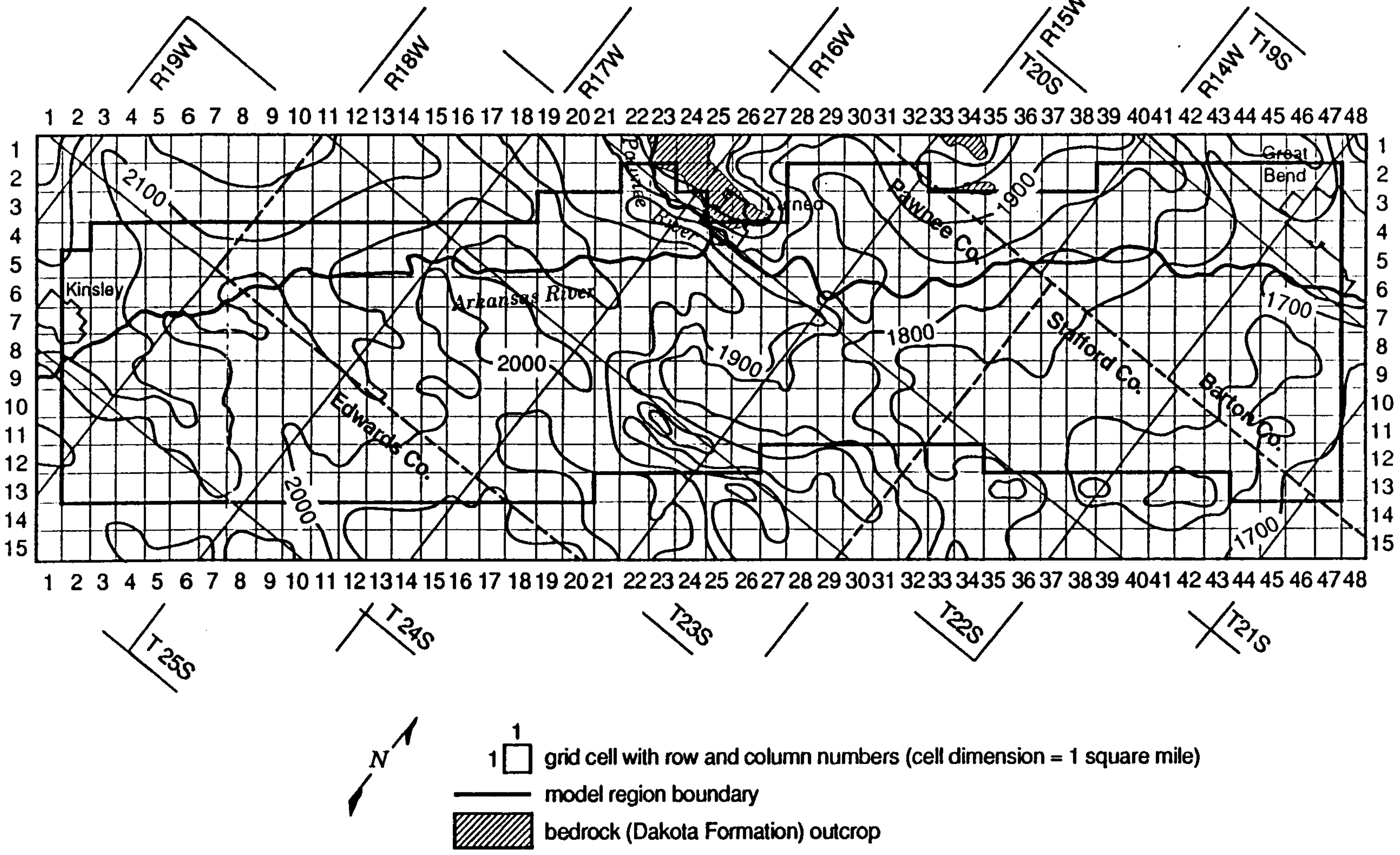


Bedrock contours (ft)

Figure 2. Bedrock contour map of the study area. Contour interval 50 ft.

2. A soils map of the Arkansas River valley from Kinsley to Great Bend has been constructed (fig. 3) based on Soil Conservation Service county reports. Also, the available water capacities of the different soils have been compiled (table 1).

3. All current (as of 1990) water rights for the Great Bend Prairie region were obtained on tape from the Division of Water Resources, and the ground-water rights have been processed and displayed on a 1:250,000 map (Sophocleous, 1990). Figure 4 displays the ground-water rights in the study area, and fig. 5 depicts the number of ground-water rights issued in the study area versus time. A complete listing of all ground-water rights in the study area, and the study-area grid-corner coordinates are shown in Appendix 1.

4. Current and historical streamflow data for the area streams have been compiled and analyzed. Average annual streamflows of the Arkansas River at Kinsley and Great Bend and of the Pawnee River at Larned are shown in figs. 6, 7, and 8, respectively. Streamflow gains or losses between Kinsley and Great Bend are shown in figs. 9 and 10. Figure 9 represents the Kinsley to Larned stretch of the Arkansas River, while fig. 10 represents the Larned to Great Bend stretch of the Arkansas River. As can be seen in these last figures, the frequency of streamflow losses from Kinsley to Great Bend increases after the early 1960's. Other stream-related data, such as stream widths and stream slopes, were obtained from topographic and other maps. As mentioned previously, because of the persistent streamflow declines in western and central Kansas, the Kansas legislature enacted the minimum desirable streamflow law in 1983, according to which minimum desirable streamflow standards have been established for a number of Kansas streams, including the Arkansas River. Figures 11 and 12 display the established monthly minimum desirable streamflows for the Arkansas River at Kinsley and Great Bend, respectively, together with the observed mean monthly streamflows at these stations from the 1960's to the present time. The increasing violations of those minimum streamflows since the early 1980's is obvious from the figures.

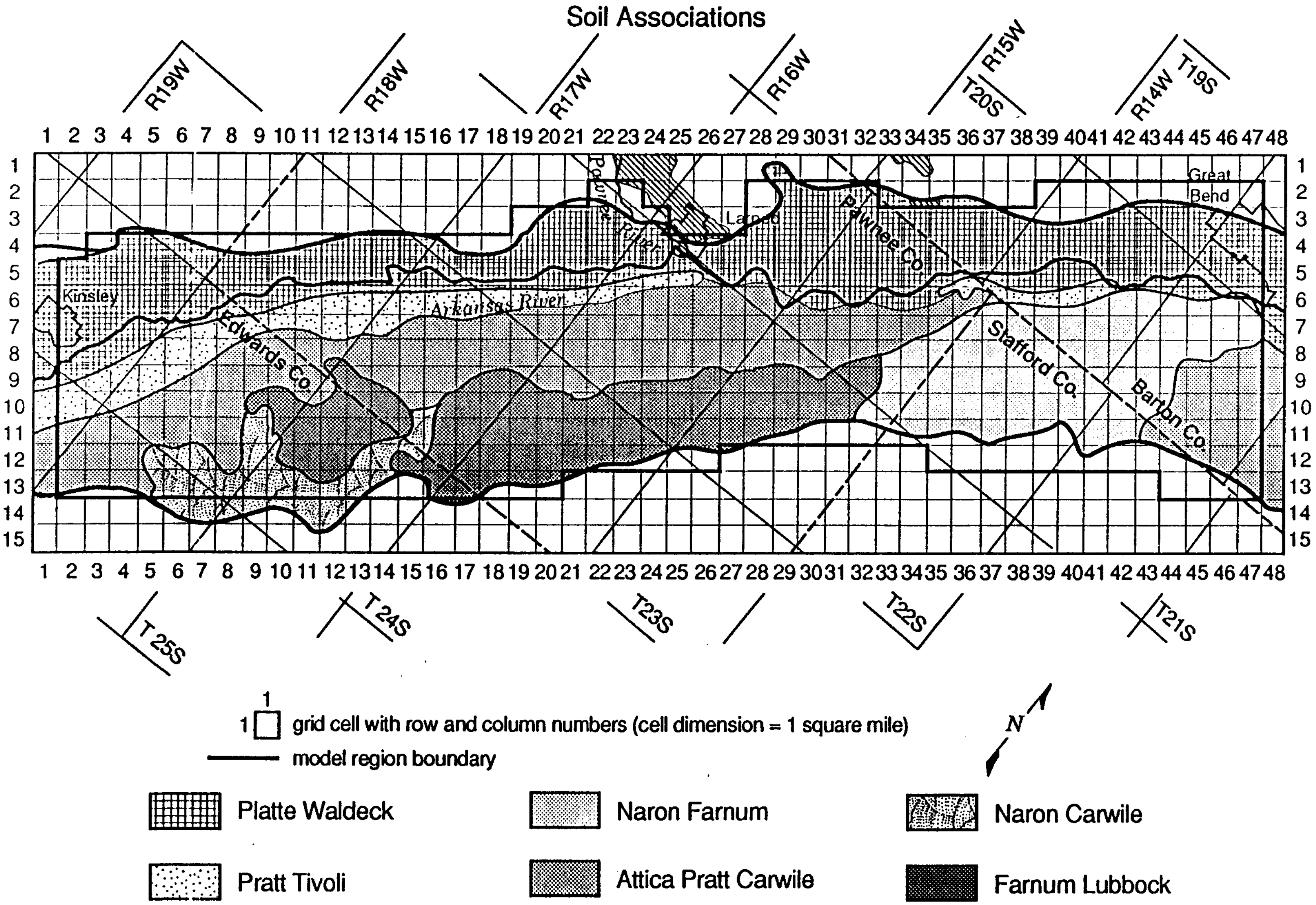


Figure 3. Soil association map of the study area.

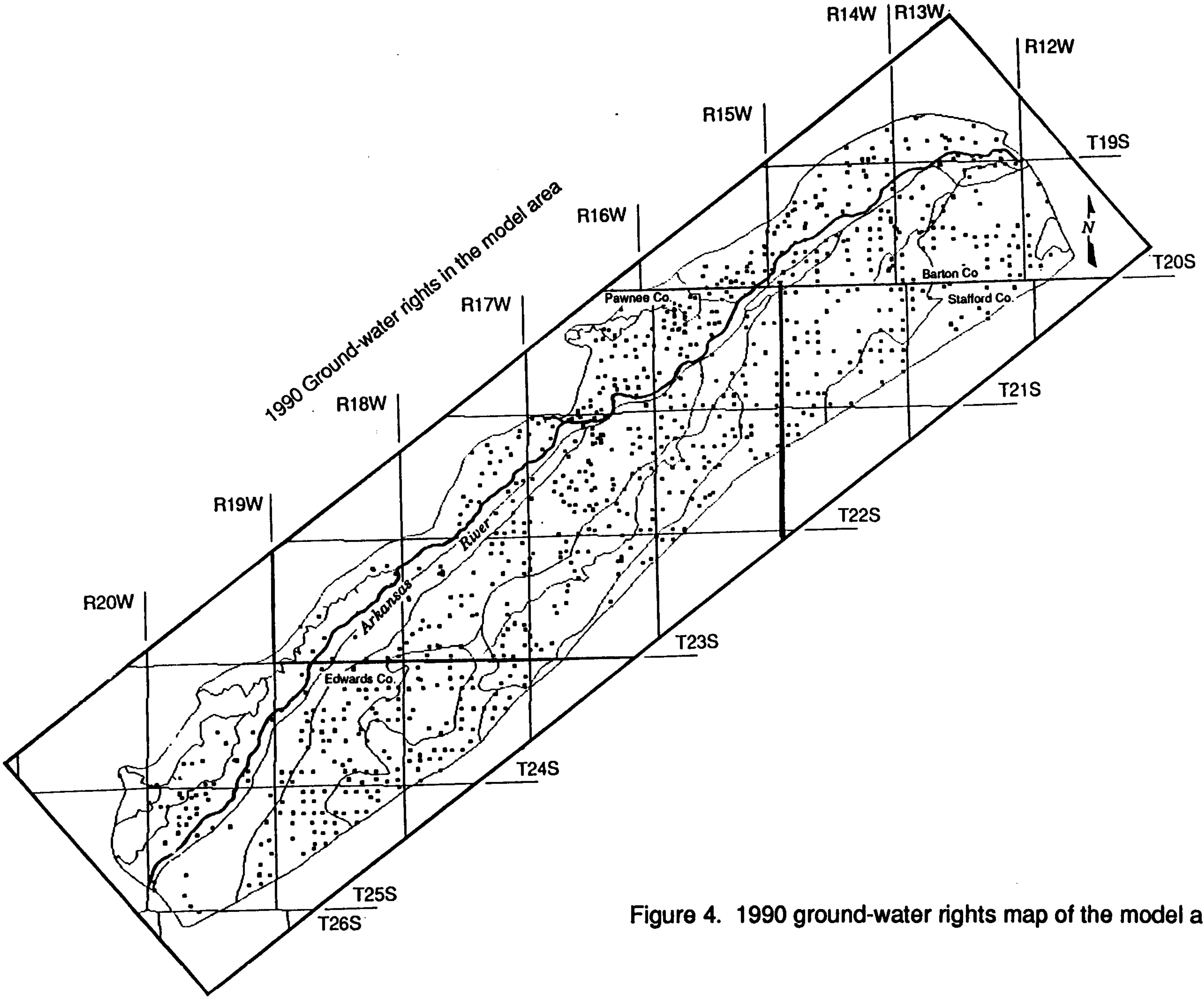


Figure 4. 1990 ground-water rights map of the model area.

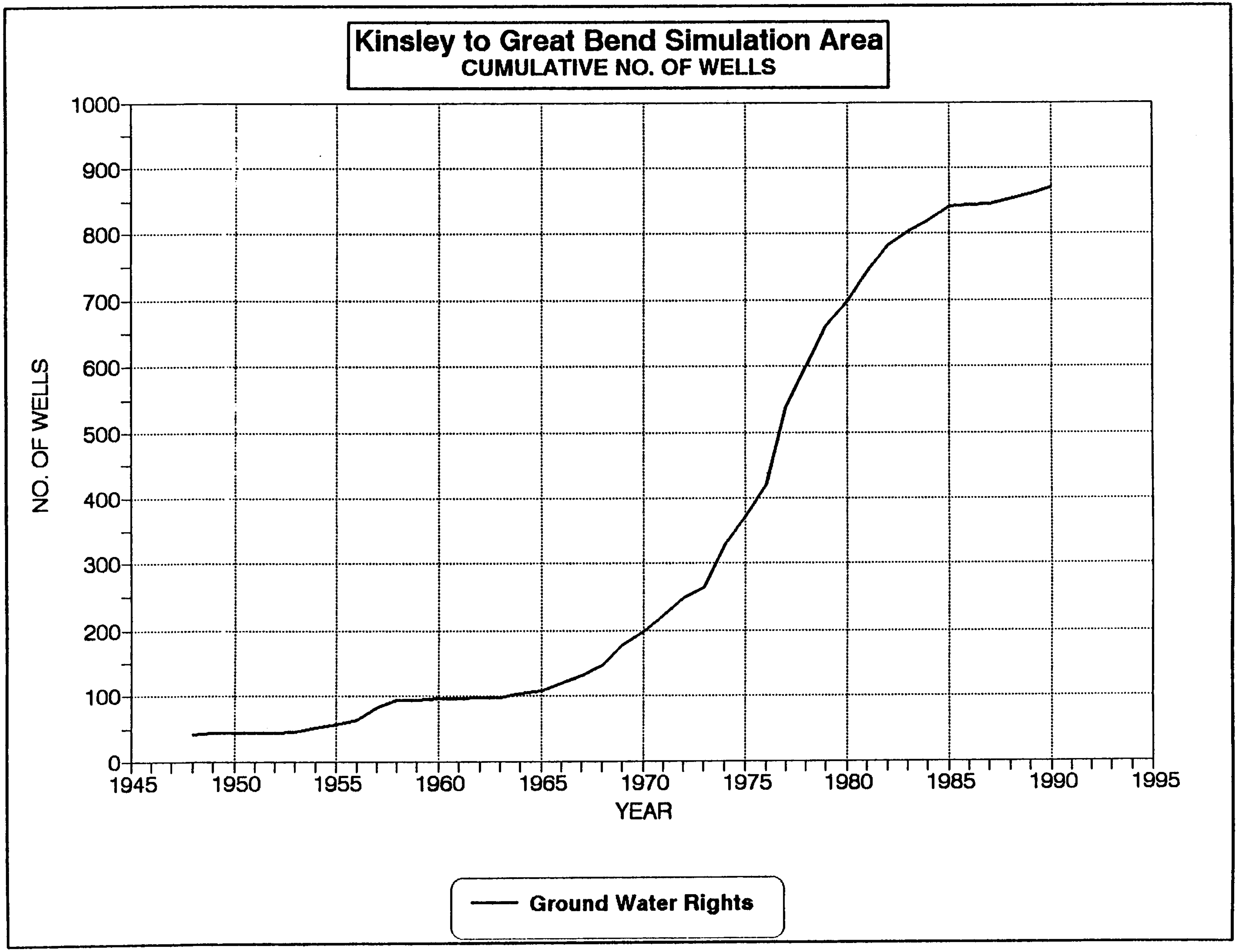


Figure 5. Number of ground-water rights issued in the study area versus time.

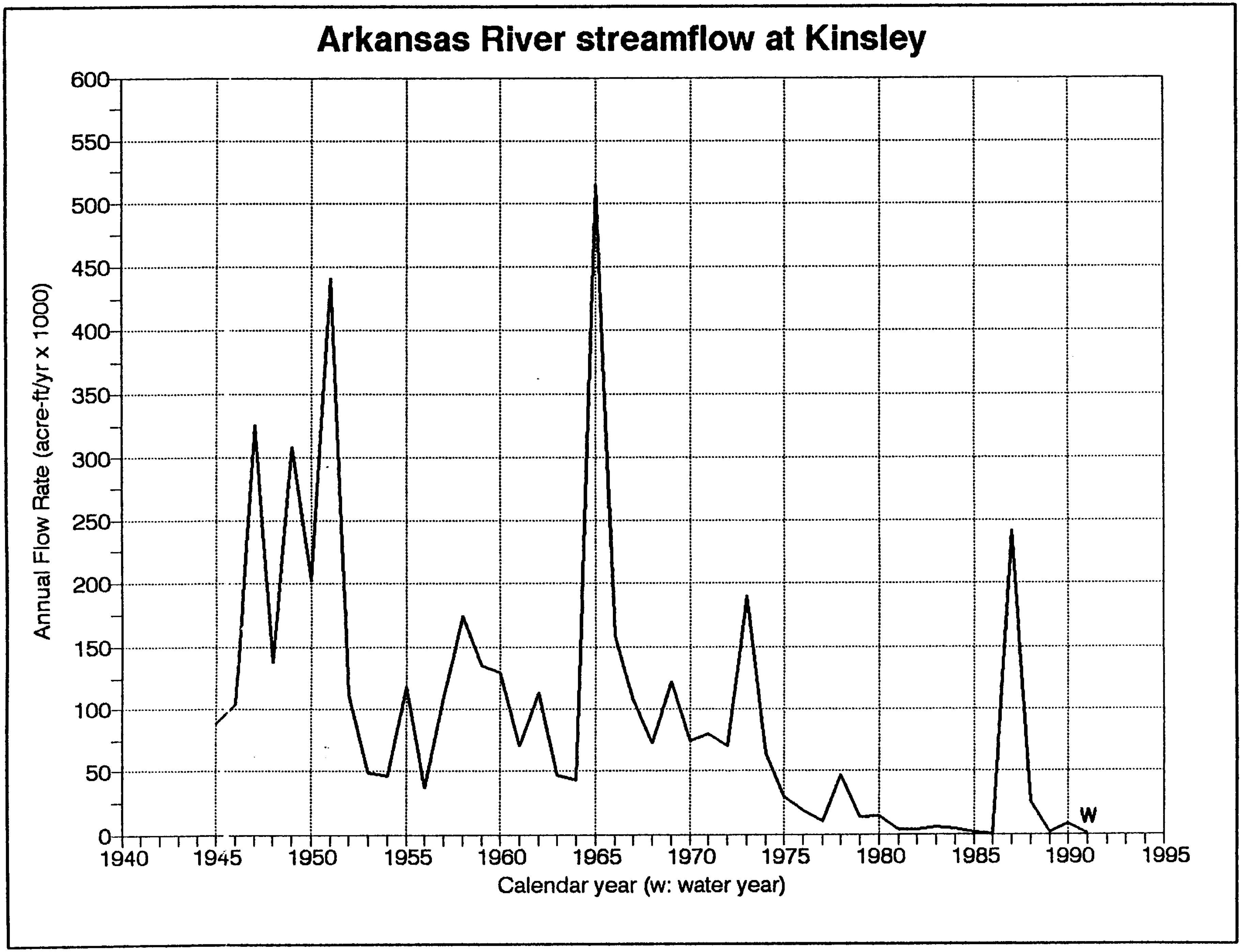


Figure 6. Average annual streamflows of the Arkansas River at the Kinsley gaging station.

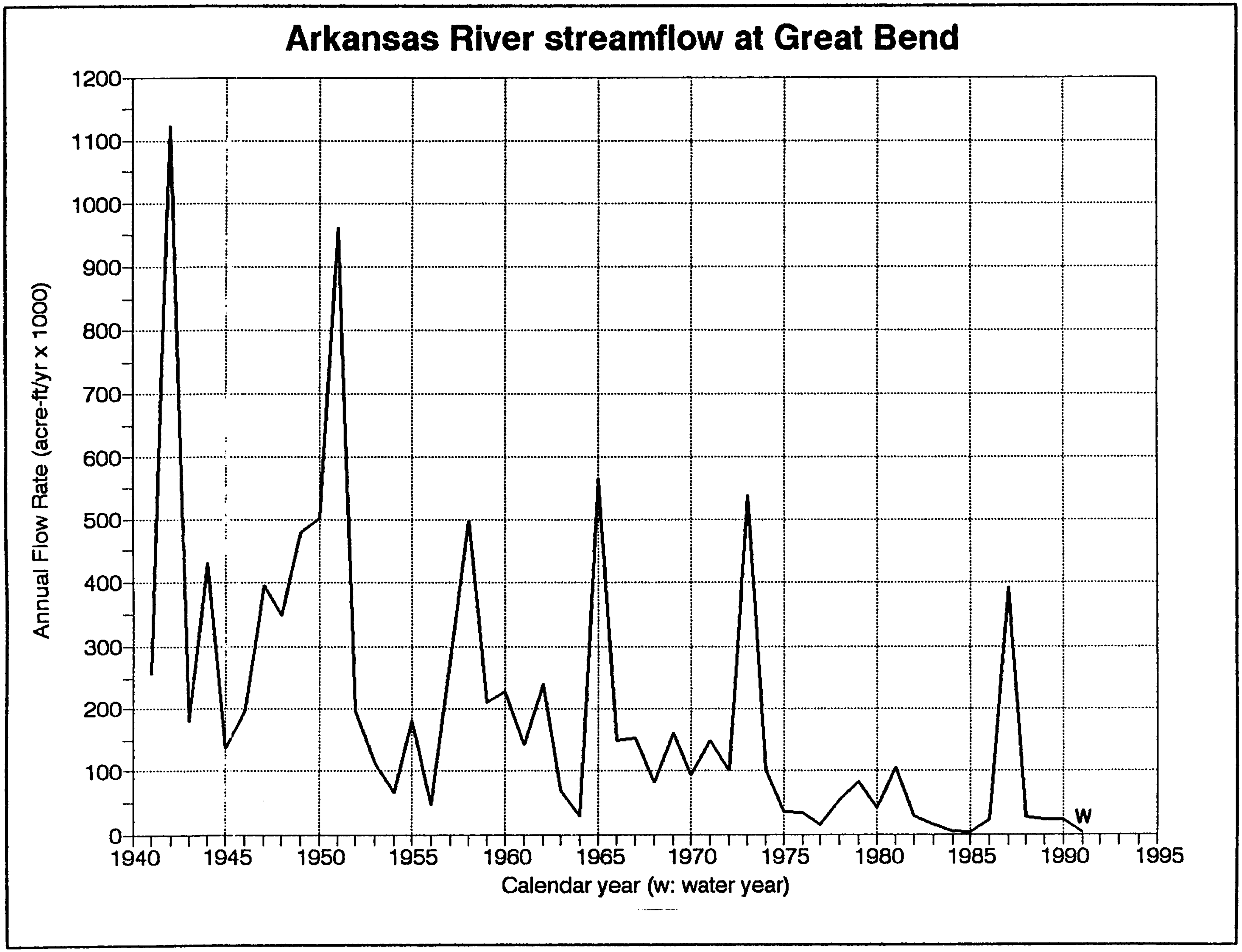


Figure 7. Average annual streamflows of the Arkansas River at the Great Bend gaging station.

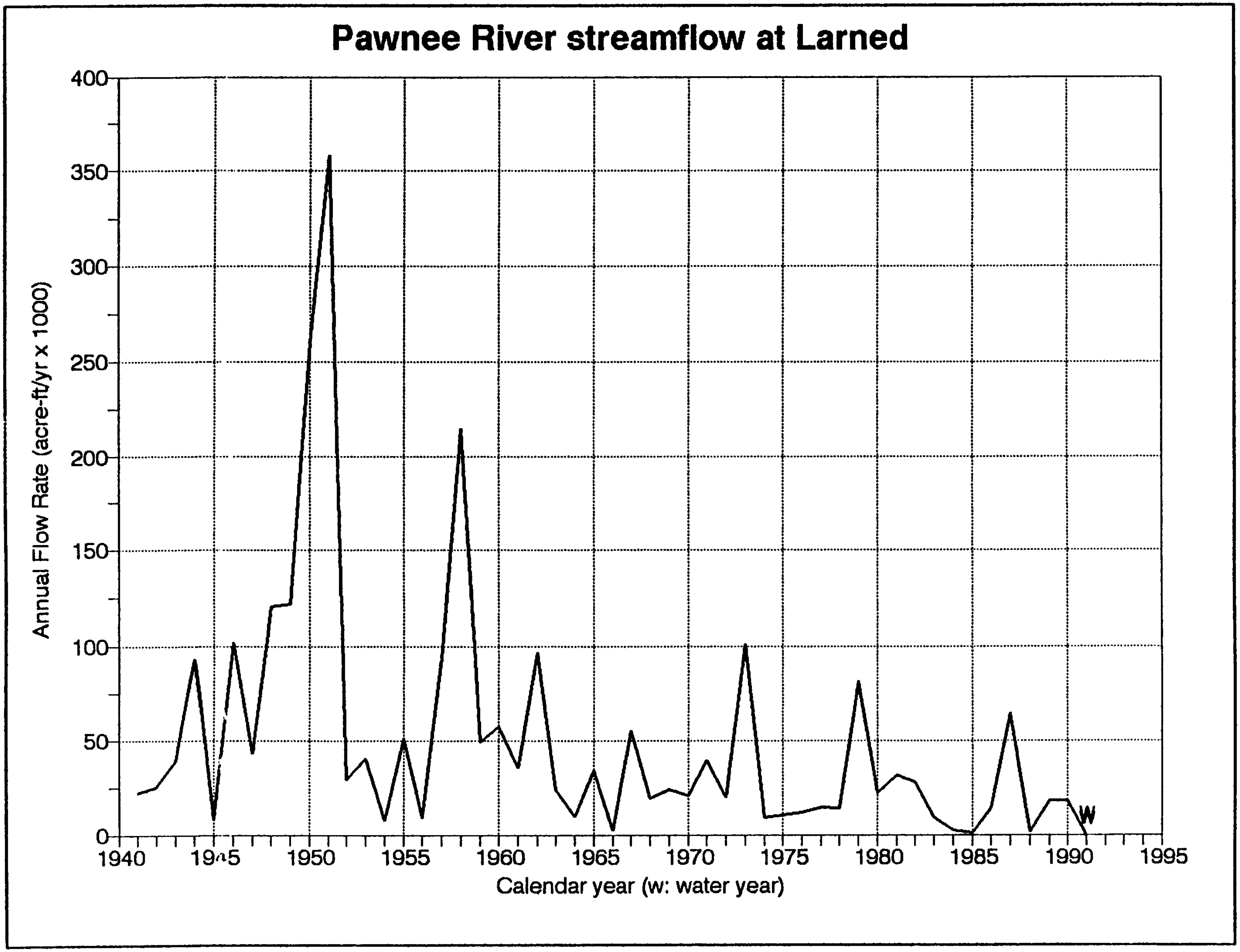


Figure 8. Average annual streamflows of the Pawnee River at the Larned gaging station.

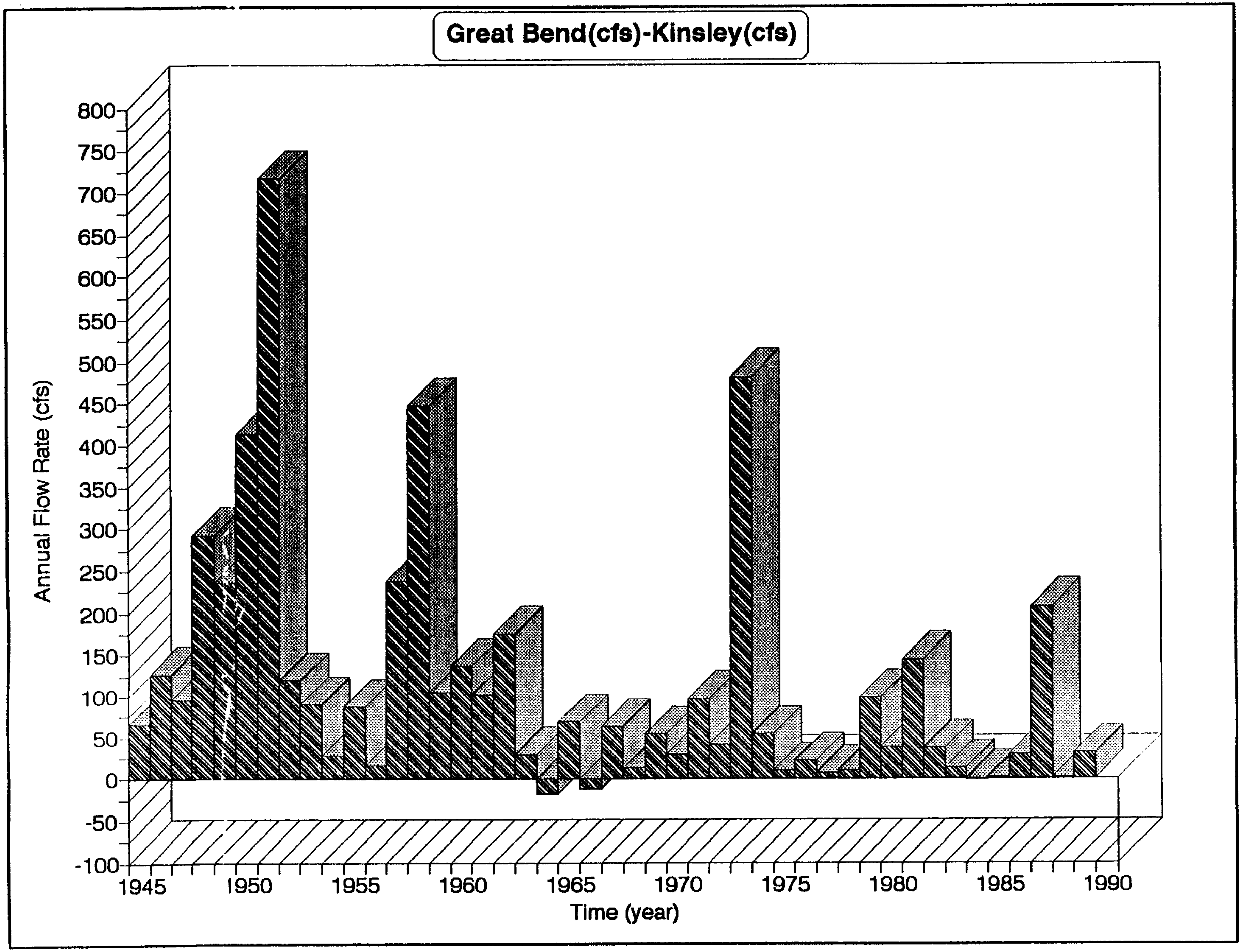


Figure 9. Average annual streamflow gains or losses of the Arkansas River between Kinsley and Larned.

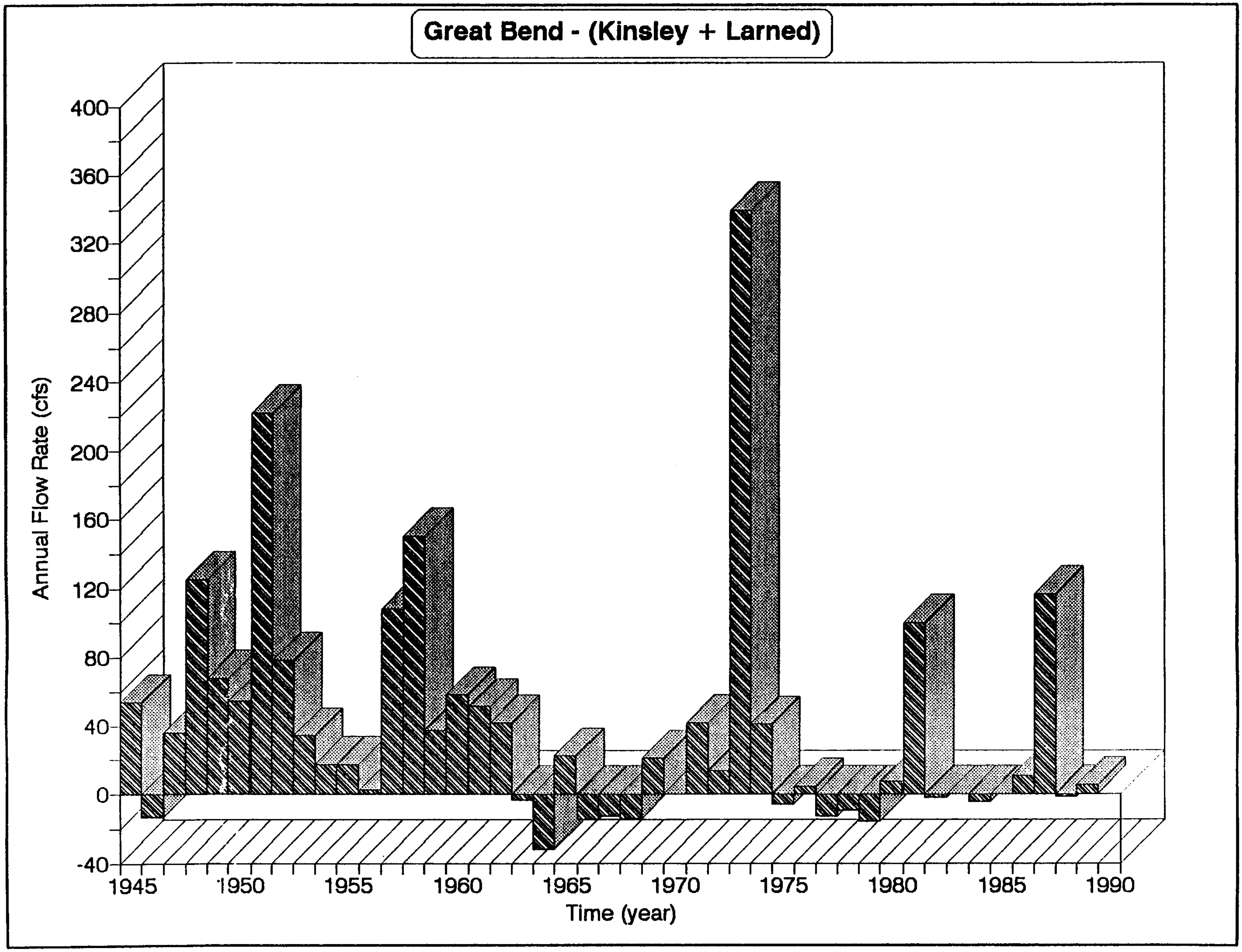


Figure 10. Average annual streamflow gains or losses of the Arkansas River between Larned and Great Bend.

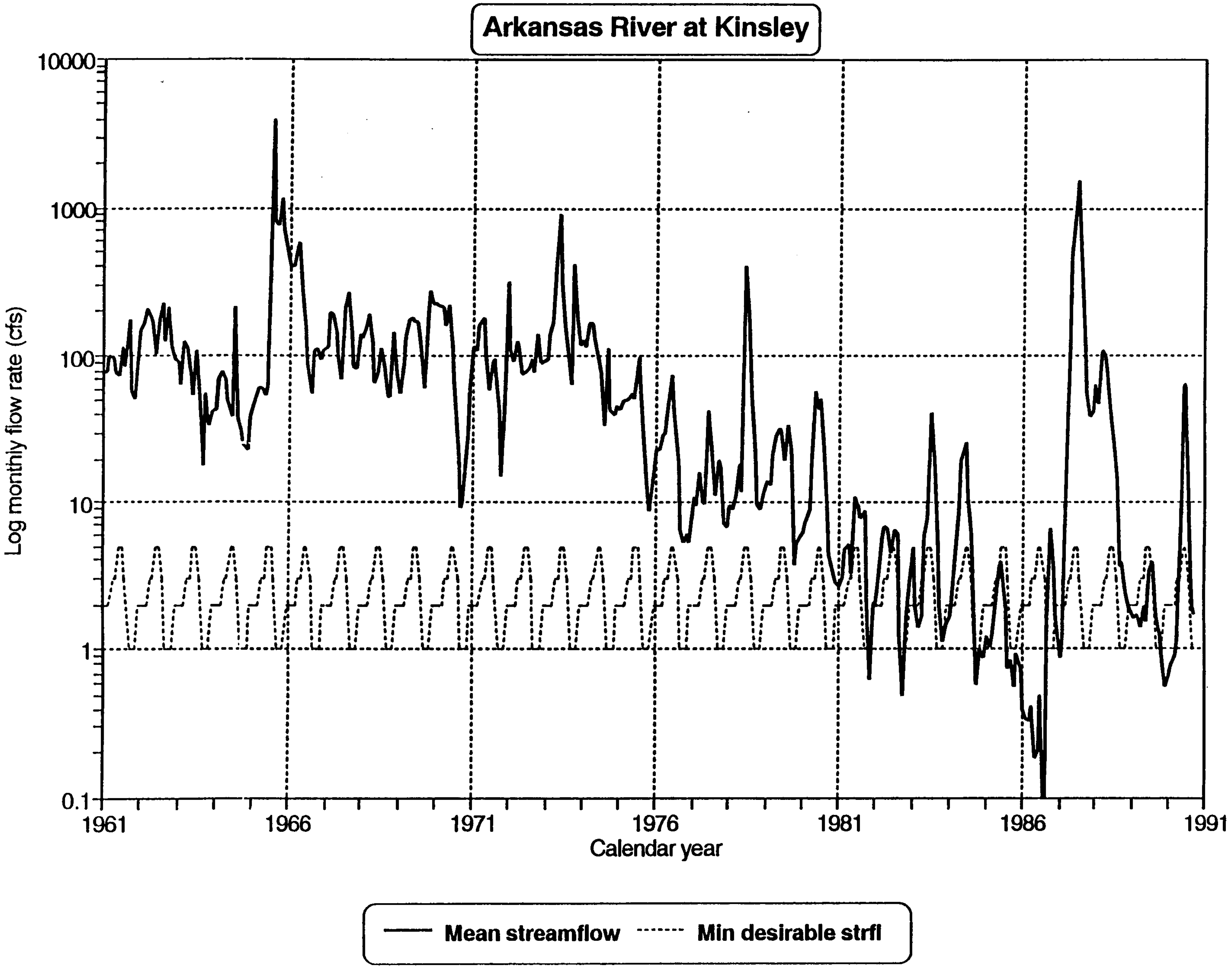


Figure 11. Average monthly streamflows and minimum desirable streamflows for the Arkansas River at the Kinsley gaging station.

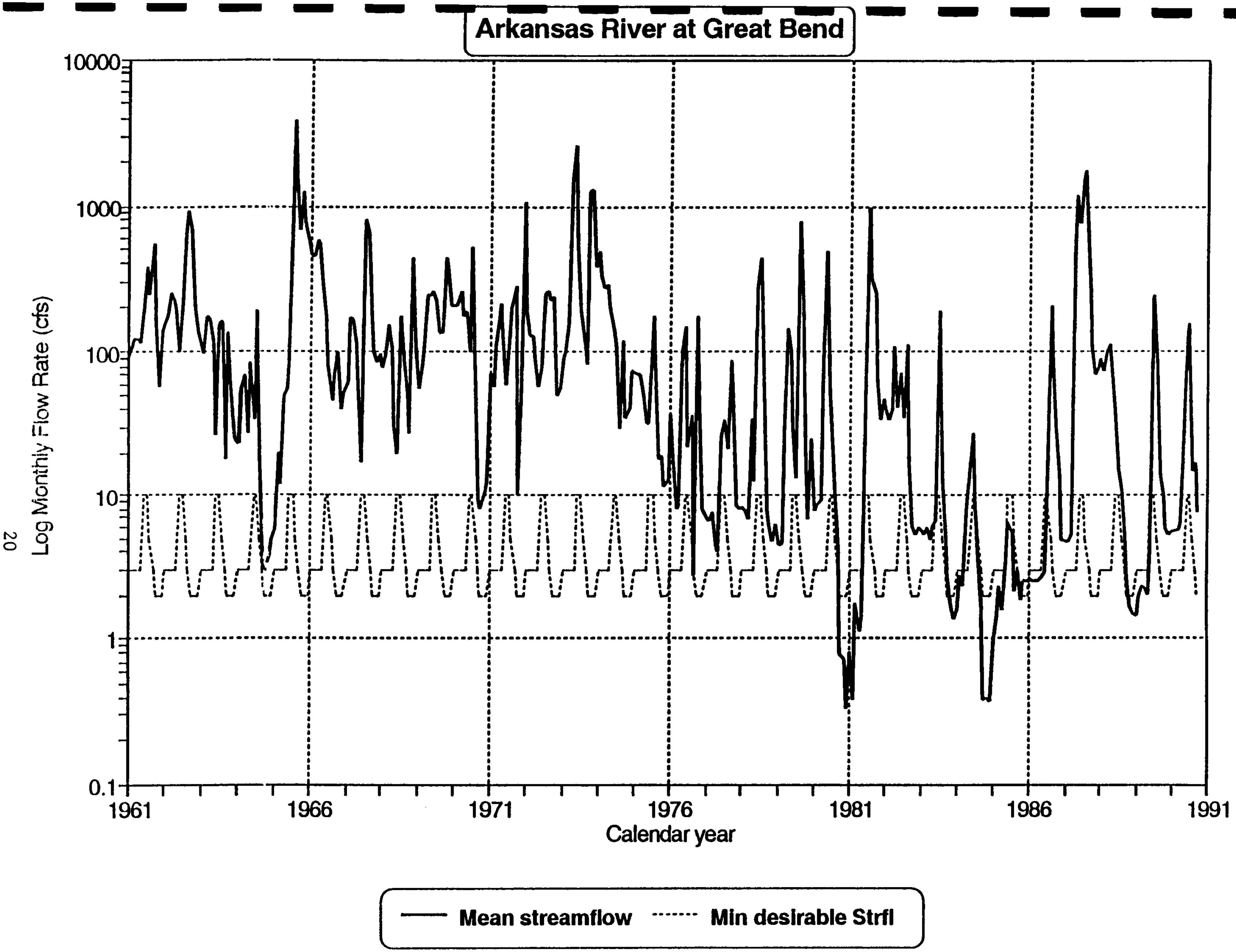


Figure 12. Average monthly streamflows and minimum desirable streamflows for the Arkansas River at the Great Bend gaging station.

Table 1. Available Water Capacities (AWC, in inches) for the upper 60 Inches of the Study Area Soils

Soil Association	Corresponding Percent Membership in Soil Association	AWC
Platte–Waldeck	50–50	4.7
Pratt–Tivoli	59–41	5.1
Pratt–Carwile	81–19	7.0
Attica–Pratt–Carwile	57–31–12	7.9
Naron–Farnum	75–25	9.3
Naron–Carwile	75–25	9.8
Farnum–Lubbock	65–35	10.8

5. Climatic data were obtained from existing NOAA climatic stations in Kansas and from an ongoing Groundwater Management District 5–Kansas Geological Survey (GMD5–KGS) cooperative study on recharge assessment in GMD5, which encompasses most of the Great Bend Prairie region, including the study area. The 1980–1990 average annual precipitation at Kinsley is 25.19 in., at Larned 22.76 in., and at Great Bend 24.68 in.

6. Water-level data from the Great Bend aquifer for various years since the 1970's have been examined and analyzed to delineate ground-water flow lines for possible selection of one boundary flow line separating the Arkansas River valley system from the Great Bend aquifer proper.

7. Most, if not all, available reports related to the study area have been examined for useful information transferable to this study.

8. A number of driller's logs from the study area, characterized by their detailed and careful descriptions, were selected and used in a computer program (Ed Gutentag, U.S. Geological Survey, personal communication, 1991) to estimate the hydraulic conductivity and storativity of the aquifer based on the lithology and thickness of the water-saturated strata. The results of this effort are shown in figs. 13 and 14.

Based on items 7 and 8, a compilation of hydrogeologic properties of the Arkansas River alluvial aquifer has been constructed (table 2).

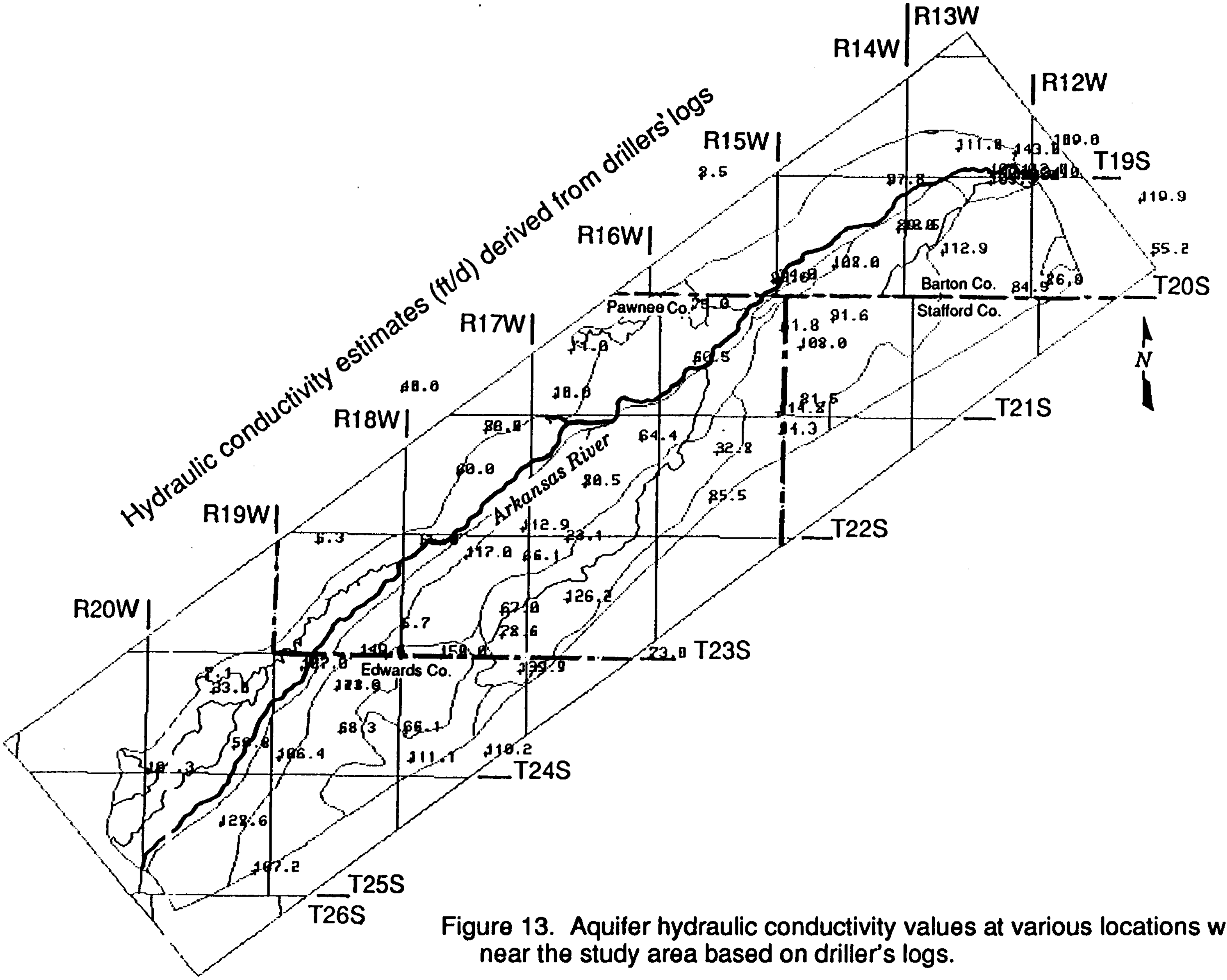


Figure 13. Aquifer hydraulic conductivity values at various locations within and near the study area based on driller's logs.

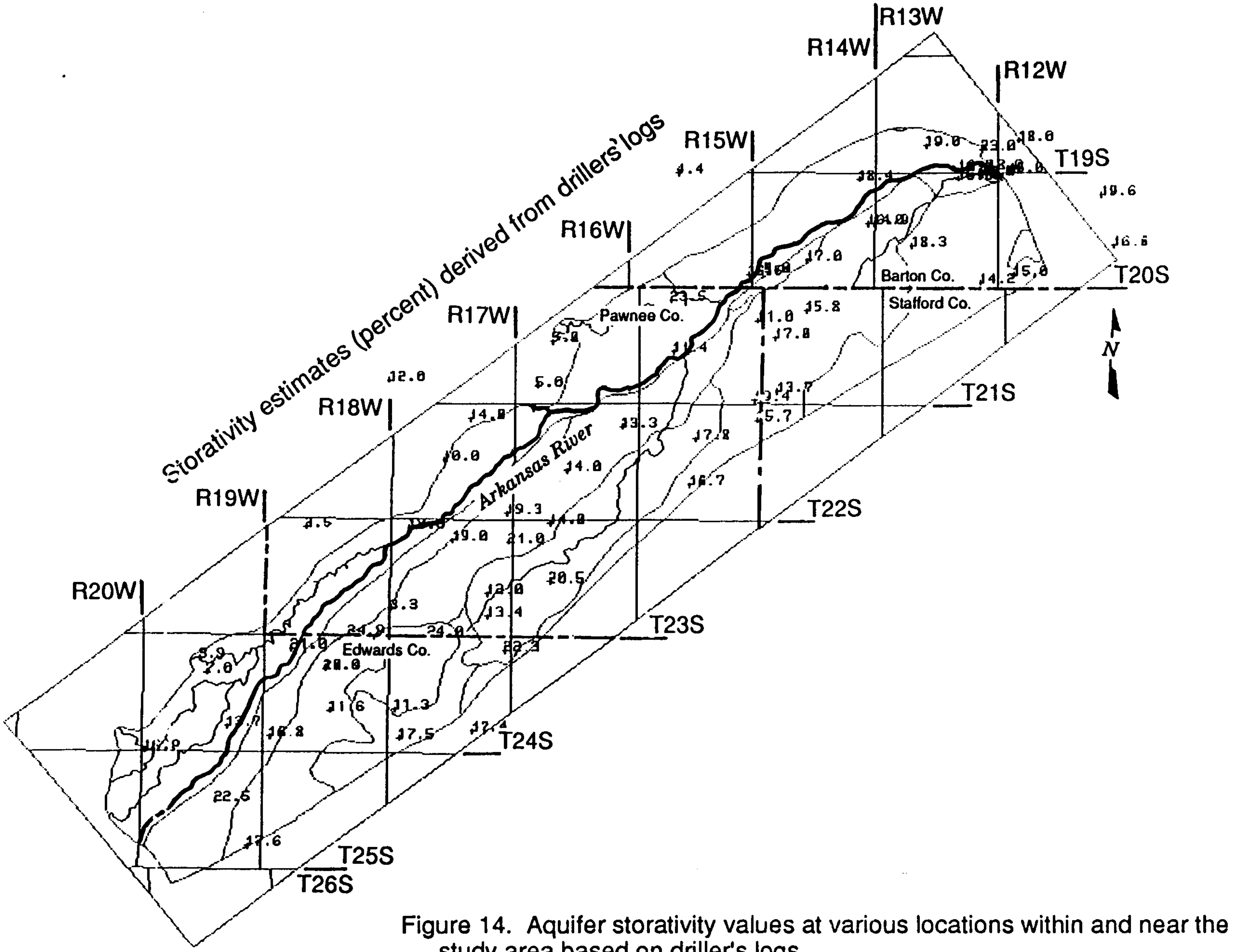


Figure 14. Aquifer storativity values at various locations within and near the study area based on driller's logs.

Table 2. Hydrogeologic Properties of the Great Bend Prairie Aquifer Including the Arkansas River Alluvium

Methodology	Transmissivity T(ft^2/d)	Hydraulic Conductivity K(ft/d)	Storativity S	Average Saturated Thickness (ft)	Source
5 aquifer tests	7,000–16,000	56–128	0.004–0.17	125	Fader & Stullken, 1978
Specific capacities of 235 irrigation wells	2,500–35,000 (ave. = 11,000)			125	Fader & Stullken, 1978
6-hr aquifer test near St. John	10,026	72	0.025	139	Cobb, 1979; 1980
8-day stream-aquifer test near Great Bend	19,404 (geom. mean)[a] 19,768 (arith. mean)[a] 4,979 (std. dev.)[a]	223 230 57	0.00056 0.000742 0.000664	87	Sophocleous et al., 1987; 1988
68 drillers' logs in the model area and vicinity (Figs. 13 and 14)	6,132 (mean) 3,171 (std. dev.)	85 37	0.15 0.05	76 30	This study

a. Average of drawdown- and recovery-derived values of 12 observation wells.

Hydrogeology and Pleistocene history of the Great Bend Prairie with emphasis on the study area

Knowing the geologic history and geologic composition and structure of the study area is a prerequisite to understanding the water-bearing and water-yielding properties of the modeled stream-aquifer system.

The Great Bend Prairie is covered with a veneer of loess deposits and sand dunes, with underlying Pleistocene alluvium forming the major aquifer of the area (Latta, 1950; Fader and Stullken, 1978). This alluvium was deposited by the ancestral Arkansas River and a small number of local streams. The Pleistocene alluvium overlies Cretaceous and Permian bedrock. A generalized columnar section of the geologic units and their water-bearing properties is given in table 3 [from Fader and Stullken (1978)].

The Permian bedrock subcrops along an approximately north-south trend in the vicinity of US–281 and constitutes a source of poor-quality (saline) water east of US–281 in northeast Stafford County. The Permian formations in the area, known as red beds, consist of reddish-

Table 3. Generalized columnar section of geologic units and their water-bearing properties [from Fader and Stullken (1978)].

System	Geologic unit	Maximum thickness, in feet	Physical character	Remarks
Quaternary	Undifferentiated Pleistocene deposits	360	Unconsolidated deposits of sand and gravel with interbedded lenses of clay, silt, and caliche. Windblown silt (loess) and dune sand occur at the surface over most of the area. Stream-laid deposits (alluvium) of late Quaternary age ranging from clay to gravel occur along the principal stream valleys.	Comprises principal aquifer. Water generally is of good chemical quality but may be of poor chemical quality in the northeastern part of the area and in deep buried valleys in the southeastern part. Yields as much as 2,000 gal/min to wells.
Tertiary	Ogallala Formation (Pliocene deposits)	65	Unconsolidated deposits of silt and fine sand with interbedded caliche. Some interbedded sand and gravel.	
Cretaceous	Undifferentiated Lower Cretaceous rocks	380	Upper unit (Dakota Formation) brown to gray fine- to medium-grained sandstone interbedded with gray sandy shale and varicolored shale. Middle unit (Kiowa Shale) dark gray to black shale interbedded with tan and gray sandstone. Lower unit (Cheyenne Sandstone) gray and brown fine- to medium-grained sandstone interbedded with dark gray shale.	Water probably of poor chemical quality. Yields 10 to 100 gal/min to wells locally in the western part of the area.
Permian	Undifferentiated Permian rocks	350	Interbedded reddish shale, siltstone, and sandstone with some beds of dolomite and anhydrite. Includes, in descending order, Whitehorse Formation, Dog Creek Formation, Blaine Formation, and Flower-pot Formation.	Water generally of poor chemical quality. May yield as much as 10 gal/min to wells.
	Cedar Hills Sandstone	200	Reddish shale, siltstone, silty shale and sandstone.	Sandstone may contribute highly mineralized water to the principal aquifer where the two units are in contact.
	Salt Plains Formation	300	Reddish-brown sandy siltstone and fine-grained sandstone.	May contribute highly mineralized water to the principal aquifer where the two units are in contact.
	Harper Sandstone	250	Brownish-red siltstone and silty shale with a few thin beds of silty sandstone. Kingman sandstone member is near the top of the formation.	Water may be of poor chemical quality. May yield no water or as much as 100 gal/min to wells in the eastern part of area.
	Stone Corral Formation	20	White and light-gray anhydrite and dolomite.	Not known to yield significant amounts of water to wells in the area.
	Ninnescah Shale	400	Red and grayish-green shale siltstone and very fine grained silty sandstone.	May yield water of fair to poor chemical quality to wells in the outcrop areas.
	Wellington Formation	550	Calcerous gray and blue shale containing several thin beds of limestone, gypsum, and anhydrite. The Hutchinson Salt Member, when present, is near the middle of the formation.	Not known to yield significant amounts of water to wells in the area.

*Chemical quality of water is classed as good if the concentration of dissolved solids is less than 500 mg/L (milligrams per liter) or the concentrations of chloride and sulfate are less than 250 mg/L, fair if dissolved solids are 500 to 1,000 mg/L or chloride and sulfate are 250 to 500 mg/L, and poor if dissolved solids are greater than 1,000 mg/L or chloride and sulfate are greater than 500 gm/L.

brown sandstone, siltstone, shale, salt, gypsum, anhydrite, and limestone. Rocks of Cretaceous age form the bedrock surface in the western part of the Great Bend Prairie, including the model area. These rocks consist of interbedded shales, sandy shales, and fine- to coarse-grained sandstones (Fader and Stullken, 1978). Of the three Cretaceous units given in table 3, only the lower unit (Cheyenne Sandstone) is a potential source of water to large-capacity wells, but the water is believed to be highly mineralized (Fader and Stullken, 1978).

Most of the Tertiary deposits making up the Ogallala Formation were removed by erosion before deposition of Pleistocene material. The stratigraphy of the Quaternary alluvium in descending order is generally (1) sand dunes; (2) a relatively continuous near-surface silt-clay bed, probably a loess deposit; (3) alternating sequences of fining-upward, sandy silt-clay, and sand and gravel lenses (not always present); (4) a basal sand and gravel bed of fluvial origin; and (5) bedrock (Rosner, 1988).

The Arkansas valley alluvium consists of stream-laid deposits that range in texture from clay and silt to sand and very coarse grained gravel. The upper 2–20 ft (0.6–6 m) of the alluvium on the Arkansas valley consists of silt and fine- to coarse-grained sand (Latta, 1950). Beneath these finer surficial deposits are thick beds of coarse-grained granitic sand and gravel. Most of the area lying south of the Arkansas River in Pawnee and Edwards counties is overlain by dune sand composed of uniform-grained, moderately well-rounded fragments of quartz and lesser amounts of silt and clay (McLaughlin, 1949). The dune sand lies above the water table and hence yields no water to wells.

In general, the present drainage system of central Kansas is the result of events that took place during the Pleistocene Epoch. The Pleistocene history of the area is complex and is marked by the cutting and filling of deep valleys and by major changes in drainage (Fent, 1950; Frye and Leonard, 1952). During early Pleistocene time, the ancestral Arkansas River, instead of following its present course around the great bend, is thought to have flowed eastward or southeastward across south-central Kansas. This can be seen on the bedrock map of the area (Sophocleous et al., 1990), where a number of west-east paleodrainage channels progress from south to north throughout the basin.

The Pleistocene drainage patterns of central Kansas record the history of the northeastward migration of through-flowing streams from the Rocky Mountain area. According to Fent (1950), this migration was caused by successive captures of the southern trunk of the ancestral stream by its own northern tributaries. The captures seem to have resulted from the difference in the debris load available in the headwater areas of the streams. Through-flowing streams originating from the Rocky Mountains, such as the Arkansas River, filled their channels throughout the Pleistocene with coarse gravel and sandy alluvium derived from igneous rocks. This material built up the surface over which they flowed, causing stream avulsions and the consequent spreading of alluvial material over wide areas. In contrast, the northern tributaries to the southern trunk stream carried only the finer-grained, less-permeable sediment load obtained by downcutting in their immediate headwater areas. The silt and fine-grained sand of local origin in the northern Great Bend Prairie, with its low permeability, favored runoff and consequently more erosion and downcutting below the level of the through-flowing streams; this downcutting led to the eventual capture of the through-flowing streams. This is evident in the relative abundance of northern tributaries to the Arkansas River in central Kansas (Fent, 1950).

The Quaternary deposits constitute an excellent source of good-quality water across most of the area. Some water-quality problems relating to mineral intrusion from the underlying Permian bedrock units render the ground water in certain areas unusable, such as the area around the Big and Little Salt marshes in northeastern Stafford County.

Field data collection

An extensive water-level survey in the Kinsley to Great Bend area was conducted in 1985 by the KGS and the GMD5. The resulting water-level map from that survey is shown in fig. 15. Also a stream-gaging survey of the Arkansas River (at Kinsley, Nettleton, Garfield, Larned, Dundee, Great Bend, and other stations) was conducted during March, April, and May 1986 by a cooperative group

January 1985 water table elevations (ft) in the study area (boxed) and vicinity
(+ = measurement point)

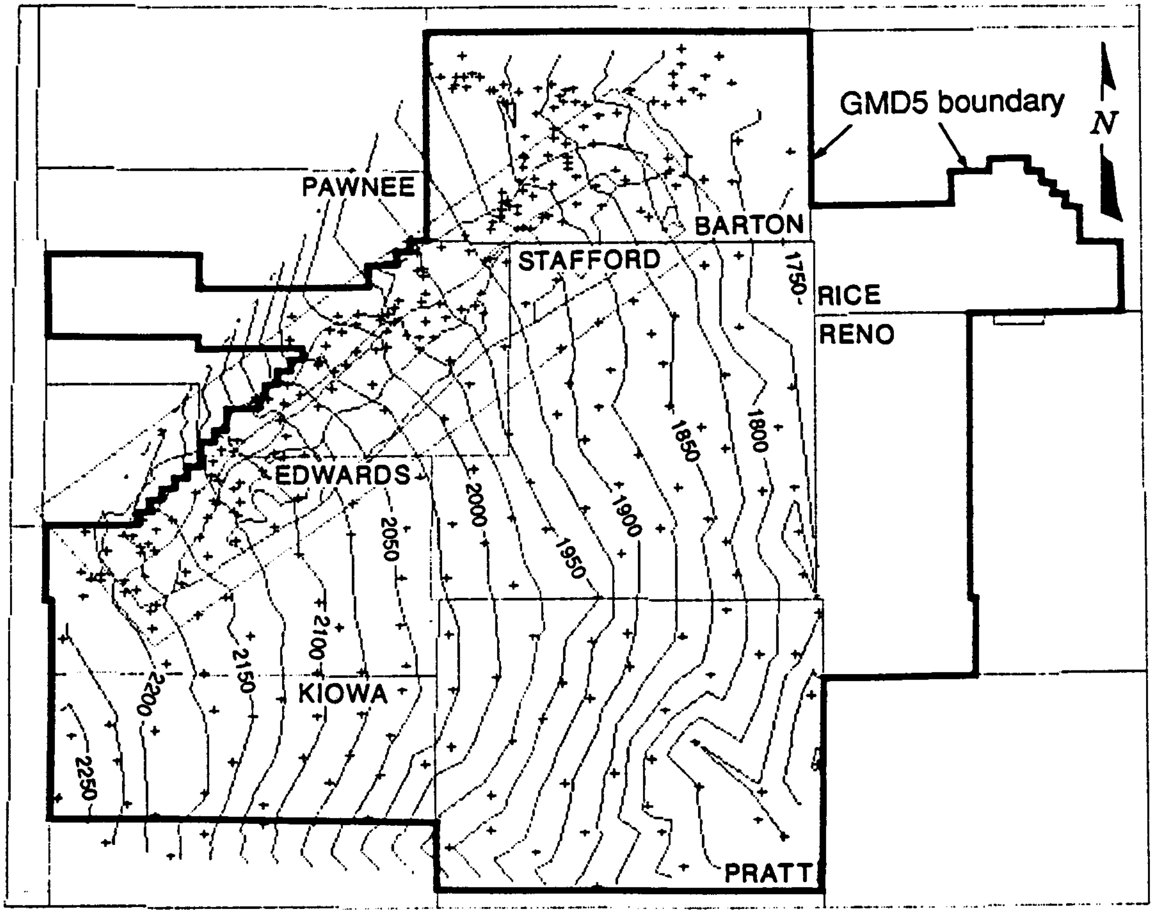


Figure 15. January 1985 water table contour map of the study area and vicinity.

from the Kansas Water Office, the Stafford Field Office of the Division of Water Resources, the GMD5, and the Kansas Department of Wildlife and Parks under the direction of the KGS. The results of that stream-gaging survey are presented in table 4.

During January and February 1991 a limited water-level survey in the study area was conducted by the GMD5 at the request of the KGS. These data combined with the annual water-level measurements taken by the Division of Water Resources in cooperation with the US Geological Survey were used to produce the January 1991 water-level map of the study area (fig. 16). This exercise was repeated in 1992 as well, and the resulting water-level map is shown in fig. 17. A stream-gaging survey of the same stations used in 1986 was also conducted during March 1991 by a cooperative group from the Kansas Water Office, the Stafford Field Office Division of Water Resources, the GMD5, and the KGS and during March 1992 by GMD5 at the request of the KGS. The results of that survey are also presented in table 4.

Numerical modeling

The major thrust of this study is to implement and analyze an appropriate stream-aquifer numerical model for the study area. The chosen simulation model to evaluate the Kinsley to Great Bend stream-aquifer system is a modified two-dimensional version of the popular modular three-dimensional finite-difference ground-water model (MODFLOW) of McDonald and Harbaugh (1988) with streamflow routing capabilities as documented by Prudic (1989). MODFLOW solves the three-dimensional ground-water flow equation using finite-difference approximations and includes the effects of many processes, such as areal recharge, rivers, drains, evapotranspiration, and pumpage. The finite-difference procedure requires that the aquifer be divided into cells. The aquifer properties in each cell are assumed uniform. The unknown head in each cell is calculated at a point or node at the center of the cell. The head is calculated by iterating through the finite-difference equations for all nodes until the maximum head change in any cell between the previous iteration and the current iteration is less than a specified small value. Once this criterion is met, the program advances to a new time step and the process of computing heads at each node is repeated.

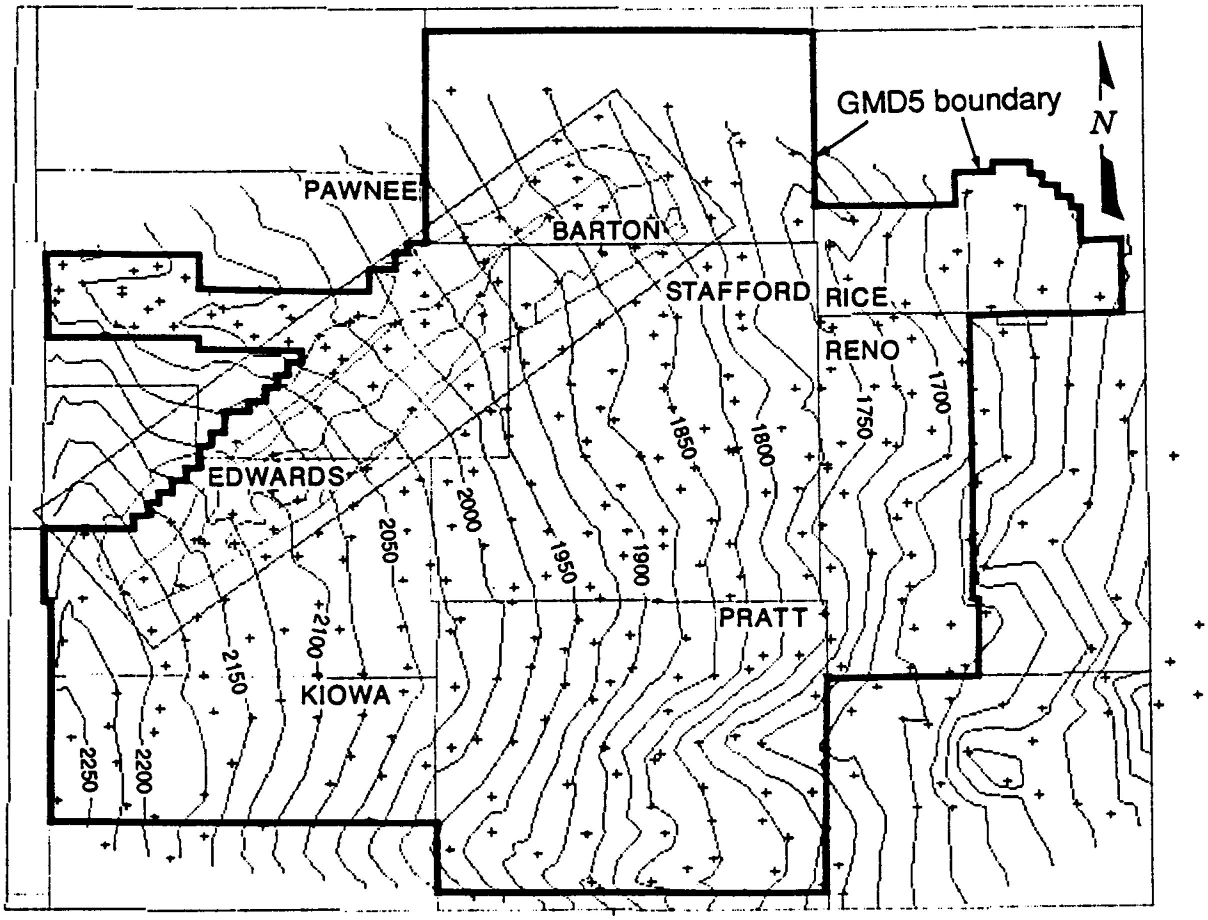

January 1991 water table elevations (ft) in the study area (boxed) and vicinity
(+ = measurement point)

Figure 16. January 1991 water table contour map of the study area and vicinity.

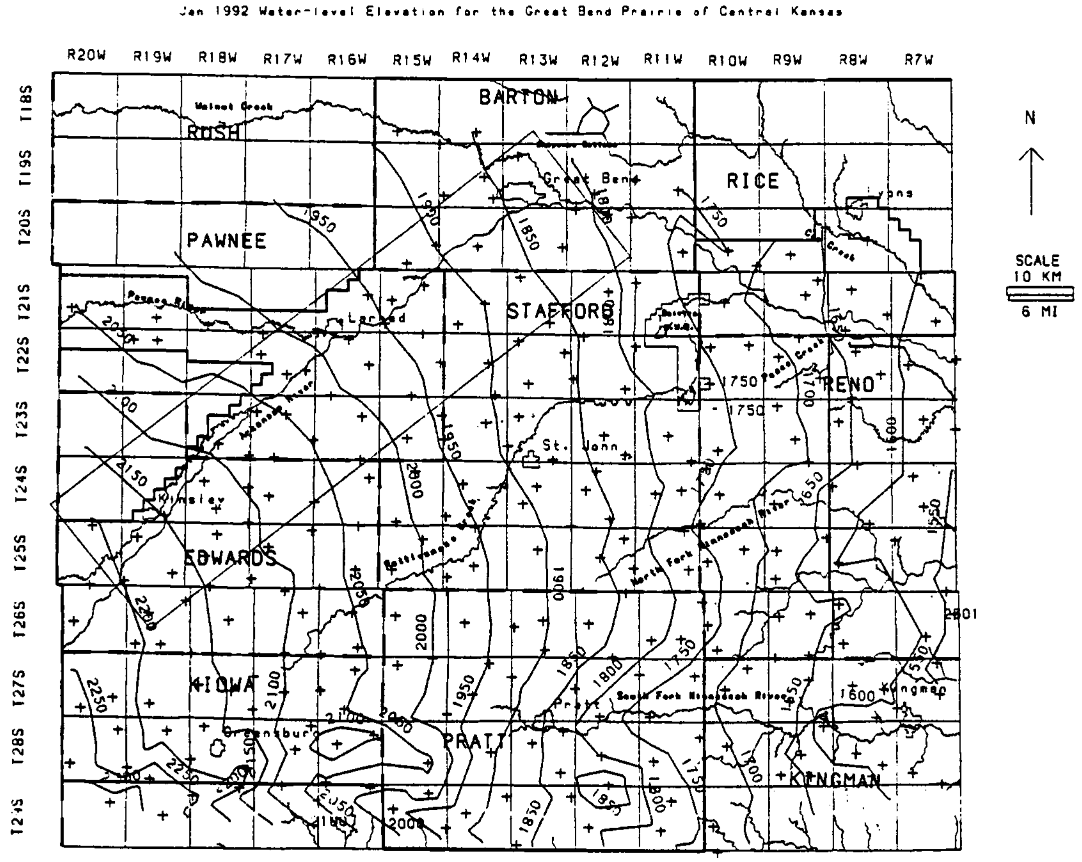


Figure 17. January 1992 water table contour map of the study area and vicinity.

Table 4. Stream-Gaging Surveys along the Kinsley to Great Bend Reach of the Arkansas River

Date	Width (ft)	Discharge (cfs)	Station	Comments
03/04/86	34.5	1.143	Arkansas R. at Kinsley	
03/18/86		1 (est.)		Impossible to get velocity with pygmy method
04/01/86		1 (est.)		Flow unchanged from last measurement
04/15/86				Noticeable flow over beaver dams
05/06/86				Same as 4/15/86
03/06/91	10.0	0.86		
03/25/92	6.5	0.105		Minimal flow; area had lots of cattails and water weeds
06/01/92		0		Dry channel
03/04/86	1.0 (channel in center of road)	0.029	Arkansas R. at Nettleton	
03/18/86		0.097		
04/01/86		0.097		Flow unchanged from last measurement
04/15/86				Flow reduced slightly but still a noticeable trickle
05/06/86				Same as 04/15/86
03/06/91				Unmeasurable
03/25/92		0		River channel dry at crossing
03/04/86	33.5	0.771	Arkansas R. at Garfield	
03/18/86		>1 (est.)		Impossible to get pygmy meter velocity
04/01/86		>1 (est.)		Flow unchanged from last measurement
04/15/86				Noticeable flow over beaver dams
05/06/86				Same as 04/15/86
03/06/91	14.0	2.093		
03/25/92		0		River ponded by beaver dams
03/03/86		<0.5 (est.)	Arkansas R. at Larned	No flow under bridge To the east, an estimated 0.5 cfs flow before confluence with Pawnee River; there is ponded water east and west of bridge
03/31/86		0		No flow under bridge
04/15/86		0		No flow under bridge Ponded areas are reduced
05/06/86		0		No flow under bridge Ponded areas are slightly larger than 2 weeks ago
03/06/91		0		No flow below confluence of Pawnee either
03/25/92		0		Dry channel
03/03/86		<0.5 (est.)	Pawnee R. at Larned	
03/18/86		0.5–1 (est.)		
03/31086		<1 (est.)		
04/15/86		0		No flow over beaver dams
05/06/86		0		Water is ponded under the bridge but there is no distinct flow
03/06/91		0.26		
03/25/92		0		Dry channel

Table 4 (continued)

Date	Width (ft)	Discharge (cfs)	Station	Comments
03/06/91		0.61	Arkansas R. at Pawnee Rock	
03/25/92		0		Water ponded in deeper areas of channel
03/03/86			Arkansas R. at Dundee	No flow under bridge 0.5 cfs (est.) on stretch of ponded water about 100 yd west of bridge
03/18/86		0		No flow under bridge
04/01/86		0		No flow under bridge
04/15/86		0	Arkansas R. at Dundee (cont.)	Ponded areas have diminished since 04/01/86
05/06/86		0		No flow under bridge Ponded areas are slightly larger
03/06/91		0		No flow
03/25/92		0		Channel dry
03/04/86	14.5	1.81	Arkansas R. at Great Bend	
03/18/86	17.0	2.695		
04/02/86	15.0	3.436		
04/16/86	15.0	2.286		
05/01/86	16.0	3.079		
03/06/91		4.84		
03/25/92	14.0	1.965		First and only real flow of '92 survey. Water was cloudy and discolored (algae)
03/04/86	28.0	1.16	Wet Walnut Creek at Great Bend	
03/18/86	17.9	0.199		
04/02/86	15.0	2.379		
04/16/86	15.0	1.436		
05/01/86	14.0	2.69		
03/04/86	29.0	9.861	Arkansas R. at Dartmouth	
03/18/86	26.0	10.715		
04/02/86	26.0	12.935		
04/16/86	25.0	8.049		
05/01/86	25.0	13.688		

Streams superimposed on the aquifer are divided into *reaches* and *segments*. A segment consists of one or more reaches. Each reach corresponds to individual cells in the finite-difference equation used to simulate ground water flow. Streamflow is accounted for by specifying flow for the first reach in each segment that enters the model area and then computing streamflow to adjacent downstream reaches in each segment as equal to inflow in the upstream reach plus or minus leakage from or to the aquifer in the reach. Leakage is calculated for each reach on the basis of the head difference between the stream and aquifer, and a conductance term:

$$Q_\ell = C_{\mathrm{str}}\,(H - h), \tag{1}$$

where Q_ℓ is the leakage to or from the aquifer through the streambed, H is the head in the stream, h is the head in the aquifer side of the streambed, and C_{str} is the conductance of the streambed, which is the hydraulic conductivity of the streambed times the product of the width of the stream reach and its length divided by the thickness of the streambed.

The stage in each reach can be computed by using the Manning formula under the assumption of a rectangular stream channel:

$$Q = \frac{c}{n}\left(AR^{2/3}S_0^{1/2}\right), \tag{2}$$

where Q is the stream discharge, n is Manning's roughness coefficient, A is the cross-sectional area of the stream, R is the hydraulic radius, S_0 is the slope of the stream channel, and c is a constant, which is 1.486 for units of cubic feet per second (cfs). The cross-sectional area A and the hydraulic radius R for a rectangular channel are

$$A = wd, \tag{3}$$

$$R = wd/(w + 2d), \tag{4}$$

where d is the depth of the water in the stream and w is the width of the channel.

The amount of leakage in each reach either into or out of the aquifer is incorporated into the ground-water flow model by adding appropriate terms to the finite-difference equation. Recharge to the aquifer in a reach ceases when all the streamflow in upstream reaches has leaked into the aquifer and the stream is dry. A stream is permitted to flow again in downstream reaches if the head in the aquifer is above the elevation of the streambed.

The ground-water flow model with the streamflow-routing package has an advantage over the analytical solution in simulating the interaction between aquifer and stream because the model can be used to simulate complex systems that cannot be readily solved analytically.

Required input data for the stream-aquifer model include (1) the areal distribution of aquifer-related parameters, such as transmissivity or hydraulic conductivity, storativity, and natural recharge; (2) water levels in the aquifer and the stream(s); (3) bedrock and land surface elevations; (4) the input stream and tributary hydrograph; (5) stream width, slope, streambed elevations, and Manning's roughness coefficients; (6) the streambed conductance (i.e., hydraulic conductivity of streambed or canal and ditch sediments divided by their thickness); (7) the location and pumping rate of wells; and (8) the initial and boundary conditions.

Calibration

One of the most important steps in setting up a ground-water model is calibration. Development of the computer model as a predictive tool is based on the premise that, if historic hydrologic phenomena can be satisfactorily approximated by the model, then so should future conditions. Calibration involves adjusting model input parameters, based on field data, to accurately predict real-world cause-and-effect relationships. The task of manually adjusting parameter and past recharge values over different parts of the aquifer until the model nearly replicates previously measured water-level measurements in a set of observation wells is an arduous one requiring many model runs. Adjustments are often made in a hit-or-miss fashion until the fit between the model and the observed water levels is acceptable. This process is often time consuming and expensive and sometimes can result in no answer. Also, questions about whether or not the derived solution is the optimum solution and how many other solutions are equally good are difficult to answer when trial-and-error methods are used. To avoid problems related to manual calibration, one can use a parameter estimation computer program that uses the MODFLOW program as its forward processor to obtain an optimum set of parameter or input values. The process by which one is attempting to solve for one or a number of the model parameters or inputs is known as *inverse modeling* (or *inverse problem*). Once we know the parameters or inputs to the model (e.g., hydraulic conductivity, storativity, recharge), it is a relatively simple matter to obtain model outputs such as heads or water levels in the aquifer. This modeling process is known as the *forward problem* or *forward modeling*. In this study we employ a parameter optimization software for MODFLOW known as MODINV (for *mod*flow *inv*erse). Using MODINV (Doherty, 1990), we can optimize the specific values taken by any parameter type that MODFLOW can read as a two-dimensional data array such that model-generated heads are as well matched as possible to those observed in the field. Steady-state and transient, single-layer and multilayer, and confined and unconfined models can all be calibrated in this manner. MODINV adjusts parameter and/or recharge values pertaining to a set of constant-value zones chosen by the modeler (based on field data) for each parameter type until the optimum fit between observed and model heads is obtained. MODINV then provides the covariance matrix, which indicates the reliability or uncertainty levels of these parameter estimates. Model and observed heads are matched according to the weighted least-squares criterion, and optimization is achieved using the Gauss–Newton–Marquardt method (Draper and Smith, 1981).

Regression problem

The calibration or parameter estimation problem can be viewed as a classical nonlinear regression problem with a solution of the appropriate flow equation forming the regression equation and all unknown quantities, such as hydrogeologic parameters, sources, sinks, and boundary fluxes, as parameters (Sophocleous, 1984). The measured hydraulic heads are observations of the dependent variable for which a set of least-squares estimates is to be obtained. This viewpoint not only has the advantage of finding the parameters of a given model that produce the best fit of the calculated hydraulic head (dependent) variable to the observed dependent variable but also allows implementation of many methods and tests that have been developed to analyze on a probabilistic basis the propagation of data errors in the estimates of parameters and the predictive capability of the model (Draper and Smith, 1981).

The basic equation that is to be fitted to the observed head data is the general form of the two-dimensional ground-water flow equation (which the MODFLOW program is designed to solve):

$$\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)+R(H-h)+W+\sum_{\ell=1}^{N}\delta(x-a_\ell)\delta(y-b_\ell)Q_\ell=S\frac{\partial h}{\partial t}, \qquad (5)$$

where T_{xx} ($= K_{xx}b$) and T_{yy} ($= K_{yy}b$) are the transmissivities in the x and y directions, respectively; K_{xx} and K_{yy} are the hydraulic conductivities of the aquifer in the x and y directions, respectively; $b(x, y)$ is the saturated thickness of the aquifer, $R(x, y)$ is the hydraulic conductance of the streambed, which is the hydraulic conductivity of the streambed times the product of the width of the stream and its length divided by the thickness of the streambed; $H(x, y, t)$ is the head in the stream; $h\ (x, y, t)$ is the hydraulic head in the aquifer; and $W\ (x, y, t)$ is a source-sink term (positive for a source, such as recharge) distributed areally. The expression $\sum_{\ell=1}^{N} \delta(x - a_\ell)(y - b_\ell)Q_\ell$ is the Dirac delta designation for N wells, each one pumping at rate Q_ℓ(t) (positive for injection) and located at coordinates $(a_\ell,\ b_\ell)$. S is the storativity (storage coefficient or specific yield); x, y are the Cartesian coordinates; and, finally, t is time.

To approximate the variability of a given parameter, the region of interest is subdivided into a number of zones in which the parameter is assumed to be constant within each zone. Zones of one type of parameter, such as hydraulic conductivity, do not necessarily correspond to zones for another type, such as recharge.

Boundary conditions, such as lateral model inflow rate or constant head levels, are often considered to be part of the model itself, being neither an input nor a parameter. Along internal discontinuities in hydraulic conductivity the hydraulic head and flux normal to the boundary remain unchanged as the boundary is crossed.

The classical problem of ground-water hydrology is to directly solve Eq. (5) together with its associated boundary conditions (including the initial head at $t = 0$) for the hydraulic head $h = h(x, y, t)$ in the aquifer, whereas an inverse solution involves solving Eq. (5) and boundary conditions for one or more of the parameters, such as T, K, S, or W.

Sources of error in ground-water data

Numerous problems involving ground-water flow modeling of real field systems exist because the data necessary for the direct or inverse solutions are usually lacking. Head distribution is never known exactly because measurements do not exist at all points and because, where the measurements do exist, they are not exact. Estimates of the parameters either are completely unknown or have been obtained by spot measurements, few of which are directly useful for construction of appropriate effective values for use in Eq. (5). It should be clear that modeling problems in ground-water hydrology involve an incomplete combination of several types of data in which error and error propagation are important considerations.

Some major potential sources of random error in head data with respect to the model [Eq. (5)] are enumerated by Cooley (1979):

1. Areal ground-water models assume that the head used is the average over the vertical, but wells may not be opened over the entire interval modeled, and, if they are, they may not measure the average,
2. Hydraulic conductivity varies from point to point, which causes water levels to vary from values they would have if hydraulic conductivity were uniform. However, models usually do not take this detailed variation into account,
3. Water levels measured in wells in use may contain unknown amounts of residual drawdown. In addition, unused wells may be near wells that are in use, with resulting unknown drawdown in the unused well,
4. Measurement of well-head elevation may be in error,
5. Measurement of water levels may be in error [although usually of the order of 0.1–0.2 ft (0.03–0.06 m)].

Actual total error from the above sources is highly problem dependent, but it is easy to imagine errors of several feet. In addition, interpolation errors are also of the order of several feet (Sophocleous, 1983). Major model errors in Eq. (5) and associated boundary conditions can be detected relatively easily and can be eliminated by analysis of model results.

Because there are several different parameters to be considered and because each can be estimated or measured in several different ways, numerous sources of error exist in parameter data.

Some examples of errors in parameter data illustrating the nature of the problem are given by Cooley and Naff (1985):

1. Too few estimates of parameters are available to compute stable estimates of statistics such as mean and variance,
2. Results of point sampling are often biased because a large amount of data does not necessarily allow computation of nearly true or effective values of a parameter and its variance. For example, permeability values from core analyses often are not representative of regional values because flow through large fractures is not reproduced by core analyses,
3. Transmissivities estimated from specific capacity data collected by drillers are subject to numerous sources of error. Common sources include mismeasured water levels or pumping rates, recovery of water level after bailing, clogging the slots or screen, and inaccurate reporting. A persistent source of bias results because drillers drill wells in favorable locations and screen only the most productive zones,
4. Transmissivities and storativities estimated from pumping-test analyses are subject to many of the same errors as in item 3, but the more carefully controlled tests should reduce their frequency and magnitude. In addition, a single test may not be representative of an entire hydrostratigraphic unit,
5. Transmissivities and storativities estimated from lithologic data are usually biased to an unknown extent.

Numerical regression solution procedure

To form the regression problem, Eq. (5) must be solved subject to the appropriate boundary conditions. For the present study the regression solution is based on a numerical solution of Eq. (5) described in detail by McDonald and Harbaugh (1988). In matrix form the solution can be written

$$D\,\mathbf{h} = \mathbf{q}, \tag{6}$$

where D is a square coefficient matrix involving parameters T_{ij} and R of order m, the number of nodes used to discretize the model region; $\mathbf{h}$ is the hydraulic head vector of order m; and $\mathbf{q}$ is the known vector involving parameters W, Q, specified head, and boundary fluxes.

The set of optimal parameters is defined as the set that minimizes the objective function

$$SS = \mathbf{e}^{\mathrm{T}} w \mathbf{e} = (\mathbf{h}^{\mathrm{obs}} - \mathbf{h})^{\mathrm{T}} w \, (\mathbf{h}^{\mathrm{obs}} - \mathbf{h}) \tag{7}$$

where $\mathbf{h}^{\mathrm{obs}}$ is the vector of observed heads, $\mathbf{h}$ is a vector of predicted heads, $\mathbf{e} = (\mathbf{h}^{\mathrm{obs}} - \mathbf{h})$ is the residual vector consisting of the deviations of calculated heads from observed heads, superscript T indicates transpose, and w is a diagonal weight matrix that describes the reliability of $\mathbf{h}^{\mathrm{obs}}$ at each node. If for observation ℓ, $w_\ell = 0$, then there is no observed head at that node. SS is the weighted sum of squared deviations of calculated heads from observed heads, which is to be minimized. The use of the objective function [Eq. (7)] is equivalent to minimizing the error variance.

If the parameters to be computed (such as all the different values of K_{xx}, K_{yy}, S, and W are designated vector $\mathbf{b}$, then the normal equations (Draper and Smith, 1981) derived by minimizing Eq. (7) with respect to each parameter can be written

$$\mathbf{e}^{\mathrm{T}} w \frac{\partial \mathbf{e}}{\partial \mathbf{b}} = 0. \tag{8}$$

The necessary elements of $\mathbf{e}$ and their derivatives are obtained through use of a Guass–Marquardt linearization scheme applied to Eq. (6). The technique yields a regression equation, which can be written (Doherty, 1990)

$$\Delta \mathbf{b} = -N^{-1} f_i, \tag{9}$$

where $\Delta \mathbf{b}_i = \mathbf{b}_{i+1} - \mathbf{b}_i$; i is the iteration number; N is the normal matrix ($J^{\mathrm{T}} w J$) consisting of the components of the Jacobian matrix J of derivatives of the elements of $\mathbf{h}$ with respect to each of the elements of $\mathbf{b}$, and f_i is the gradient of the objective function (i.e., the weighted sum of squared head differences between the model and the observed heads).

The sensitivity coefficients J_{ij}, or simply sensitivities, indicate the change in the value of head h_i for a unit change in parameter b_j. The regression algorithm uses only observed values of head in the criterion *SS* for the best-fitting solutions.

Assumptions for the regression analysis

The nonlinear model—assumed to be the true model—represented by the solution of Eq. (6) for $\mathbf{h}$, which is the subset of $\mathbf{h}_m$ applying at nodes that are observation nodes, can be written for observation ℓ as

$$h_\ell^{\text{obs}} = f(\xi_\ell,\ \beta) + \varepsilon_\ell, \tag{10}$$

where f indicates a function that is the solution of Eq. (6); ξ_ℓ is a vector of independent variables that is an undetermined but observable function of coordinates x, y, the problem geometry, and boundary conditions; β is the vector of true parameters; and ε_ℓ is an error in observation.

To analyze statistically the results of and the predictions made by the regression model, we assume (Draper and Smith, 1981) that

$$\mathrm{E}(\varepsilon_\ell) = 0 \tag{11}$$

$$\mathrm{Var}(\varepsilon_\ell) = \sigma^2 \tag{12}$$

$$\mathrm{Cov}(\varepsilon_\ell, \varepsilon_m) = 0, \qquad \ell \neq m, \tag{13}$$

where E, Var, and Cov are the expected value, the variance, and the covariance, respectively. These assumptions indicate that ε_ℓ is considered a random variable with zero mean and constant variance σ^2 and that ε_ℓ and ε_m ($\ell \neq m$) are uncorrelated. In addition, it is often assumed that ε_ℓ is normally distributed with mean 0 and variance σ^2 (I is an identity matrix and $I\sigma^2$ is a scalar diagonal matrix–covariance matrix) such that

$$\varepsilon \sim N(0, I\sigma^2) \tag{14}$$

This means that the elements of ε are independent and uncorrelated and allow the use of statistical tests and measures involving the F and t distributions (Draper and Smith, 1981).

Because β is unknown, ε is not observable, and the assumptions cannot be checked directly. However, they can often be checked indirectly, after the regression and model analysis have been performed, as demonstrated later.

III. Model Implementation and Calibration

Grid selection

The study area consists of a 48 × 15 mile (77 × 24 km) rectangle in a southwest to northeast direction incorporating the Arkansas River from Kinsley to Great Bend (fig. 18). The Pawnee River joins the Arkansas River at approximately the middle of the northwest side of the study rectangle. This rectangle is divided into 720 squares or cells of 1 square mile area each, thus forming a rectangular cell-centered finite-difference grid used by MODFLOW. A total of 472 grid cells form the active area within the boundaries of the model region.

Boundary conditions

The model boundaries for the study area, as shown in fig. 18, were arrived at by superimposing the water-level, soil, and bedrock maps mentioned previously. The southeast boundary of the Arkansas River Valley system was thus separated from the rest of the Great Bend aquifer by following a bounding southwest to northeast flow line, which is equivalent to a no-flow boundary condition (because no flowlines can cross each other). The northwest boundary (no-flow) separation presents no significant problems because the valley is mostly bounded by relatively impervious Lower Cretaceous (Dakota Formation) strata and clayey soils in that direction. The northeast and southwest boundaries were cut along appropriate iso-water-level contours near Kinsley and Great Bend, respectively, thus forming assumed constant head end boundaries.

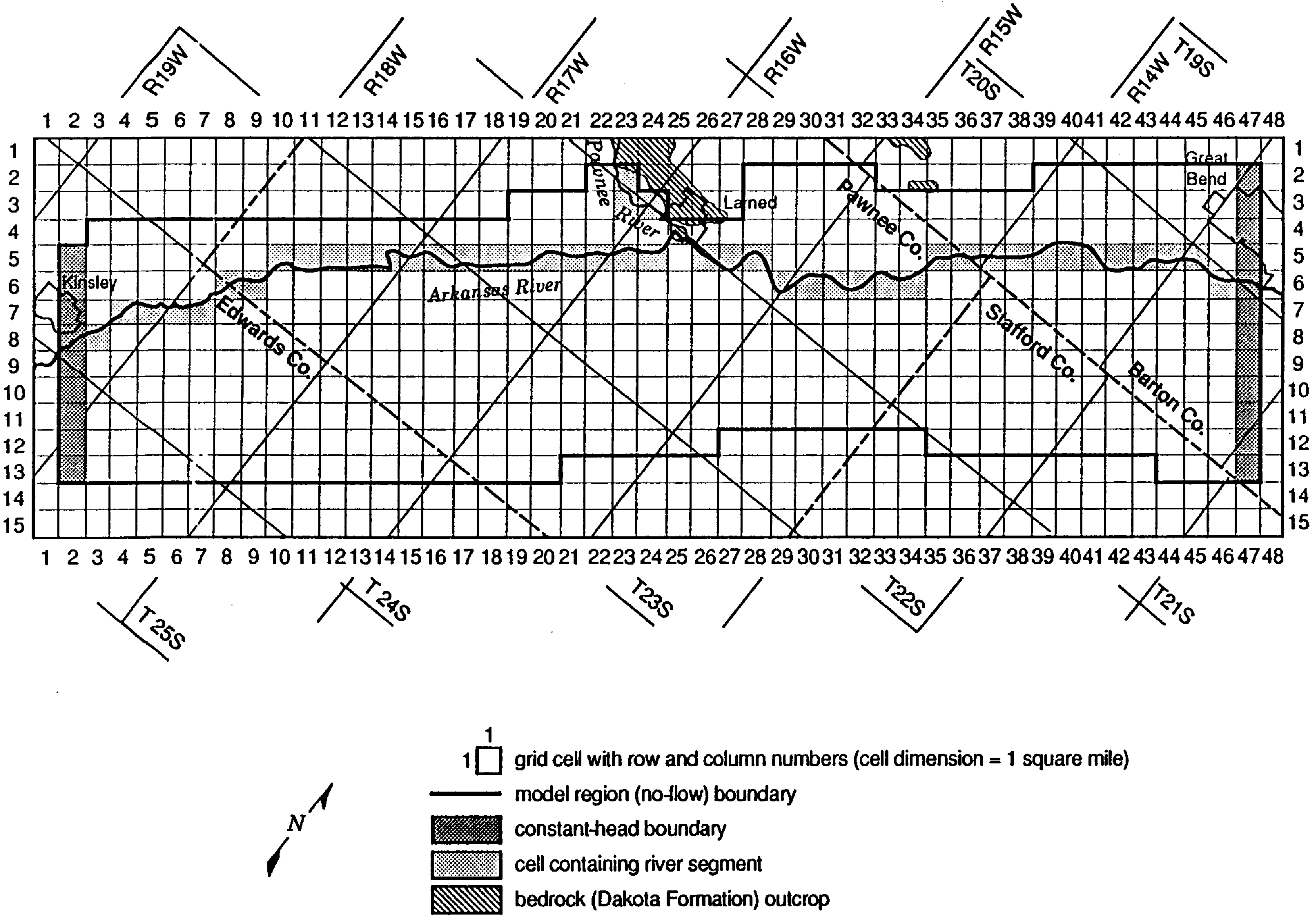


Figure 18. Finite-difference grid of the model area.

Model stresses

The period of simulation is divided into a series of "stress periods" within which specified stress parameters are constant. Each stress period, in turn, is divided into a series of yearly time steps. The system of finite-difference equations of the form of Eq. (6) is formulated and solved to yield the head at each node at the end of each time step.

Ground-water pumpage

A computer program was written to read and reformat the water rights tape obtained from the Division of Water Resources and to sort water rights according to year, application number, or legal location. Figure 5 is a plot of all ground water rights versus year of issue in the model area. To simplify matters and to avoid excessive input files to the model, we decided to approximate this curve by dividing it into segments of uniform number and distribution of wells starting in 1955, which is considered an indicator year of predevelopment conditions. Thus the time period from 1955 to 1962 is represented by the 1955 ground-water rights distribution, the 1963–1969 period by the 1967 ground-water rights distribution, the 1970–1975 period by the 1972 distribution, the 1976–1982 period by the 1979 distribution, and the 1983–1990 period by the 1990 distribution, as shown by the filled squares in fig. 19. Therefore pumping-well matrices for the different pumping stress periods, as indicated by the chosen index years 1955, 1967, 1973, 1979, and 1990, were prepared as input to the model. The distribution and the increase with time of the pumping irrigation wells are shown in figs. 20–24. In those figures each model cell with a number represents the number of wells in that cell.

Incoming streamflows

Another stress to the model system is represented by the fluctuating amount of incoming streamflow in the model area from the Arkansas River, as monitored at the Kinsley station, and from the Pawnee River, as monitored west of Larned. To simplify matters in a way similar to that done for the pumping stresses, we divided the average annual incoming streamflows at Kinsley

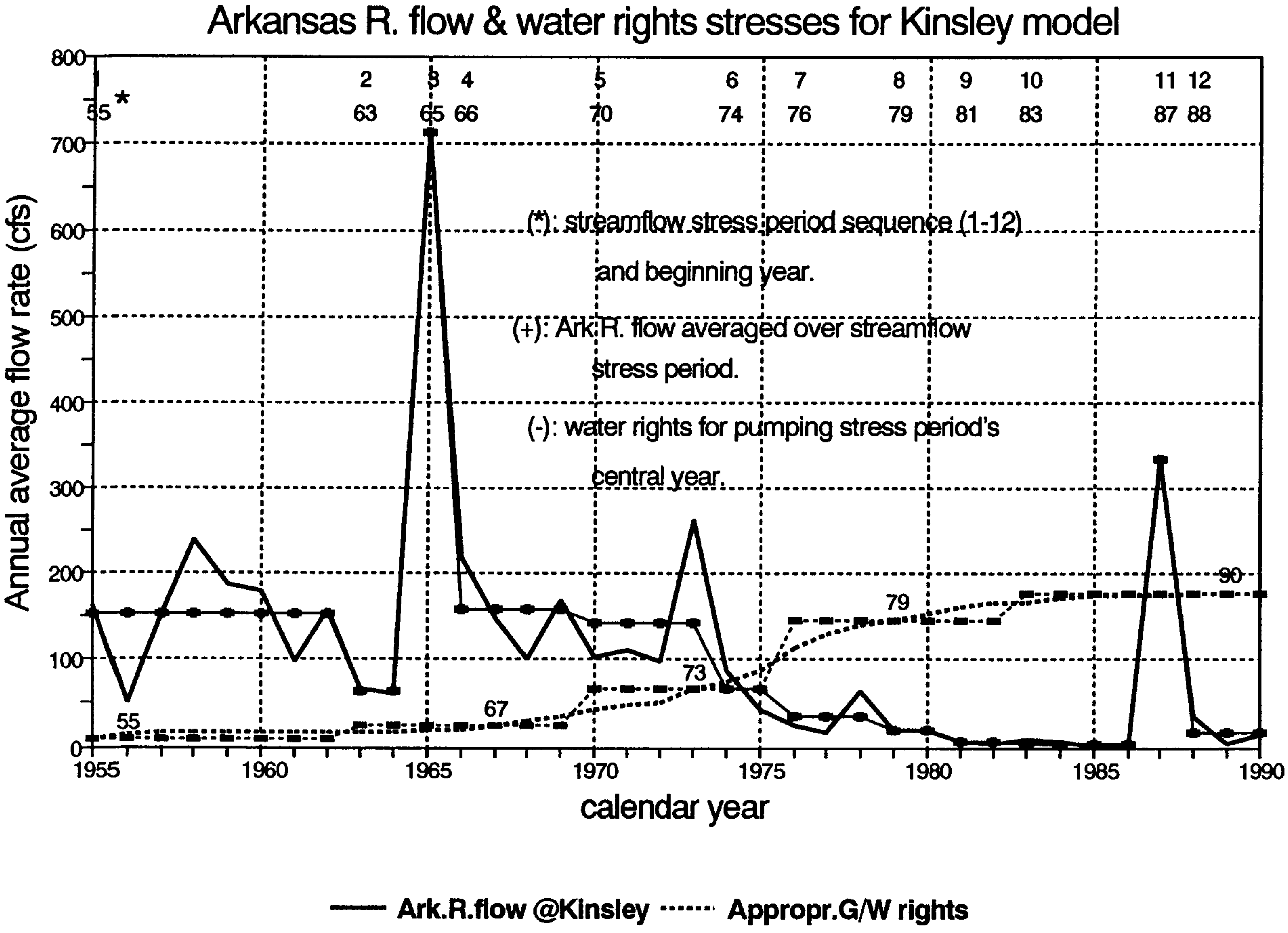


Figure 19. Model stresses (incoming streamflows and ground-water pumping) versus time.

1955 Irrigation Wells

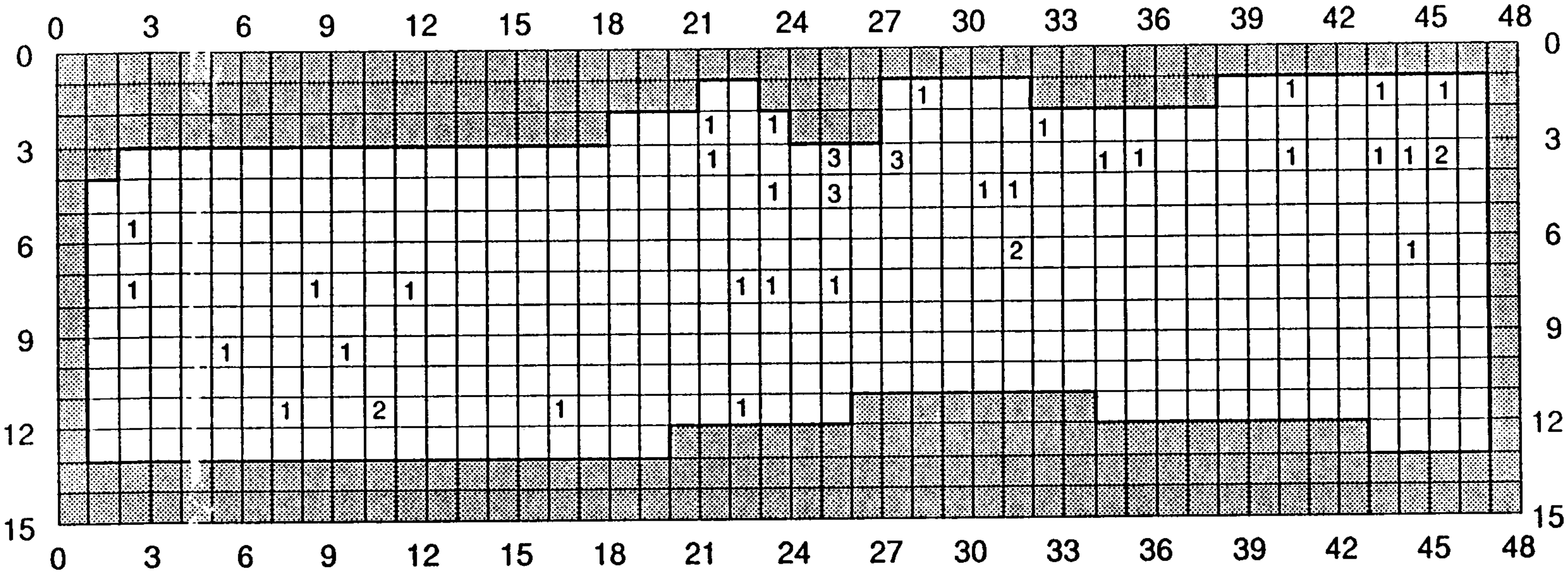


Figure 20. Distribution of ground-water irrigation wells in the model area at the beginning of 1955. Numbers indicate the number of irrigation wells in each grid cell.

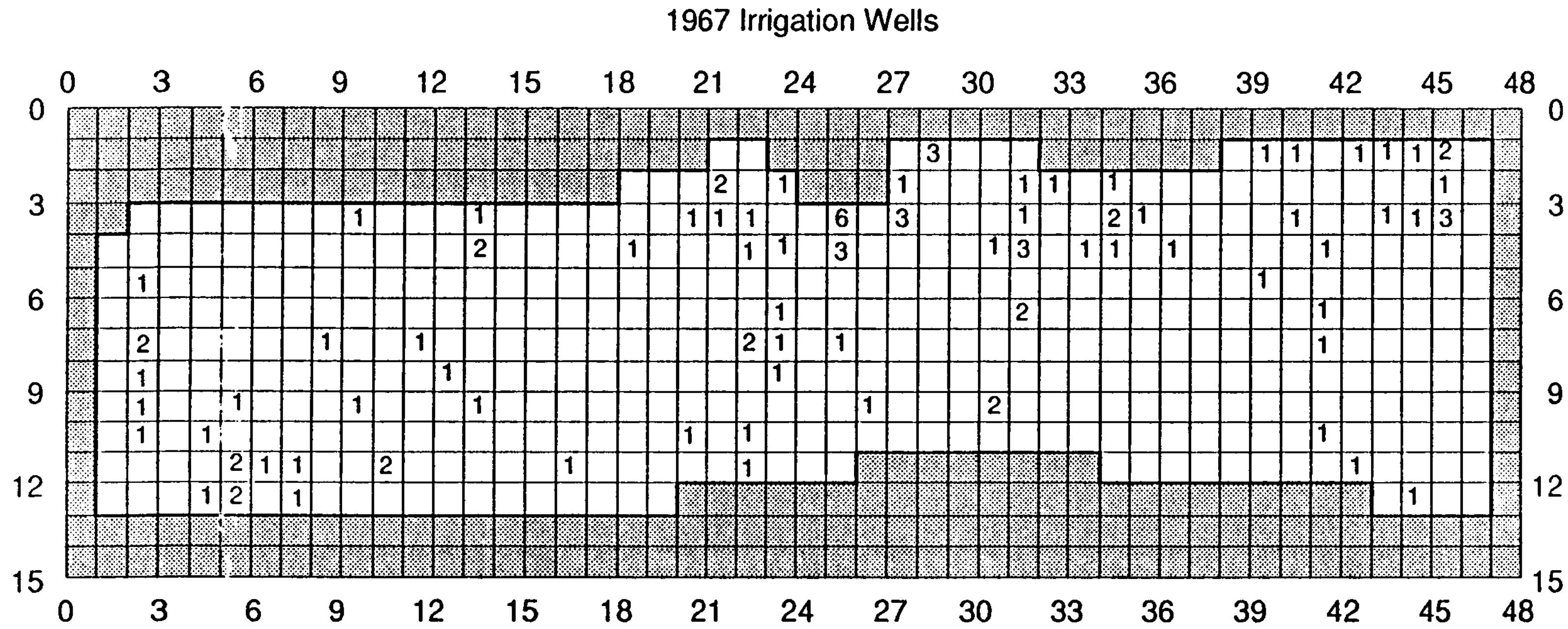


Figure 21. Distribution of ground-water irrigation wells in the model area at the beginning of 1967. Numbers indicate the number of irrigation wells in each grid cell.

[redacted]

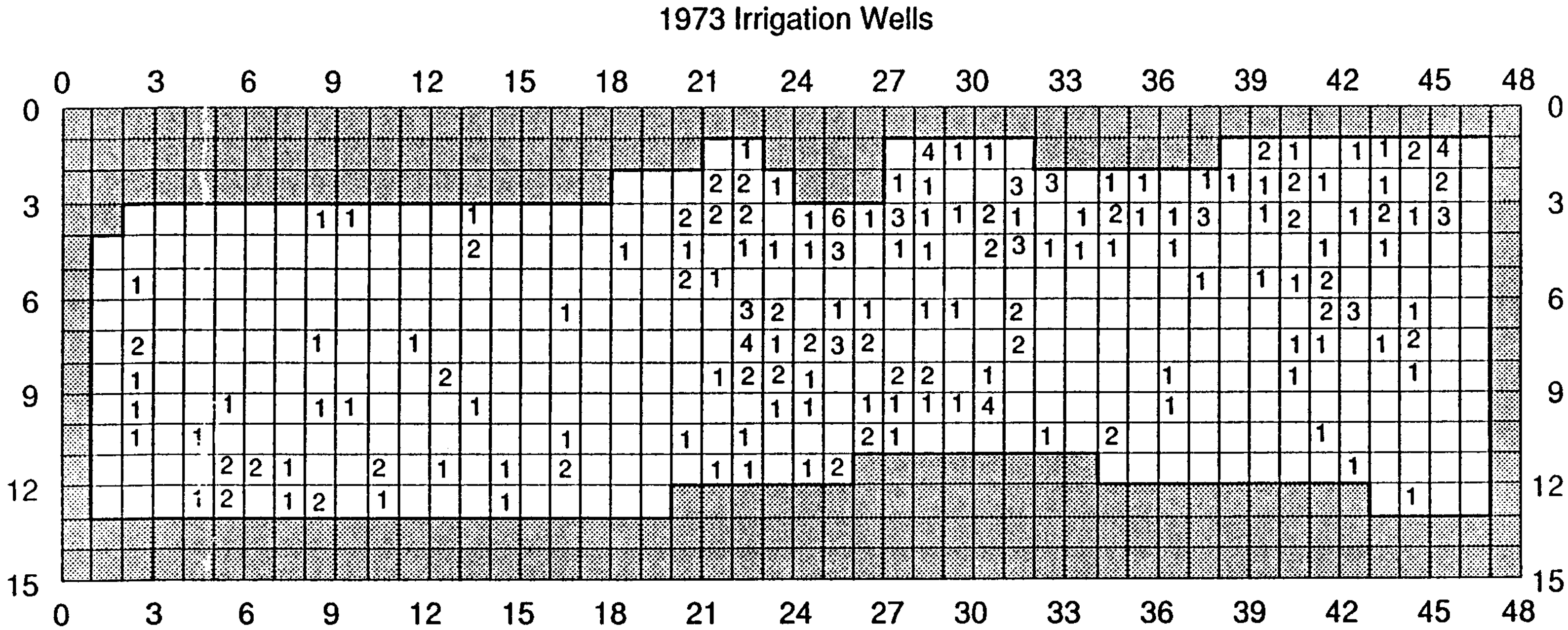
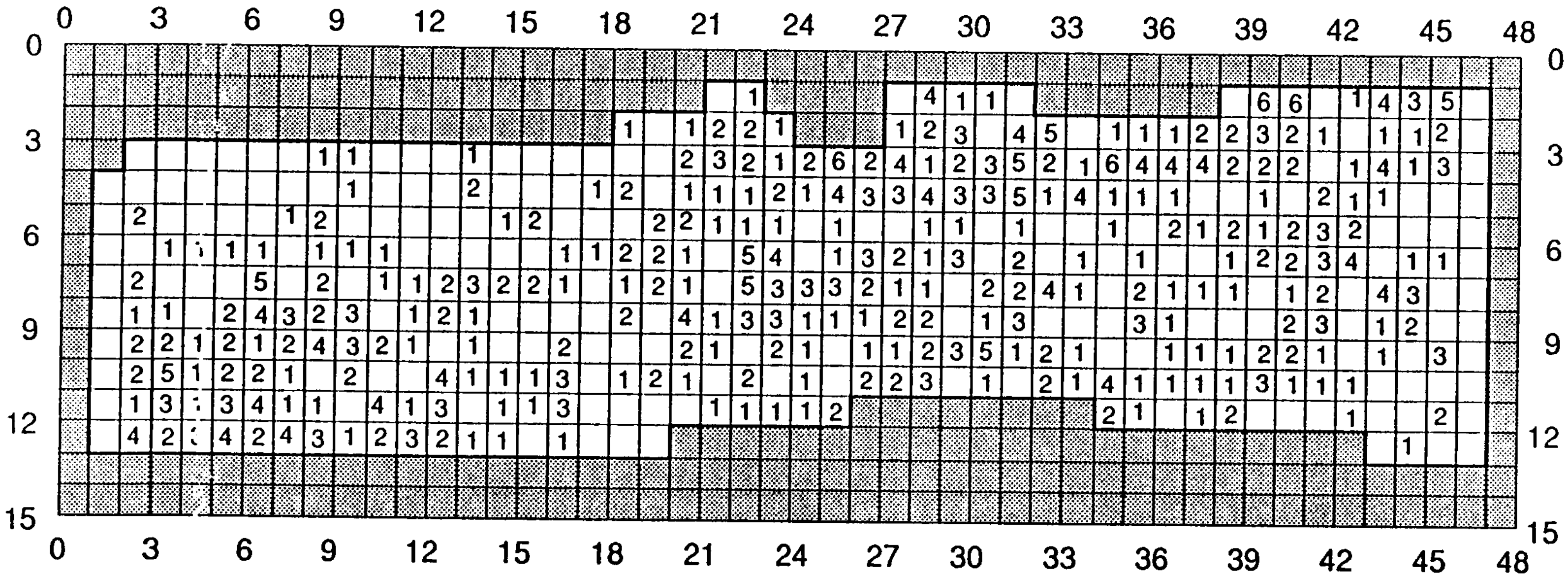


Figure 22. Distribution of ground-water irrigation wells in the model area at the beginning of 1973. Numbers indicate the number of irrigation wells in each grid cell.

1979 Irrigation Wells



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
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5			2					1	2						1	2				2	2	1	1	1		1			1	1		1			1		2	1	2	1	2	3	2					
6				1	1	1	1		1	1	1						1	1	2	2	1		5	4		1	3	2	1	3		2		1		1			1	2	2	3	4		1	1		
7			2				5		2		1	1	2	3	2	2	1		1	2	1		5	3	3	3	2	1	1		2	2	4	1		2	1	1	1		1	2		4	3			
8			1	1		2	4	3	2	3		1	2	1					2		4	1	3	3	1	1	1	2	2		1	3				3	1				2	3		1	2			
9			2	2	1	2	1	2	4	3	2	1		1			2				2	1		2	1		1	1	2	3	5	1	2	1			1	1	1	2	2	1		1		3		
10			2	5	1	2	2	1		2			4	1	1	1	3		1	2	1		2		1		2	2	3		1		2	1	4	1	1	1	1	3	1	1	1					
11			1	3	[illegible]	3	4	1	1		4	1	3		1	1	3					1	1	1	1	2									2	1		1	2				1			2		
12			4	2	[illegible]	4	2	4	3	1	2	3	2	1	1		1																												1			
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Figure 23. Distribution of ground-water irrigation wells in the model area at the beginning of 1979. Numbers indicate the number of irrigation wells in each grid cell.

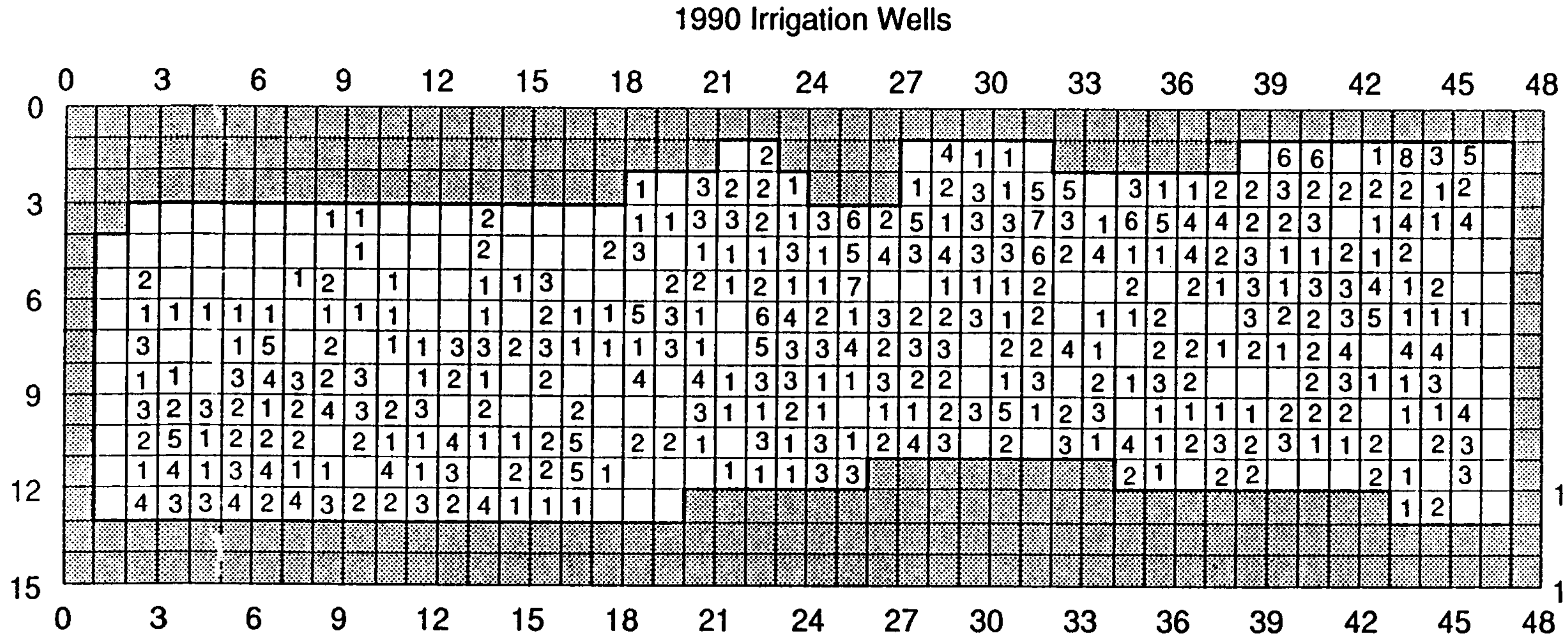


Figure 24. Distribution of ground-water irrigation wells in the model area during 1990. Numbers indicate the number of irrigation wells in each grid cell.

(and similarly at Larned) into periods of relatively uniform incoming streamflows (fig. 19). These periods and the average Arkansas River streamflows are shown in table 5. The progressive decline in incoming streamflow is clearly evident from these data and in fig. 19.

By combining the pumping and incoming streamflow stress periods, we obtained 12 pumping and stream stress periods and therefore 12 corresponding input data matrices for the model in simulating stream-aquifer conditions from 1955 to 1990. Table 5 details these 12 stress periods.

Aquifer-related data

Aquifer base

The aquifer base was extracted from the compiled bedrock map (fig. 2) by superimposing the model grid on that map and reading (or interpolating) a bedrock elevation value at the center of each cell block.

Predevelopment and other water levels

The same procedure as that used to define the aquifer base was followed for the predevelopment water-level map (fig. 1). Water levels from the 1985 (fig. 15) and 1991 (fig. 16) surveys were used to create additional observed water-level matrices for comparisons with corresponding simulated results.

Hydrogeologic properties

Several existing values of hydrogeologic properties from previous reports (table 2), including the stream-aquifer pumping test of the Arkansas River near Great Bend (Sophocleous et al., 1987, 1988), were considered. Initial parameter values were used by averaging such data. In addition, hydrogeologic property distributions resulting from analyzing drillers' logs, as indicated in section II (figs. 13 and 14), were used to divide the model region into zones of higher and lower values of a particular hydrogeologic property (figs. 25 and 26).

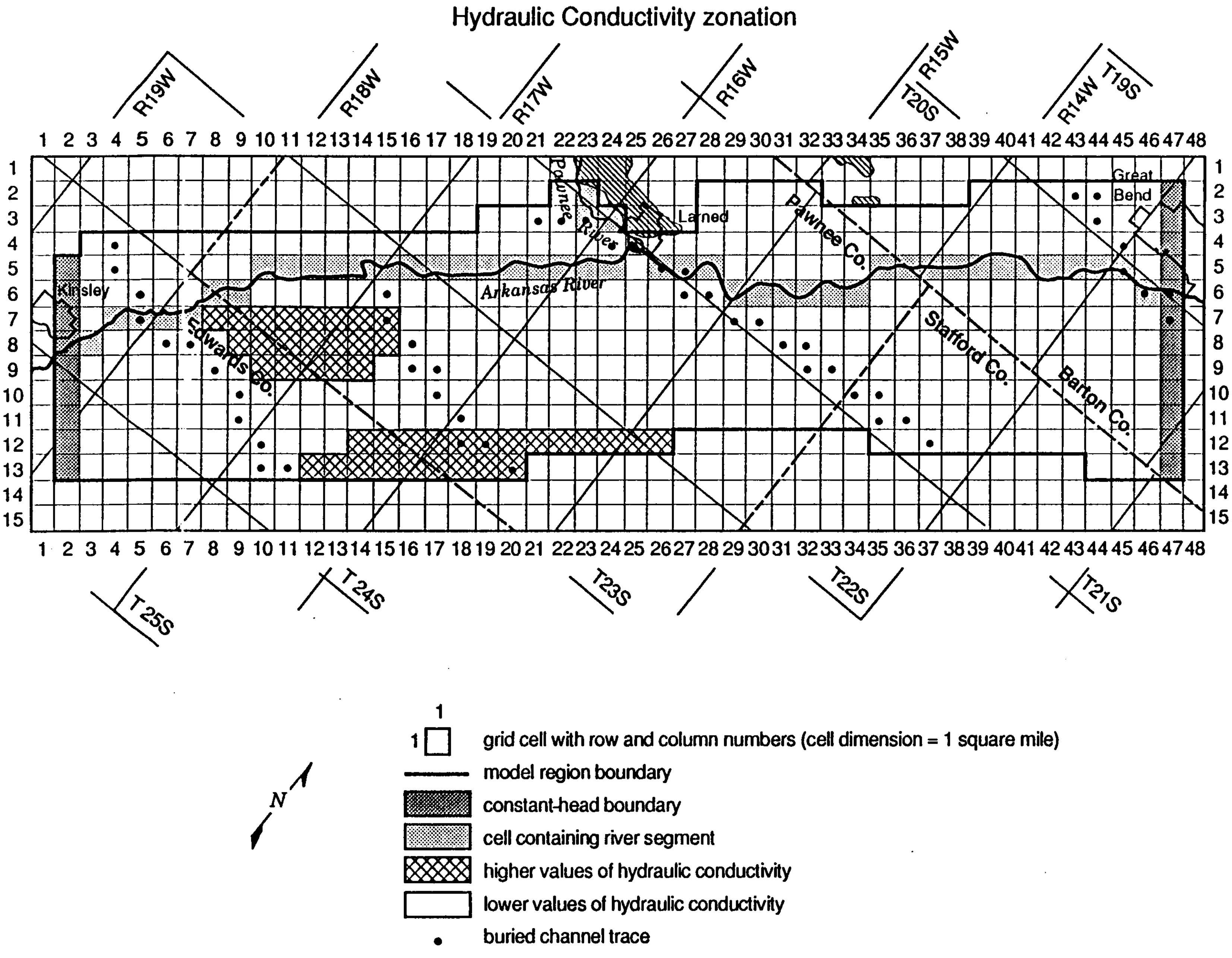


Figure 25. Hydraulic conductivity zonation of the study area.

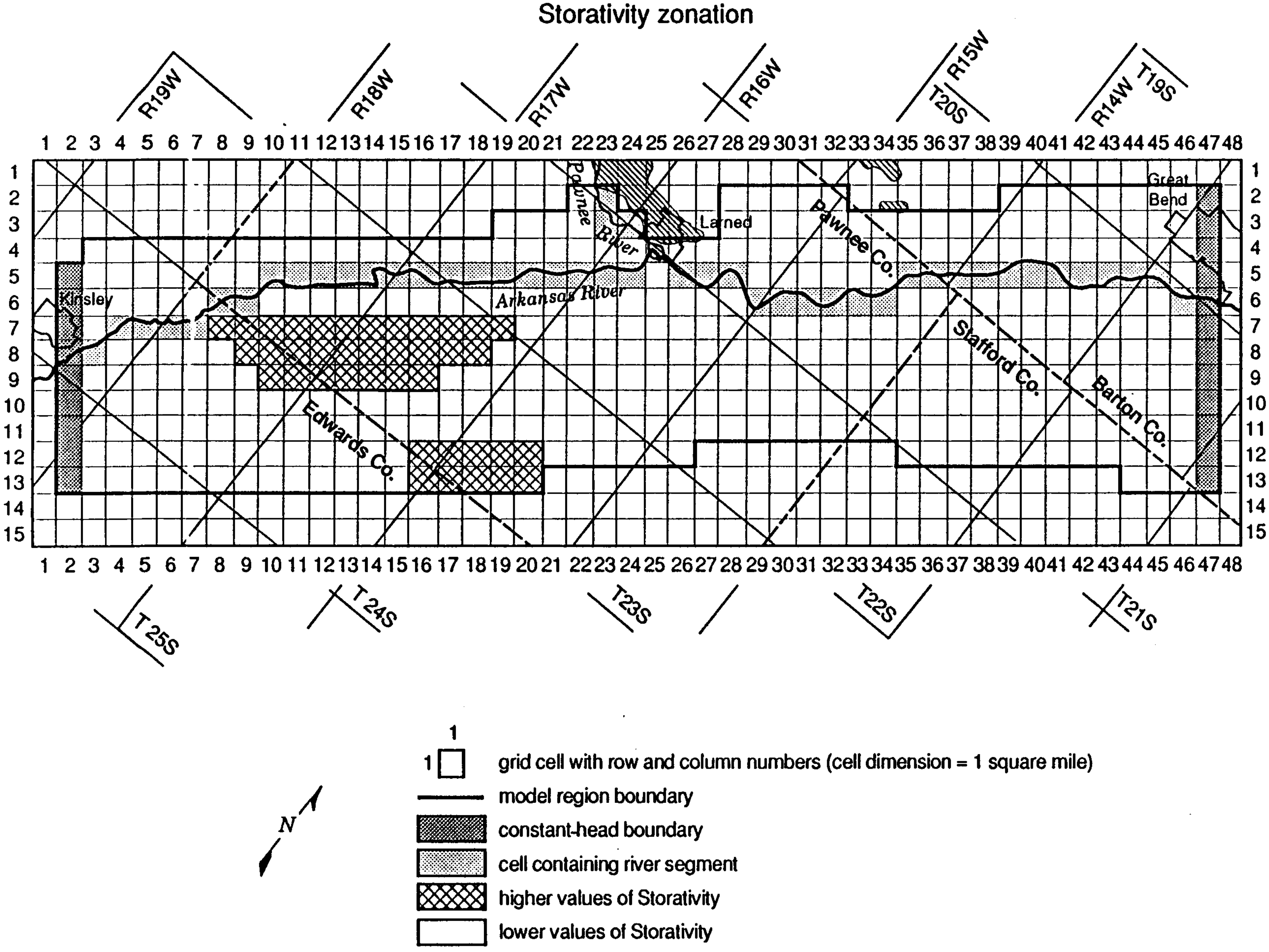


Figure 26. Storativity zonation of the study area.

Table 5. Stress Periods Employed in the Model

Pumping Averaging Period	Year Representing Pumping Period	Number of Ground-Water Pumping Wells	Appropriated Ground Water Pumpage (acre-ft/yr) in the Model Area	Incoming Streamflow Averaging Period	Average Annual Streamflow (cfs)	Stress Period
1955–1962	1955	44	5,409	1955–1962	153.5	1
1963–1969	1967	103	15,294	1963–1964	63.1	2
1963–1969	1967	103	15,294	1965	711.1	3
1963–1969	1967	103	15,294	1966–1969	158.7	4
1970–1975	1973	229	37,021	1970–1973	143.3	5
1970–1975	1973	229	37,021	1974–1975	65.3	6
1976–1982	1979	590	101,936	1976–1978	35.2	7
1976–1982	1979	590	101,936	1979–1980	19.3	8
1976–1982	1979	590	101,936	1981–1982	4.6	9
1983–1990	1990	767	128,805	1983–1986	4.4	10
1983–1990	1990	767	128,805	1987	334.0	11
1983–1990	1990	767	128,805	1988–1990	16.6	12

Recharge data

Recharge data from an ongoing study on ground water recharge assessment of the GMD5 (Sophocleous, 1991) and other studies (Sophocleous, 1992) have been used as initial estimates. Also, the study area was divided into higher and lower recharge zones (fig. 27) based on the available water capacity of soil (table 1; fig. 3).

Stream-related data

Stream widths and slopes for the model area were estimated, as mentioned previously, from topographic and other maps. Streambed hydraulic conductance was approximated based on knowledge of the area geology. Manning's coefficients were obtained from tables (Chow, 1959; White 1979) based on our knowledge of the area streams.

Calibration

Calibration involves adjustment of model input using alternative combinations of parameter values and/or zones to obtain reasonable agreement with measured data. The model was calibrated

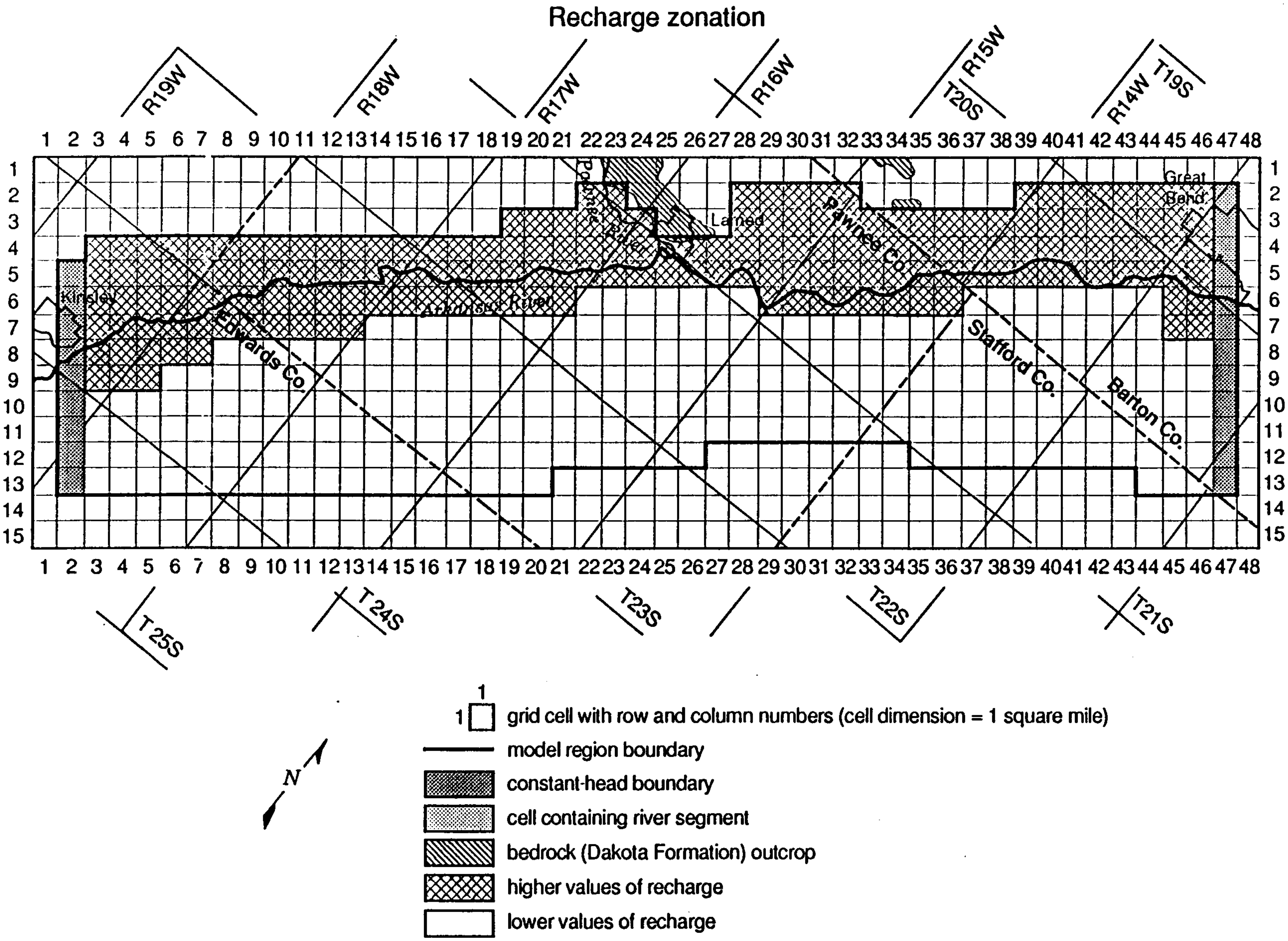


Figure 27. Recharge zonation of the study area.

for both steady-state and transient conditions. A principle adhered to in this regard for this study is the *principle of parsimony*, according to which in a choice among competing hypotheses, other things being equal, the simplest (i.e., the smallest possible number of parameters for adequate representation) is preferable.

Steady-state calibration

Because of the relatively large number of data points used in the construction of the predevelopment water-level map (Sophocleous et al., 1990) and the minimal amount of external stresses (e.g., pumpage) imposed on the aquifer, the interpolated predevelopment water levels for each active cell of the model grid were considered of similar accuracy to the actually measured ones. Thus all active model grid cells are considered to be cells with observed (measured) values, which were identical to the initial (starting) water-level cell entries in the model.

Initially, the model area was divided into three zones of uniform but different hydraulic conductivity [high (170), medium (100), and low (60) hydraulic conductivity, *K* (ft/d)] based on an analysis of drillers' logs (figs. 13 and 14). The high *K* values are based on the stream-aquifer pump test in Great Bend (Sophocleous et al., 1987). Using this *K* zonation and a uniform recharge estimate of 2 in./yr based on ongoing GMD5 recharge assessment measurements (Sophocleous, 1991), we ran the MODINV model to optimize the hydraulic conductivity values using the predevelopment (steady-state) conditions, as exemplified by the predevelopment water levels and the 1955 irrigation well distribution. However, when we reran the same computer run using only two hydraulic conductivity zones [high and (medium + low)], the results and the sum of squares of the deviations between simulated and observed heads were nearly identical. Therefore the two *K* zonations indicated in fig. 25 were adopted. Using a single *K* zone increased the sum of squares of the deviations significantly, and thus it was not adopted. Also, addition of another zone consisting of the inferred buried channels in the area (Sophocleous et al., 1990; fig. 25) did not result in any marked improvement.

Following this *K* optimization and assuming that the hydraulic conductivity is known, we then optimized the amount of recharge. The final result of these parameter optimization iterations is shown in section IV. Reducing the amount of pumpage by 20% did not result in a significant difference, most probably because of the relatively small amount of total pumpage in that period. Simultaneous optimization of both recharge and hydraulic conductivity in a steady-state model may result in a singular normal matrix [Eq. (5)] because the values taken by one parameter type (hydraulic conductivity) for a particular head distribution depend on the values taken by the other parameter type (recharge).

Transient-state calibration

To ensure that the transient model will simulate future conditions in the real system, we found it necessary to first simulate with reasonable accuracy as much hydrologic history as practical. Therefore the transient calibration was run in two stages, using yearly time steps: first, from 1955 to 1985 using the detailed 1985 water-level survey (fig. 15) for comparison of predictions versus observation; and, second, from 1985 to 1990, using the January 1991 water-level measurements (fig. 16) for comparison. This second step was undertaken mainly so that we could demonstrate a reasonable ability to simulate observed historic responses to historic conditions different from those for which the model was calibrated. When the model is thus validated, it can be used to project stream-aquifer responses to hydrologic conditions (Sophocleous, 1988).

Starting with the optimized parameter estimates from the steady-state calibration and employing the stress periods indicated in the "Model Stresses" section, we ran the MODINV parameter estimation program to optimize, in sequence, storativity and recharge, keeping the already optimized hydraulic conductivity values constant (recharge was reoptimized for the new simulation periods to allow for fluctuating climatic condition influences). Employing two zones of storativity, based on the results of drillers' log analysis (figs. 14 and 26), versus one zone did not result in any significant difference in the sum of squares of deviations between simulated and observed values of hydraulic head, and thus a single storativity zone was used. In the transient runs the ground-water pumpage was held at 100% and 80% of the appropriated amounts in separate runs, with the latter pumpage resulting in somewhat improved model fit. We judged that 80% of the appropriated water rights was closer to the one actually used, and therefore all transient runs were run under this assumption.

A reported-water-use tape was requested and received from the Division of Water Resources, and a comparison of reported use and appropriated amounts confirmed our first guess that the irrigators in the area used approximately 80% of their appropriation on average. An analysis of water-use data indicated that a number of irrigators used more than 100% of their appropriated amount, as indicated by the large red circles in fig. 28, which depicts the areal distribution of water use. The smaller red circles indicate overuse ranging from 5% to 100% of their appropriated amounts. (The green circles indicate near equality of appropriated and used amounts, and the black symbols indicate underutilization.) Figure 29 shows the distribution of water over- or underuse as a function of water right amount.

IV. Simulation Results and Model Analysis

As mentioned previously, the calibration or parameter estimation problem is in essence a regression problem, and the various methods and tests that have been developed to analyze regression problems can also be applied to studies using ground water flow models. Many of these procedures are used in the following steady-state and transient-state model analyses.

Predevelopment (steady-state) conditions

The results of the steady-state analysis are shown in table 6, in which the fit of simulated and observed values of head is very good, as indicated by the high value of the correlation coefficient ($R = 0.9994$). The standard error of the estimate for the ith parameter [given by the square root of the ith diagonal component of the parameter variance-covariance (or simply covariance) matrix] is a measure of the range over which the parameter can be varied to produce a

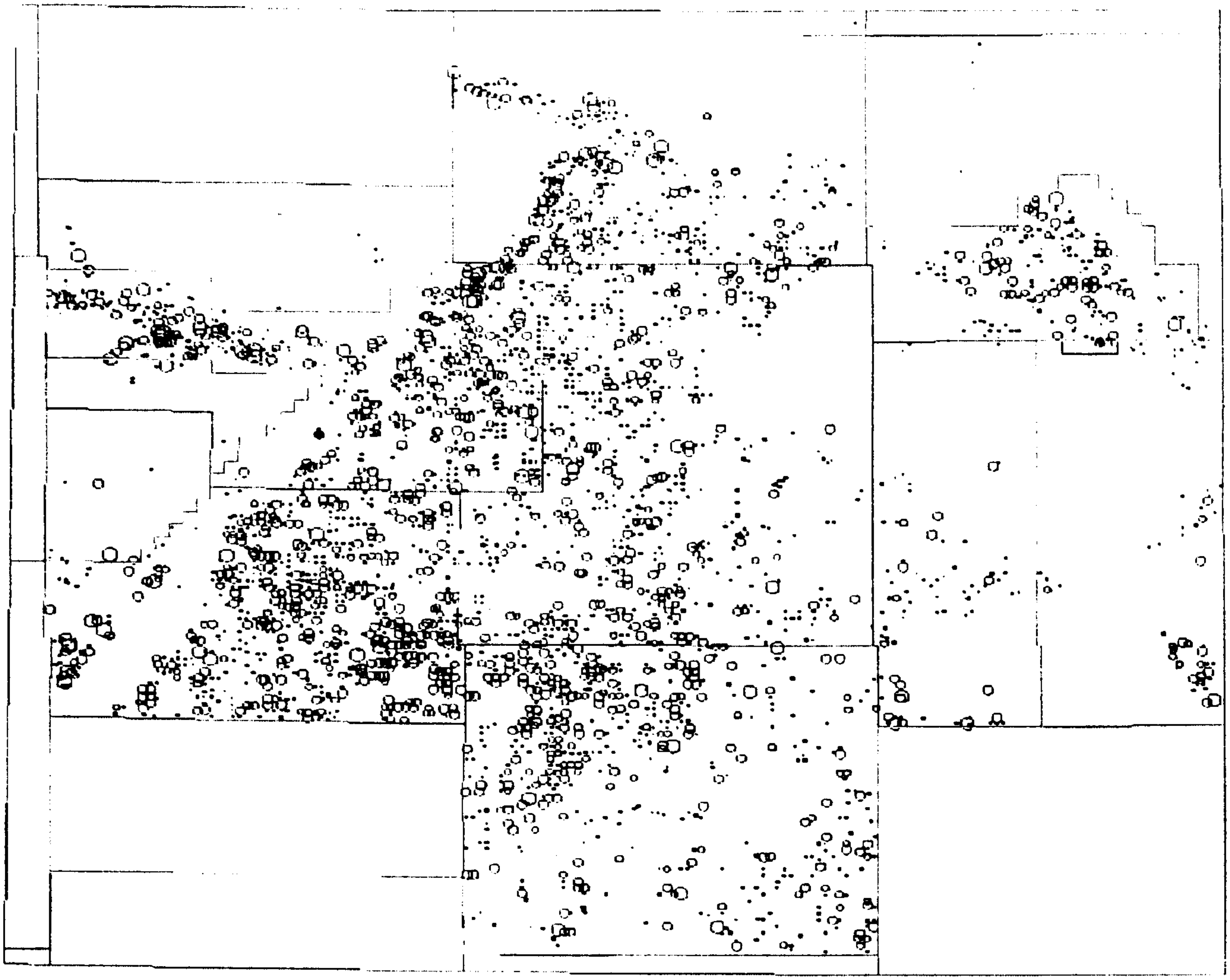


Figure 28. Areal distribution of reported (1990) ground-water use in the Ground water Management District No. 5 (blue outline). See text for explanation of symbols.

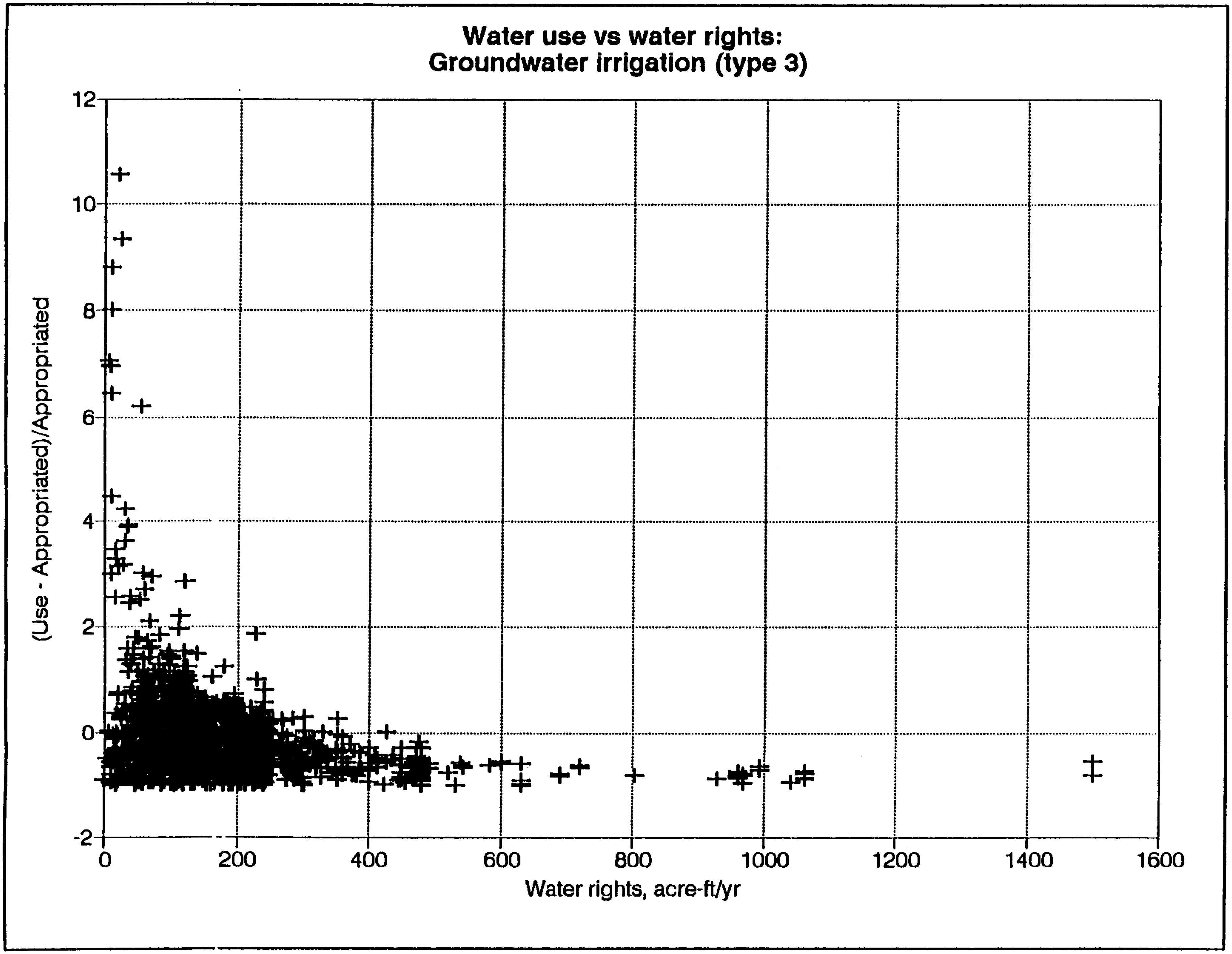


Figure 29. Distribution of ground-water over- or underuse as a function of water right appropriation amount.

Table 6. Steady-State Analysis Results

Zone	*K*(ft/d)	Std. Error	r_{12}	Recharge (in/yr)	Std. Error
1	160	3.8	0.29	1.0	0.02
2	209	11.7	0.29	1.0	0.02

s = square root of the error variance = 2.9 ft.
R = correlation between simulated and observed water levels = 0.9994.
N = number of observations = 407.
SS = weighted sum of squares of the deviations between simulated and observed values of head = 3,506.
$s/\Delta h$ = 0.0089 (Δh = 330 ft).
r_{12} = correlation between hydraulic conductivity (K) estimates for zones 1 and 2.
Std. error = $\sigma/\sqrt{N}$

similar solution for the dependent variable (i.e., hydraulic head) to the one obtained using the estimated parameter. Standard errors are indications of the precision of the determined parameters. Examination of table 6 indicates that the standard errors for the parameters are generally less than 5% of the magnitude of the parameters. Converting such standard errors into a confidence interval requires the assumption of some probability distribution for these errors. For example, if the central limit theorem holds, a 95% confidence interval for the parameter values will be given by $\hat{b} \pm 1.96\sigma_E$, where $\hat{b}$ is the estimated value of the parameter and σ_E is the standard error.

The parameter covariance matrix is one of the most useful pieces of information to come out of the inversion process. The diagonal elements of this matrix are the variances of the individual parameter values, whereas the off-diagonal elements are the covariances between parameter pairs; these covariances are indicative of how highly correlated two different parameter values are. The principal role of the parameter covariance matrix is as an indicator of how well the observation-well head measurements are able to define aquifer properties (including recharge), because although the model heads may be well matched to the measured heads (the reference or error variance may be satisfactory), some parameter value standard deviations may still be large. This indicates that, as mentioned earlier, these parameter values can be made to vary by large amounts with little effect on the model heads at the observation wells. If this applies to a single parameter value, the value will have a high variance and will be uncorrelated with other parameter values. If, however, two or more parameter values can be simultaneously varied in a certain relationship to each other while causing minimal change to the model heads at the observation wells over time, then each of these parameter values will have a high standard deviation and the covariance between pairs of such parameters, as indicated by the pertinent off-diagonal elements of the covariance matrix, will also be large. This indicates high parameter value correlation. Thus the parameter covariance matrix tells us something about our model that the goodness of fit between model and observed heads cannot tell us. For example, if the density of observation wells is low or zero over a certain part of the aquifer, parameter values estimated in that area may not be well defined, and this will be indicated in the covariance matrix. Although the model may appear to be well calibrated, because the model replicates observed heads at the existing observation wells with a good degree of accuracy, its capacity to predict water levels in other parts of the aquifer may be highly suspect if the calculation of these latter heads relies on parameter values that are locally ill-defined.

The correlation r_{12} between the hydraulic conductivity estimates of zones 1 and 2 (table 6) gives an estimate of the degree of linear dependence of one parameter (K in this case) in one zone with the corresponding parameter in another zone throughout the course of repeated experiments if such experiments were to be carried out. A high degree of correlation between parameter value pairs (1 and 2) is indicated by a correlation coefficient r_{12} close to 1 or -1. The higher the degree of parameter value correlation, the closer the normal matrix resulting from the weighted least-squares minimization of the residuals will approach singularity and the greater the possibility of numerical instability. Examination of table 6 indicates that the correlation of the K parameters in zones 1 and 2 is negligible, implying a good K parameter estimation.

The error variance s^2 of the hydraulic head values is another measure of overall goodness of fit of the model. [It is calculated as the ratio of the weighted sum of squares of the deviations between simulated and observed values of head (SS) over the number of observation points minus the number of estimated parameters.] A good overall fit between modeled and measured heads indicates that the head measurement standard deviations (i.e., the square roots of the error variances) are small. The value of the ratio of the square root of the error variance over the difference between the highest and the lowest value of head in the model region ($s/\Delta h$) is 0.009 (table 6), a relatively small value, so that errors in the model are considerably less than the model response, as indicated by the maximum head loss (Δh) between Kinsley and Great Bend of 330 ft (100.6 m). A comparison of observed and model-simulated water table contours, shown in fig. 30, indicates a satisfactory match.

The main reasons for analyzing residuals are to examine the validity of the various assumptions concerning their distribution given earlier [Eqs. (11)–(14)], and to investigate the correctness of the model. Aspects that could be investigated include evidence for spatial nonrandomness and evidence that the residuals are not approximately normally distributed (Sophocleous, 1984). Draper and Smith (1981) give a number of methods for examining residuals, and they emphasize that graphical procedures involving visual analysis are valuable tools for detecting nonrandomness, because violations of assumptions serious enough to require corrective action generally are apparent on the various plots. Appendix 2 includes a number of such residual plots which all show that the employed model is probably adequate for the available data.

Water budget

A summary of all inflows and outflows to a region is generally called a water budget. Because in the model program the water budget is calculated independently of the equation solution process, it provides independent evidence of a valid solution. The difference between total inflow and outflow is printed as a percent error, calculated using

$$D = \frac{100(\mathrm{In} - \mathrm{Out})}{(\mathrm{In} + \mathrm{Out})/2}, \qquad (15)$$

where In is the total inflow to the system, Out is the total outflow, and D is the percent error term. If the model equations are solved correctly, the percent error should be small. The overall model water budget is presented to check the acceptability of the solution and to provide summarized

Kinsley to Great Bend predevelopment (1955) simulated and observed water levels

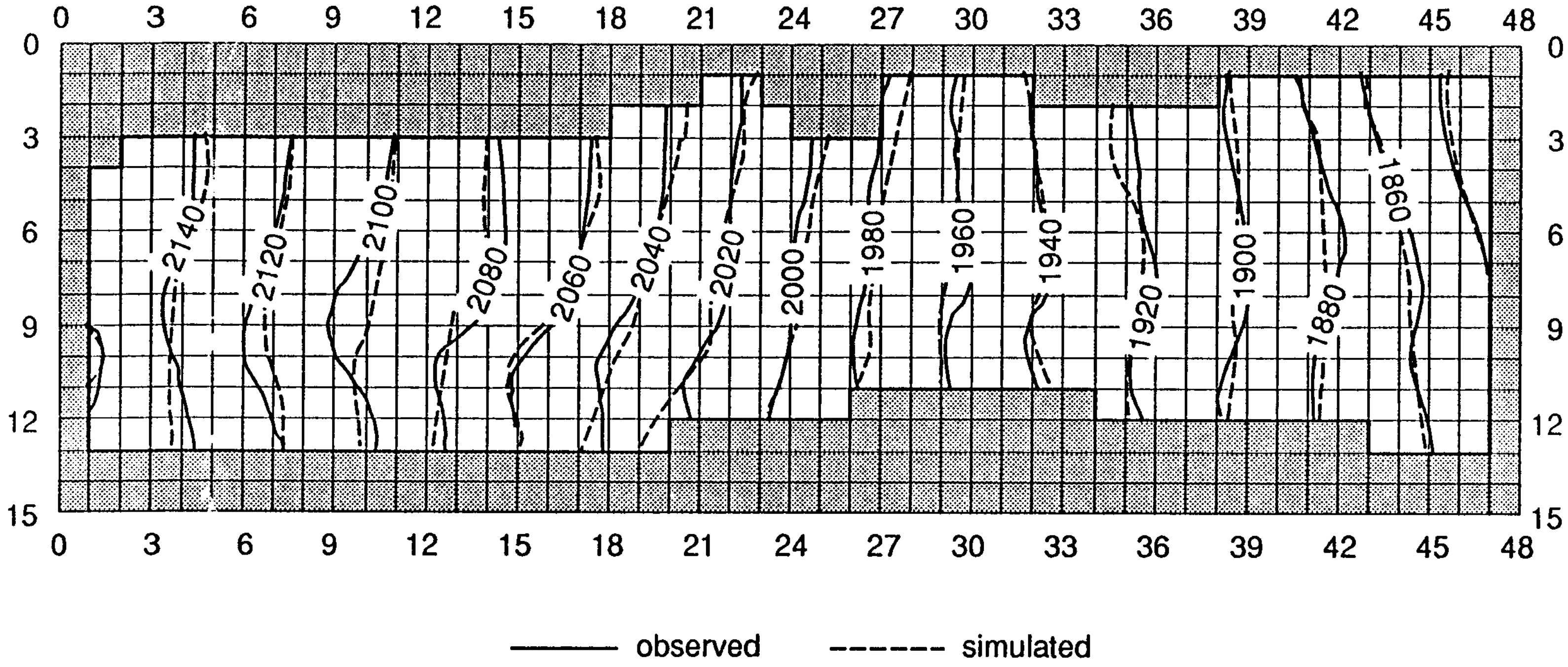


Figure 30. Comparison of observed and model-predicted predevelopment (c. 1955) water table contours.

information on the flow system. The volumetric water budget for the model area under predevelopment conditions is presented in table 7. It is evident from the table that the bulk input to the stream-aquifer system is ground-water recharge and that the largest outflows from the system are outflows from the constant-head boundary by Great Bend and streamflow gains from ground water (stream baseflows). Note that the irrigation pumpage is a relatively minor element of total system outflow for the considered period.

Transient-state simulations

The results of the transient-state simulations from 1955 to 1985 are shown in table 8. The value of the ratio $s/\Delta h$ (0.0135) is still relatively small, indicating that errors in the model are considerably less than the model response, as indicated by the maximum head loss. Comparisons of predicted versus observed values of hydraulic head depicted in figs. 31 (for 1985) and 32 (for 1990) are satisfactory. However, because of the smaller number of cells with observed hydraulic head values (compare the N values of tables 6 and 8), the standard errors of the parameter estimates are relatively larger. Appendix 2 includes a number of residual plots that indicate that this model is probably adequate for the employed data.

Table 7. Volumetric Water Budget for Model under Predevelopment Conditions (c. 1955)

		Volumetric Rates (acre-ft/yr)
Aquifer inflows	Constant head	4,324
	Recharge	23,355
	Stream leakage	7,754
Total inflows		**35,433**
Aquifer outflows	Constant head	15,848
	Pumping wells	5,409
	Stream leakage	14,175
Total outflows		**35,432**

Discrepancy = 0.00%

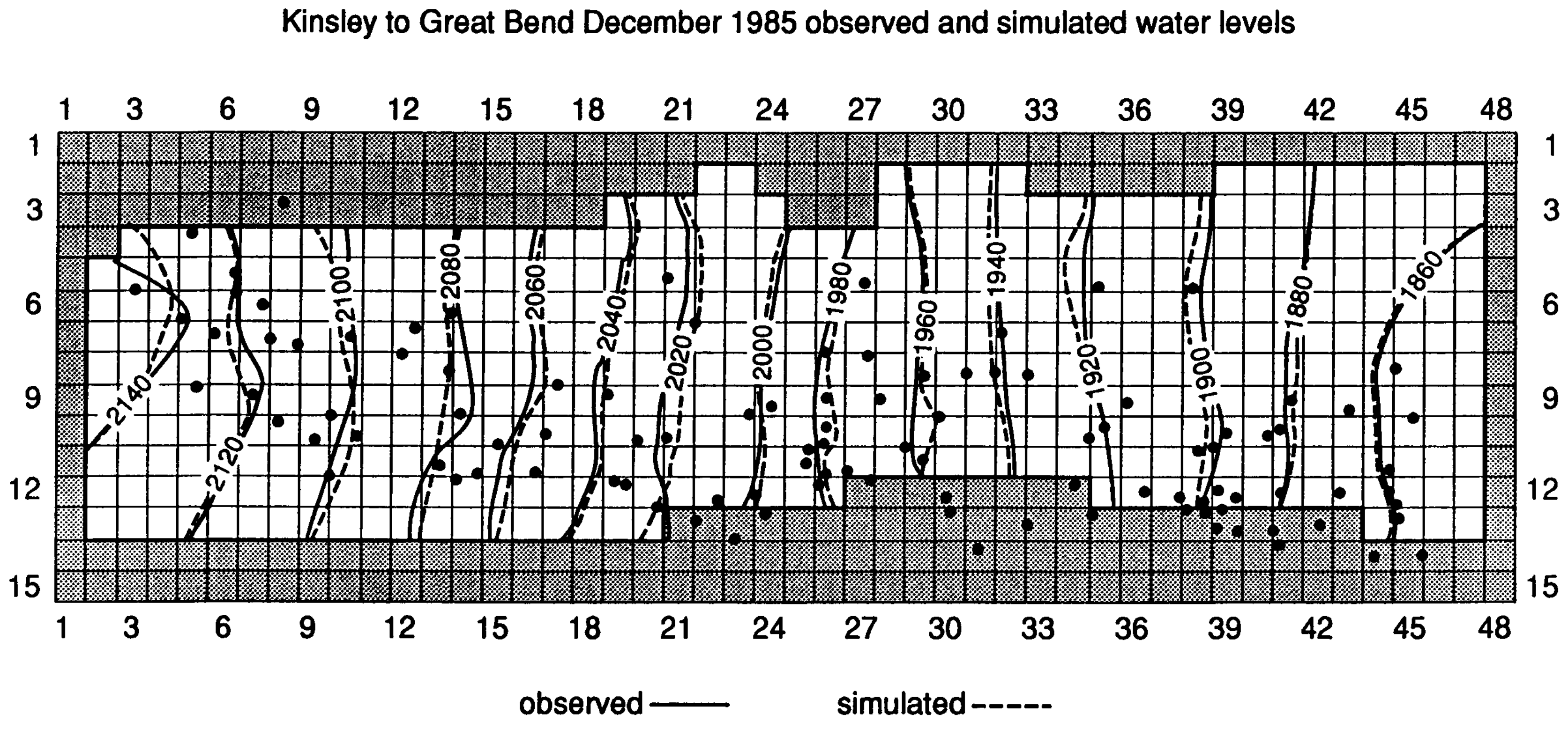


Figure 31. Comparison of observed and model-predicted January 1985 water table contours.

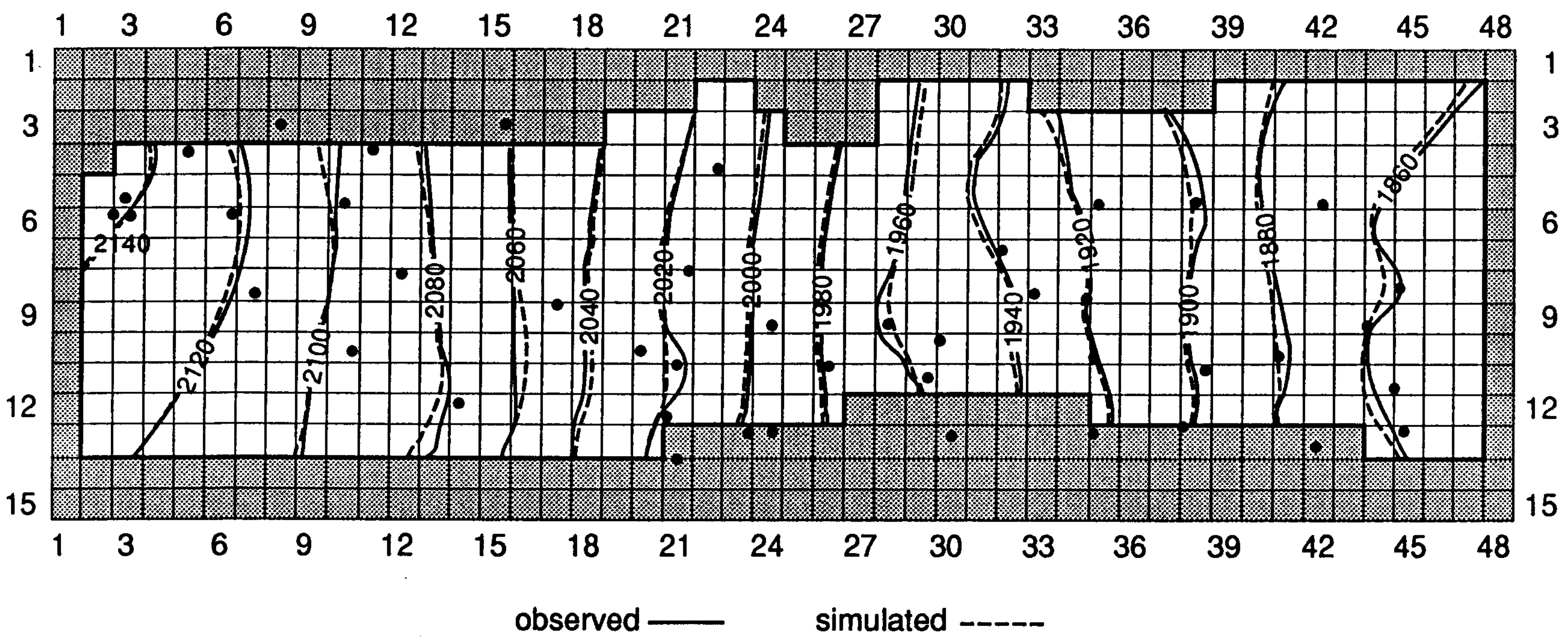

Kinsley to Great Bend January 1990 observed and simulated water levels

Figure 32. Comparison of observed and model-predicted January 1991 water table contours.

Table 8. Transient 1955–1985 Analysis Results

Zone	*K* (ft/d)	Recharge (in/yr)	Std. Error	Storativity	Std. Error
1	160	1.8	0.06	0.23	0.02
2	209	1.8	0.06	0.23	0.02

s = square root of the error variance = 4.1 ft.
R = correlation between simulated and observed water levels = 0.9985.
N = number of observations = 113.
SS = weighted sum of squares of the deviations between simulated and observed values of head = 1,844.
$s/\Delta h$ = 0.0155.
Std. error = $\sigma/\sqrt{N}$.

Comparison of predicted ground-water discharge and observed average annual streamflow for the 1955–1990 simulation period at Great Bend shows a satisfactory match, as indicated in fig. 33. As can be seen from that figure, the model underpredicts ground-water discharge during periods of high streamflow because the model does not simulate overland runoff. During periods of low flow, however, most streamflow is derived from ground-water discharge.

Under natural conditions the water table gradient slopes toward the river, and ground-water discharges from the aquifer into the river. This can be seen by the curvature of the iso-water-level contours pointing upstream (fig. 1). However, under pumping conditions the water table gradient decreases, and ground-water discharge to the stream is reduced. If pumping is of sufficient volume and duration, the gradient may be reversed, and water from the stream will move by induced infiltration through the streambed into the alluvial aquifer. Figure 34 and 35 depict the model-simulated reaches of the Arkansas River and Pawnee River that are gaining or losing water based on average yearly streamflows. Note the progressively increasing number of river reaches that are losing water with time because of progressively decreasing ground-water contributions to streamflow. These model results are satisfactorily consistent with the observed streamflow measurements shown in table 4.

The overall volumetric water budgets for the model area during the 1955–1985 and 1985–1990 transient-state simulations are presented in table 9. The convention followed in MODFLOW is that flow into or out of storage is considered part of the overall budget inasmuch as accumulation in

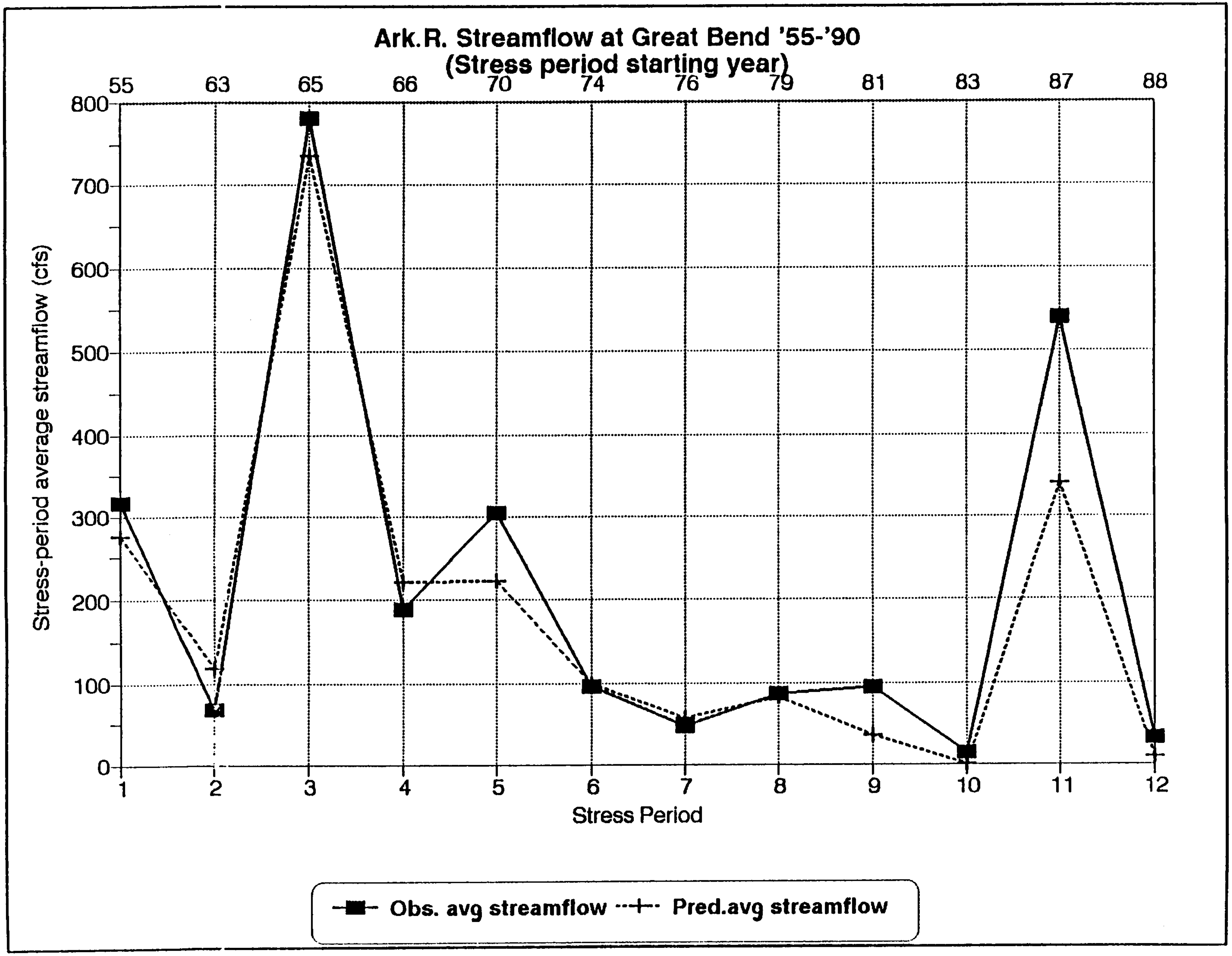


Figure 33. Comparison of predicted Arkansas River streamflow (baseflow) and observed streamflow at the Great Bend gaging station.

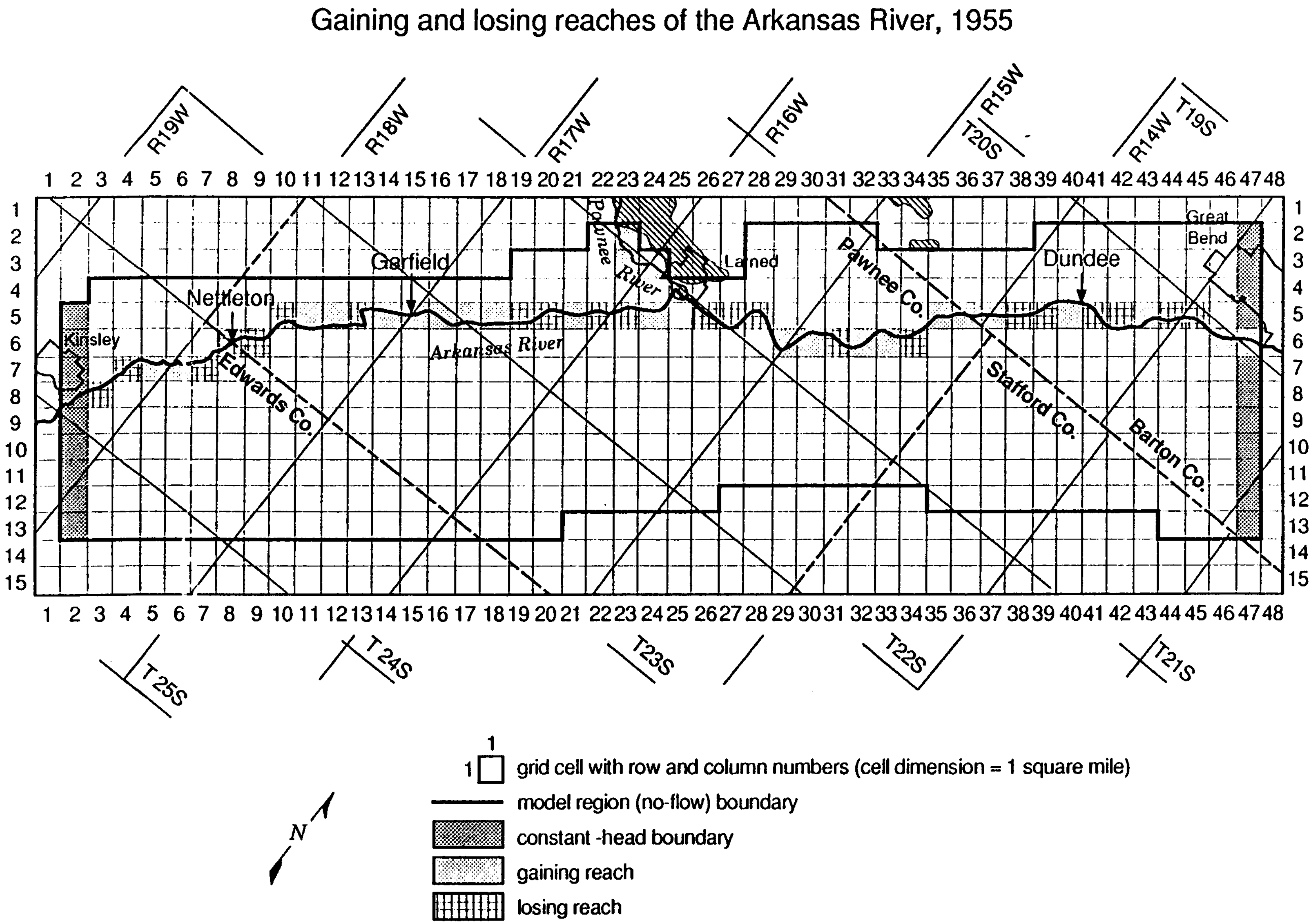


Figure 34. Model-predicted 1955 gaining and losing reaches of the Arkansas River.

Gaining and losing reaches of the Arkansas River, 1990

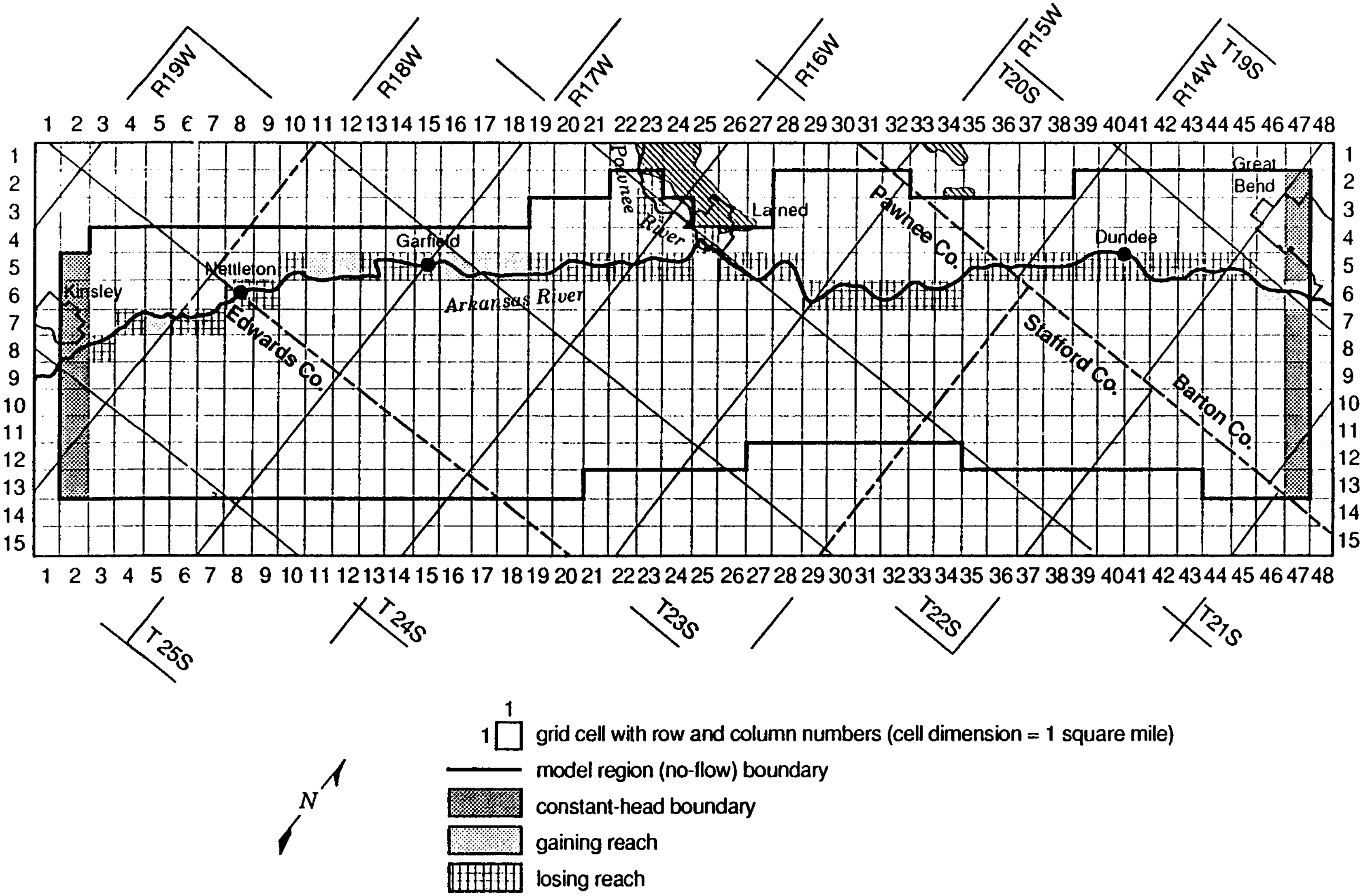


Figure 35. Model-predicted 1990 gaining and losing reaches of the Arkansas River.

Table 9. Volumetric Water Budgets for 1955–1985 and 1985–1990.

		Average Volumetric Rates (acre-ft/yr)
1955–1985 Aquifer inflows	Constant head	5,106
	Recharge	44,334
	Stream leakage (losses)	9,102
	Net water released from storage	14,111
Total inflows		**72,653**
1955–1985 Aquifer outflows	Constant head	16,289
	Pumping	39,014
	Stream leakage (gains)	17,352
Total outflows		**72,655**
Discrepancy = 0.00%		
1985–1990 Aquifer inflows	Constant head	7,835
	Recharge	42,824
	Stream leakage (losses)	31,116
	Net water released from storage	33,868
Total inflows		**115,643**
1985–1990 Aquifer outflows	Constant head	10,211
	Pumping	100,630
	Stream leakage (gains)	4,807
Total outflows		**115,648**
Discrepancy = 0.00%		

storage effectively removes water from the flow system and storage release effectively adds water to the flow—even though neither process, in itself, involves the transfer of water into or out of the ground-water regime (McDonald and Harbaugh, 1988).

The major aquifer inflow and outflow for the 1955–1985 period is ground-water recharge and pumping, respectively. Also note the significant increase in stream losses and decrease in stream gains compared to the 1955 period; this trend continues into the 1985–1990 period to such an extent that the current major source of aquifer inflow comes from streamflow losses (instead of natural recharge) and the bulk of aquifer outflows goes to pumping.

The predevelopment and present-day water budgets for the study area are shown in fig. 36. In contrast to what was the case during the 1950's, the present-day dominant outflow component from the aquifer is ground-water pumpage for irrigation, which is a new discharge superimposed on the predevelopment (steady-state) system. This irrigation pumpage must be balanced by (1) an

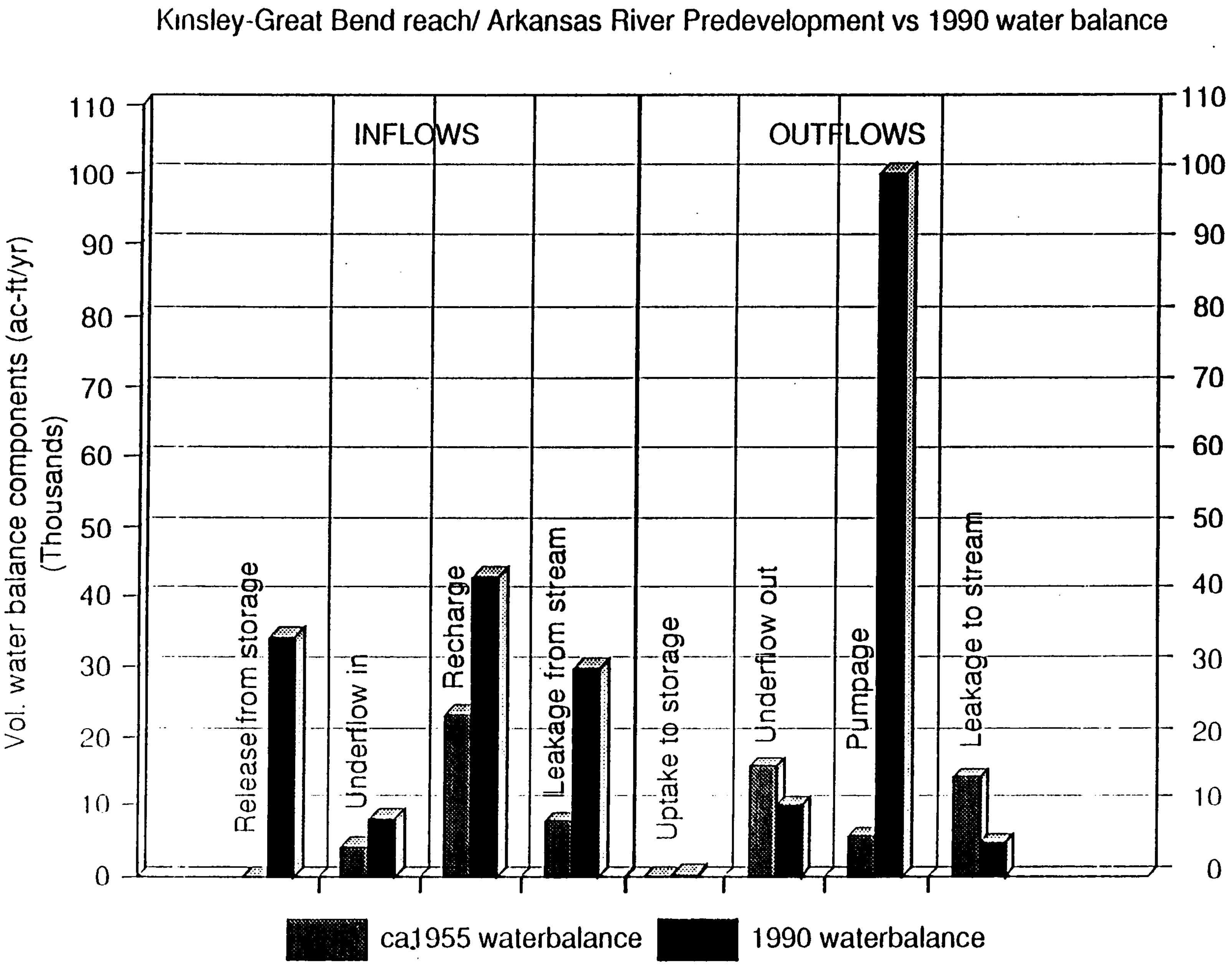


Figure 36. Predevelopment and present-day water budgets for the model area.

increase in the aquifer recharge (by increased induced leakage from streams, drainage of the dewatered aquifer sediments, irrigation return flows, capture of previously "rejected" recharge as surface runoff by increased hydraulic gradients between recharge areas and areas with significant irrigation well development); (2) a decrease in the old natural discharge (by decreased baseflow contributions to streams, decreased outflows to seeps and springs, decreased ground-water evapotranspiration); (3) loss of water storage in the aquifer, as manifested by long-term ground-water-level declines; or (4) a combination of these changes. Indeed, a combination of all three types of change is indicated in the water budget of the model area, which shows an increase in recharge, a loss of water in storage, and a decrease in baseflow contributions to streamflows compared to the predevelopment water budget (table 5).

A temporal evolution of the water balance components for the reach is shown in fig. 37, in which depletion from storage (symbol x) is shown to have occurred since the mid-1970's, resulting in water-level declines. The triangles indicate ground-water pumpage, plus signs indicate cumulative recharge, squares indicate the difference between stream gains and losses, and stars indicate the differences between incoming and outgoing underflows from the study area.

A cross-sectional evolution of the water table (fig. 38) during the 1955–1990 simulation period along column 29 (fig. 18) east of Larned indicates that up to stress period 7 (i.e., up to 1978) the Arkansas River was a gaining stream with the water table gradient toward the river. From stress period 9 (1981) onward the Arkansas River became a losing stream, as can be clearly seen in fig. 38a, and this trend continues with steeper water-level gradients away from the Arkansas River during the 20-year prediction simulation run (fig. 38b).

Sensitivity analysis and predictive runs

Sensitivity analysis, which quantifies the model's response to input parameter changes, gives insight into mechanisms and dependencies. Therefore an analysis was made to determine the sensitivity of the model to variations in the values of selected parameters on both the aquifer and the stream. The input and aquifer parameters considered were pumpage, recharge, hydraulic

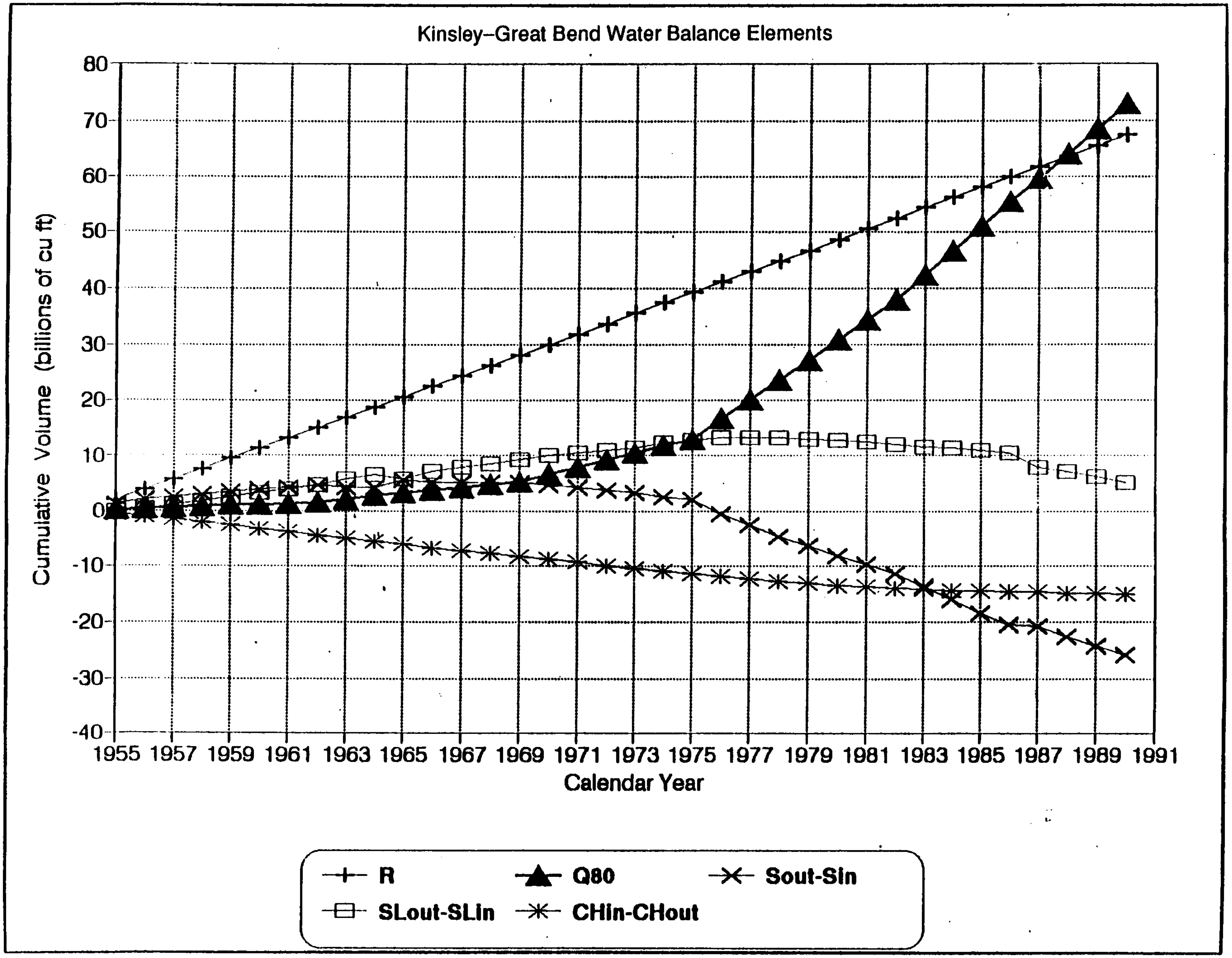


Figure 37. Time-distribution of water balance components during the 1955–1990 simulation period.

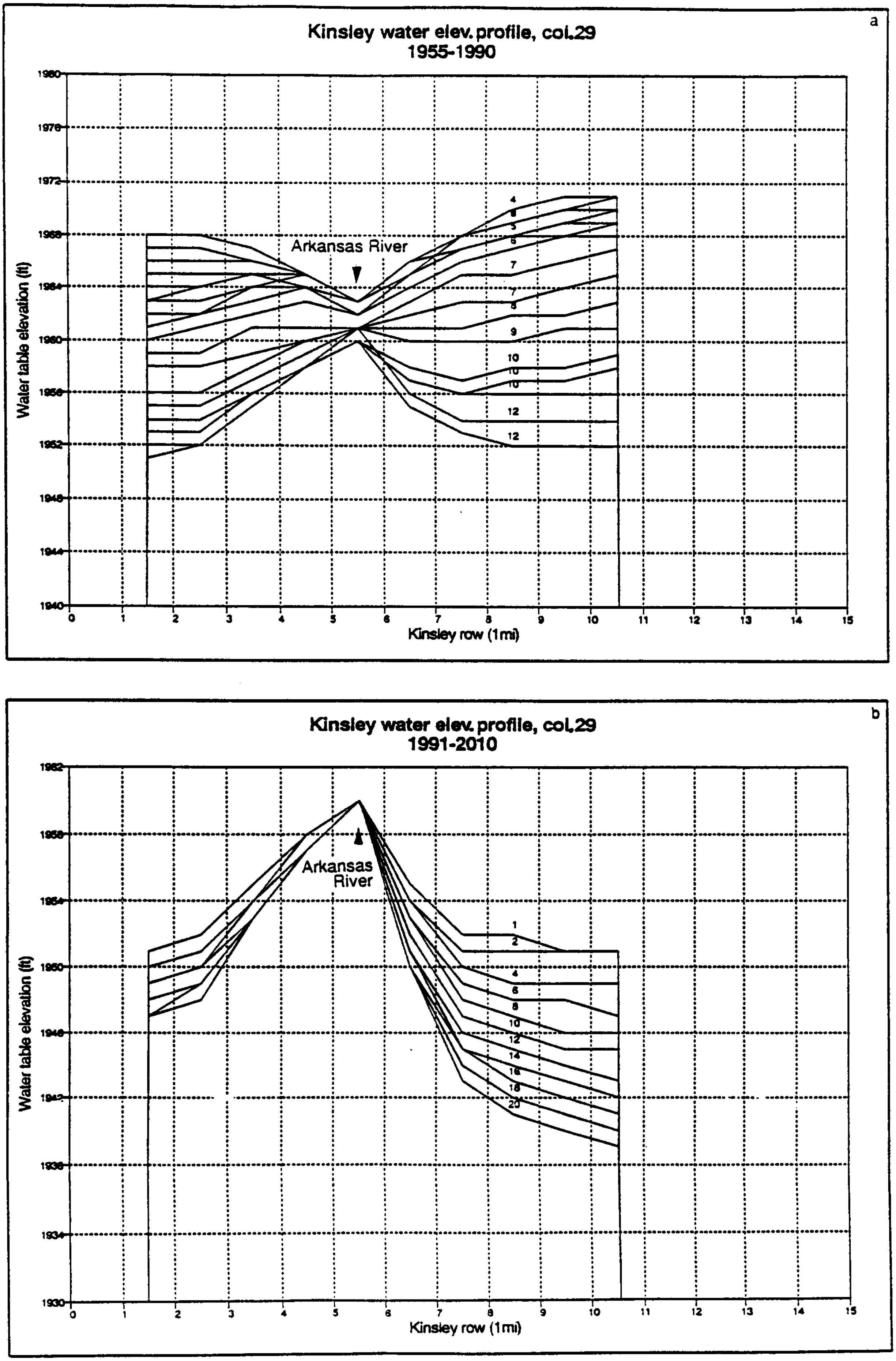


Figure 38. Cross-sectional evolution of the water table during (a) the 1955–1990 simulation period and (b) the 1991–2010 prediction period along model grid column 29 east of Larned. Numbers indicate stress periods.

conductivity, and storativity. The stream parameters considered were conductance of the streambed, Manning's roughness coefficient, stream slope, and stream width. Sensitivity to each of these parameters was determined by running the model with the optimized parameters for 1990 in a predictive mode from 1990 to 2010 and by varying (increasing and decreasing) each parameter by 50%. Corresponding changes in ground-water hydraulic heads at typical nodes near Kinsley [node at row 10, column 6, (10, 6)], Larned [node (8, 24)], and Great Bend [node (7, 42)] were observed, tabulated, and graphed (figs. 39, 40, and 41), and the corresponding changes in streamflow (ground-water runoff or baseflow) were displayed for the Arkansas River near Great Bend [node (6, 46); fig. 42] and Garfield [node (5, 16); fig. 43].

Sensitivity of hydraulic head to changing aquifer and input parameters

Examination of figs. 39, 40, and 41 indicates that water levels (hydraulic head values) at different parts of the aquifer respond to changing input and parameter values in both similar and different ways. The similarity of response is that, in general, ground-water pumpage has the greatest effect on water levels, followed to a lesser degree by ground-water recharge, hydraulic conductivity, and storativity. However, different parts of the aquifer respond differently in absolute amount to changing parameters, with the relative significance of some parameters altered in some instances. For example, near Kinsley (fig. 39) the hydraulic conductivity parameter seems to be more sensitive (and thus relatively more important) than ground-water recharge, whereas near Great Bend the opposite seems true. Figures 39, 40, and 41 clearly show which parameters are the more important ones in different parts of the model area with regard to their impact on ground-water levels.

Sensitivity of streamflows to changing aquifer, input, and stream parameters

Examination of figs. 42 and 43 indicates that, similar to what was observed with regard to water levels, streamflows respond differently to various parameters in different parts of the modeled area. The aquifer and aquifer input-related parameters in this case have a much more

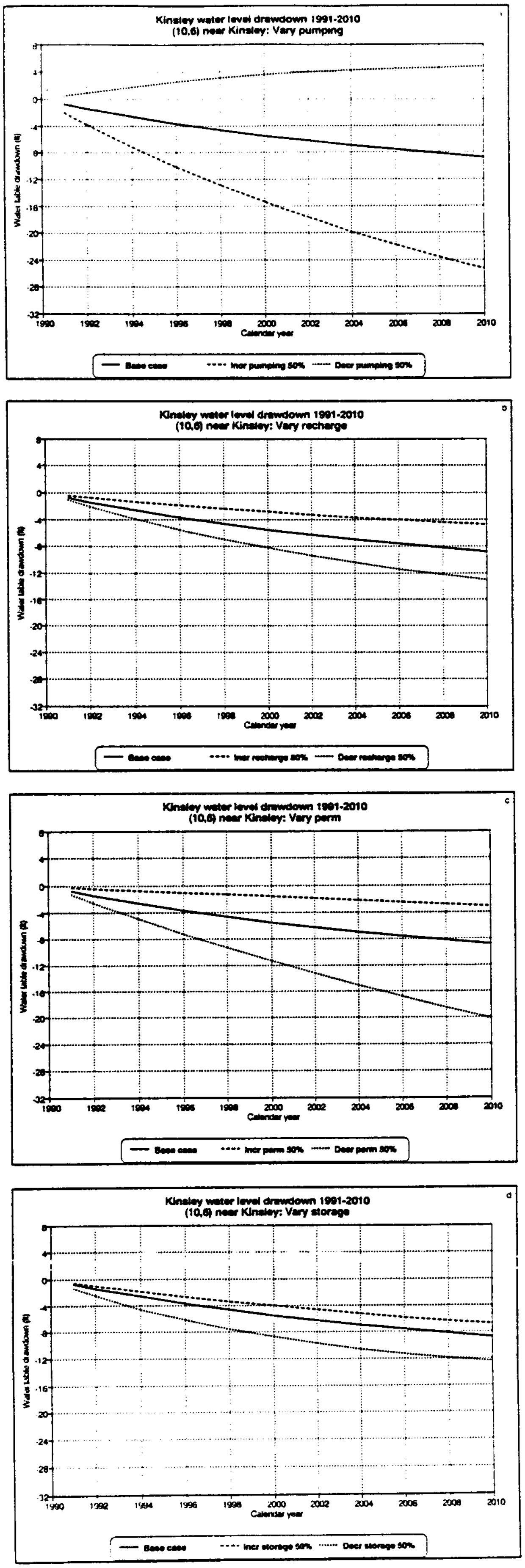


Figure 39. Sensitivity plots of drawdown with changing pumpage, recharge, hydraulic conductivity, and storativity at grid cell 10, 6 (row, column) near Kinsley.

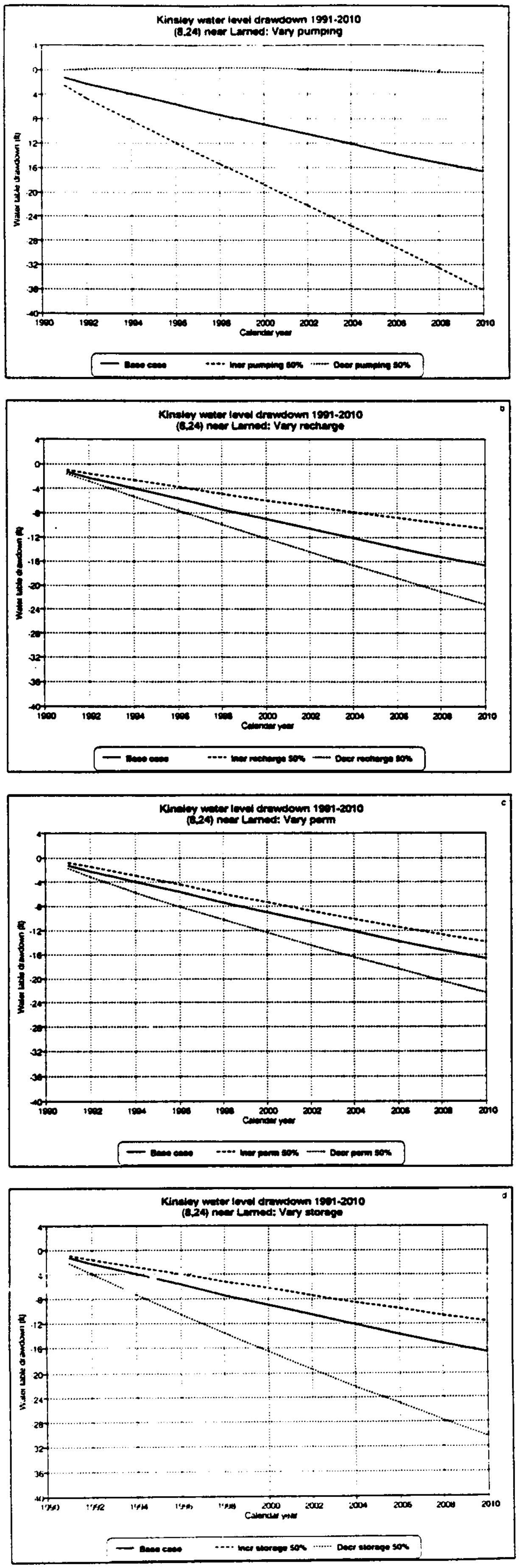


Figure 40. Sensitivity plots of drawdown with changing pumpage, recharge, hydraulic conductivity, and storativity at grid cell 8, 24 (row, column) near Larned.

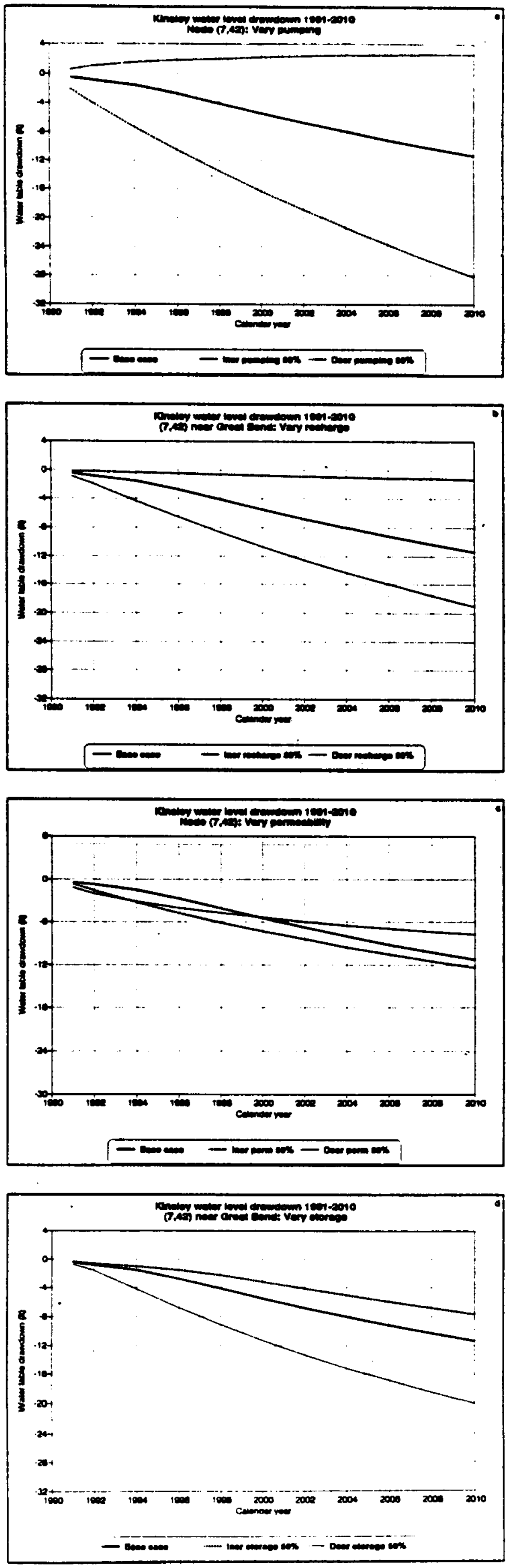


Figure 41. Sensitivity plots of drawdown with changing pumpage, recharge, hydraulic conductivity, and storativity at grid cell 7, 42 (row, column) near Great Bend.

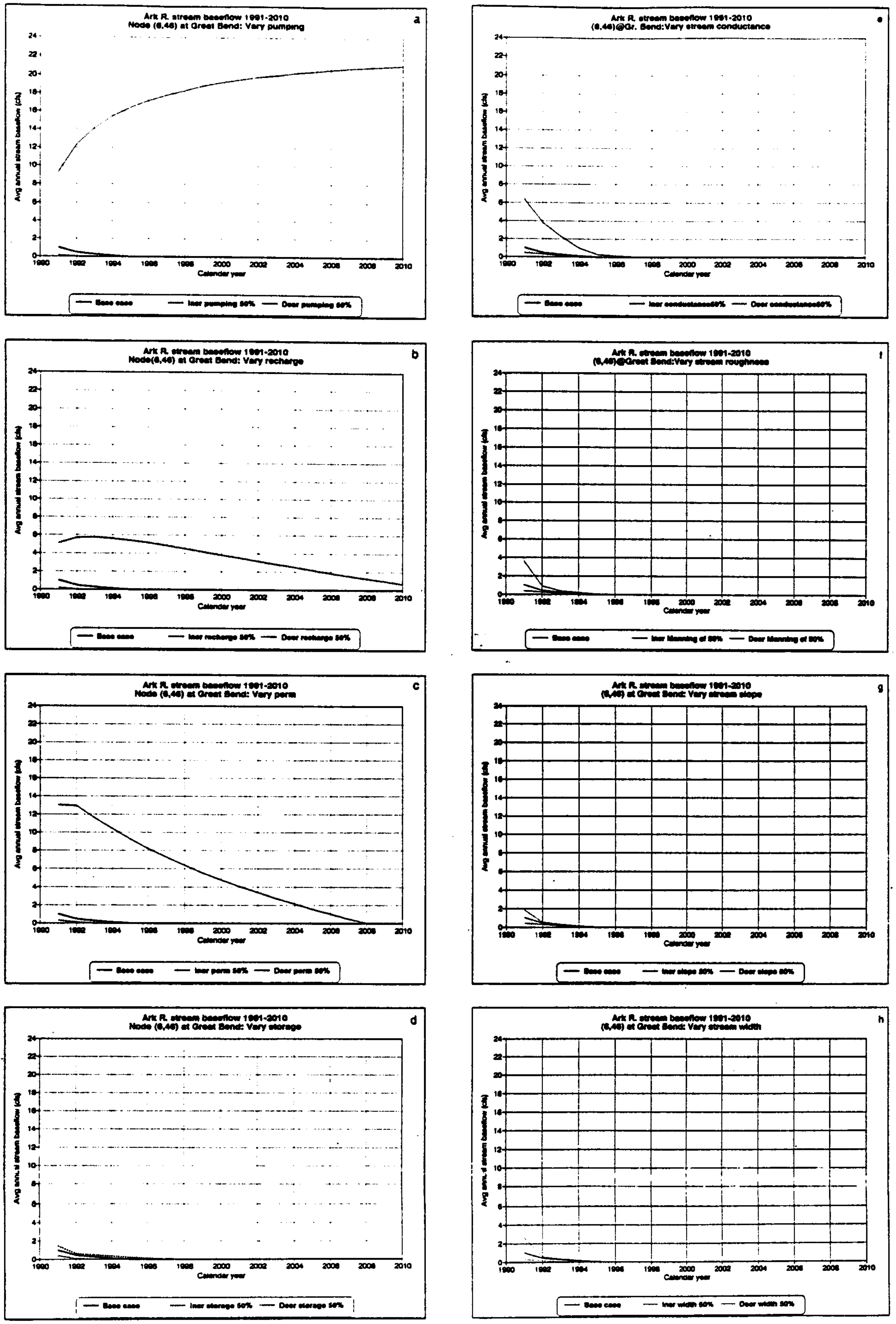


Figure 42. Sensitivity plots of stream baseflow with changing input, aquifer and stream-related parameters at grid cell 6, 46 (row, column) near the Great Bend gaging station.

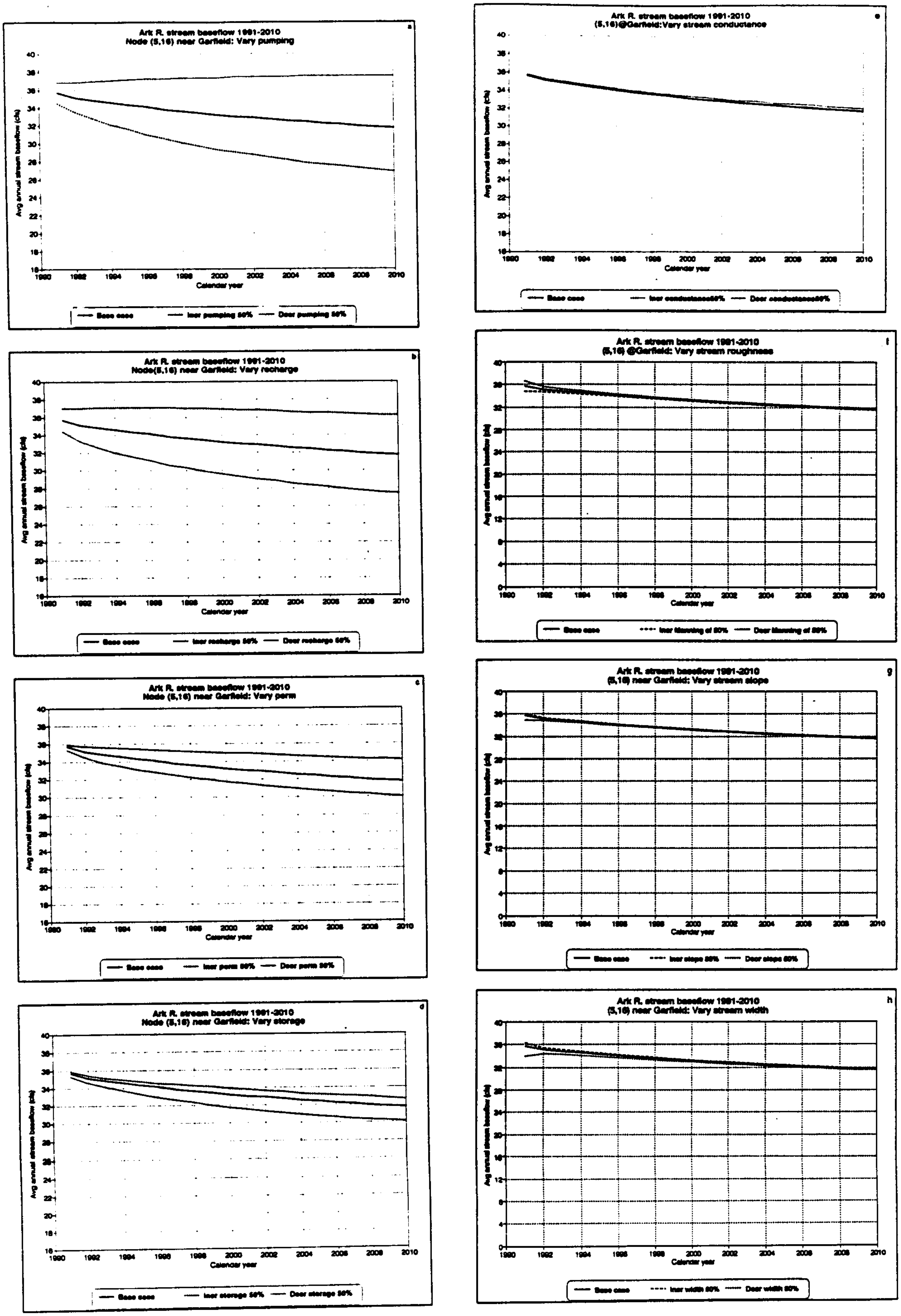


Figure 43. Sensitivity plots of stream baseflow with changing input, aquifer, and stream-related parameters at grid cell 5, 16 (row, column) near Garfield.

pronounced effect on streamflows than stream-related parameters do. For example, ground-water pumpage, recharge, and hydraulic conductivity are more sensitive parameters than streambed conductance, Manning's roughness coefficient, stream slope, or stream width (figs. 42 and 43).

V. Management Alternatives

The predictive capabilities of the calibrated model permit hypothetical conditions to be explored by simply changing the data input to emulate the situations desired. The following set of scenarios have been tested:

1. How would ground water levels and streamflows respond to increased incoming streamflows in the Arkansas River?
2. What effect do climatic fluctuations (i.e., sequence of flooding and drought years) have on the stream-aquifer system?
3. What effect do changing pumping patterns, including water conservation and improved irrigation efficiency, have on the stream-aquifer system?
4. How can specified minimum desirable streamflows be maintained throughout the Kinsley to Great Bend reach of the Arkansas River?
5. What effect would protective stream corridors of different sizes have on streamflows?
6. In case of drought, what is the most vulnerable subregion of the study area, and what ameliorating options are available?

Cause and effect of several management alternatives on the Kinsley to Great Bend stream-aquifer system

The cause and effect of various management alternatives from the above list are outlined in table 10 and are summarized in what folows. The effects of flood-drought cycles on the stream-aquifer system are outlined subsequently.

A model prediction of streamflows, not taking into account surface runoff within the model boundaries and assuming that present conditions of ground-water pumpage, recharge, and the

Table 10. Management alternatives considered for the Kinsley to Great Bend model area.

Incoming streamflows at Kinsley	Pumping patterns	Effects	Results in fig.
Average of calendar years 1988–1990 (16.64 cfs)	Base case 1: 1990 "status quo" maintained (pumpage 80% of appropriations)	Stream reaches 35–46 (Great Bend) dry by 2010. Streamflow declines practically along the entire stream length.	44
"	50% pumping reduction throughout model area	Streamflows at Great Bend restored to incoming streamflows at Kinsley by 2010	45
"	1-mi stream corridor along the Arkansas River with pumping moratorium	Short term (5–6 yrs) improvement in streamflows at Great Bend; however, by 2010 stream reaches 38–46 would be dry.	46
"	3-mi stream corridor centered along the Arkansas River with pumping moratorium	Kinsley to Larned reach stabilized. Streamflow regime along critical Larned to Great Bend reach definitely improved, with streamflows at Great Bend ranging from 17 to 11 cfs by 2010.	47
Average of calendar years 1970–1979 (~83 cfs)	1990 "status quo"	Streamflows along entire reach much improved; no pumping restrictions needed. Streamflows at Great Bend range from 42 to 30 cfs.	49
Average of calendar years 1988–1990 (20.66 cfs)	Base case 2: 1990 "status quo" maintained (pumpage 80% of appropriations)	Stream reaches 35–46 (Great Bend) dry by 2010. Streamflow declines practically along the entire stream length.	50
"	Various percentage pumping reductions ranging from 0% (.8Q) through 37.5% (.5Q) and 50% (.4Q) to 75% (.2Q) throughout model area	Streamflows along entire reach will significantly improve except for the 0% pumping reduction ("status quo").	51
"	3-mi stream corridor along Larned-Great Bend reach of the Arkansas River with varying pumping reductions (50%, 80% and complete moratorium) along that corridor	Only complete pumping moratorium along a 3-mi stream corridor will eliminate all dry reaches in that critical stretch of the Arkansas River.	52
"	Model area below the confluence of Pawnee River and Arkansas River subjected to varying pumping reductions (50%, 80% and complete moratorium)	All cases result in elimination of all dry stream reaches and significant streamflow improvement in that critical stretch of the Arkansas River.	53

average of the last reported three calendar years (1988–1990) of incoming streamflows at the Kinsley (16.64 cfs) and Larned (17.62 cfs) gages persist throughout the 1991–2010 period, is shown in fig. 44. The stream reach from Larned to Great Bend is the most vulnerable in the sense that the sharpest (steepest) declines in streamflow occur there. The river reach from Dundee to Great Bend is particularly vulnerable. Streamflows at Great Bend are predicted to decrease by 100%, whereas at Garfield they are predicted to decrease by 25% by the year 2010 (fig. 44). Stream reaches (1-mile cells) 33 through 46 (figs. 35 and 44) will be dry by the year 2010. We would use fig. 44 as a base case to compare against a number of possible management scenarios for the purpose of restoring streamflows to those dry reaches.

A 50% simulated reduction in present-day ground-water pumpage (assumed 80% of appropriated amounts) over the study area would restore flows at Great Bend to the level of present-day incoming streamflows at Kinsley over the next 20 years (fig. 45). Streamflows in the Kinsley to Larned reach of the Arkansas River would be effectively stabilized.

Imposing a complete ground-water pumping restriction for the next 20 years along a 1-mile corridor of the Arkansas River (fig. 46) would partially improve the streamflow regime at Great Bend for the next 5 to 6 years, but it would not be enough to maintain streamflows there. Compared to the base case, stream reaches 38 through 46 would be dry by the year 2010.

Imposing a ground-water pumping moratorium for the next 20 years along a 3-mile corridor around the Arkansas River (fig. 47) would definitely improve the streamflow regime not only at Great Bend but along the entire Larned to Great Bend reach of the Arkansas River, with streamflows above 10 cfs by the year 2010 throughout that reach. A portion of the 3-mile stream corridor for the Larned to Great Bend segment of the Arkansas River is shown in fig. 48.

If the incoming streamflows at Kinsley were restored to the average annual streamflows that existed during the 1970's (i.e., to approximately 83 cfs per year for the next 20 years), then no present-day pumpage restrictions would be required to maintain adequate streamflows in the Arkansas River (fig. 48). Streamflows at Great Bend would range from 30 to 42 cfs (compared to

[redacted]

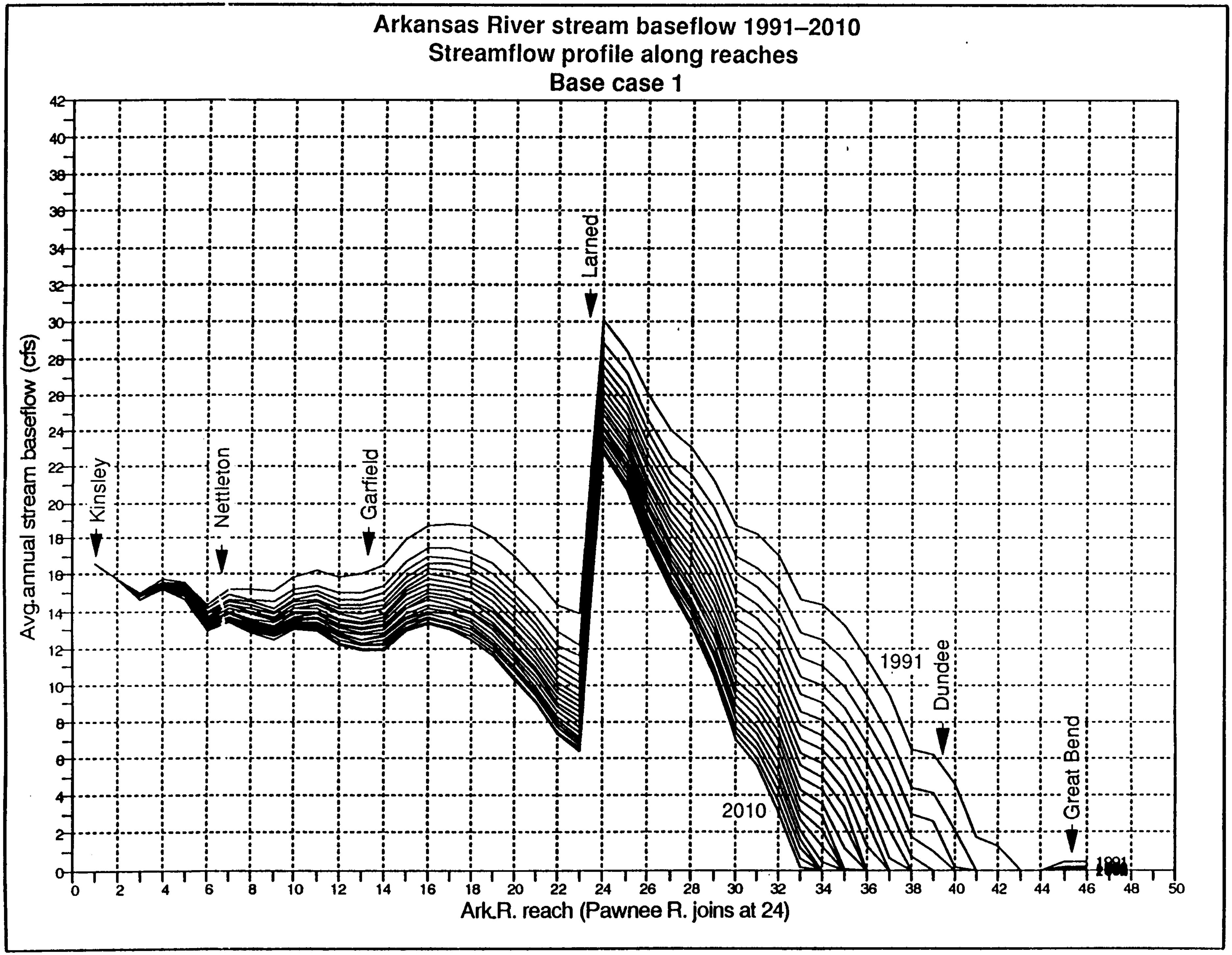


Figure 44. Model-predicted streamflows for the next 20 years assuming 1988–1990 calendar-year average incoming streamflows at Kinsley and Larned and 1990 ground water pumpage. Base case 1.

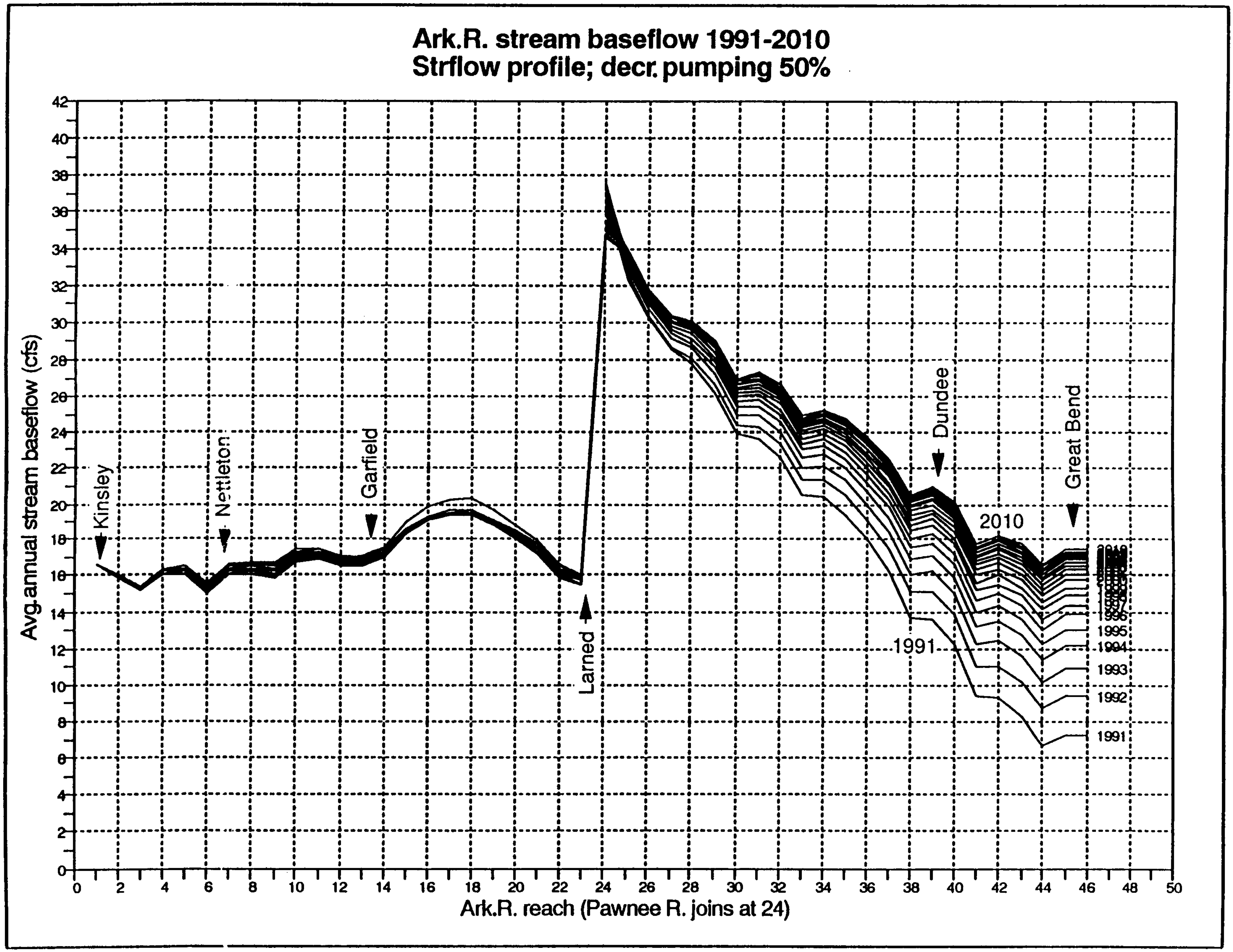


Figure 45. Model-predicted streamflows for the next 20 years assuming 1988–1990 calendar-year average incoming streamflows at Kinsley and Larned and 50% reduction in 1990 ground water pumpage.

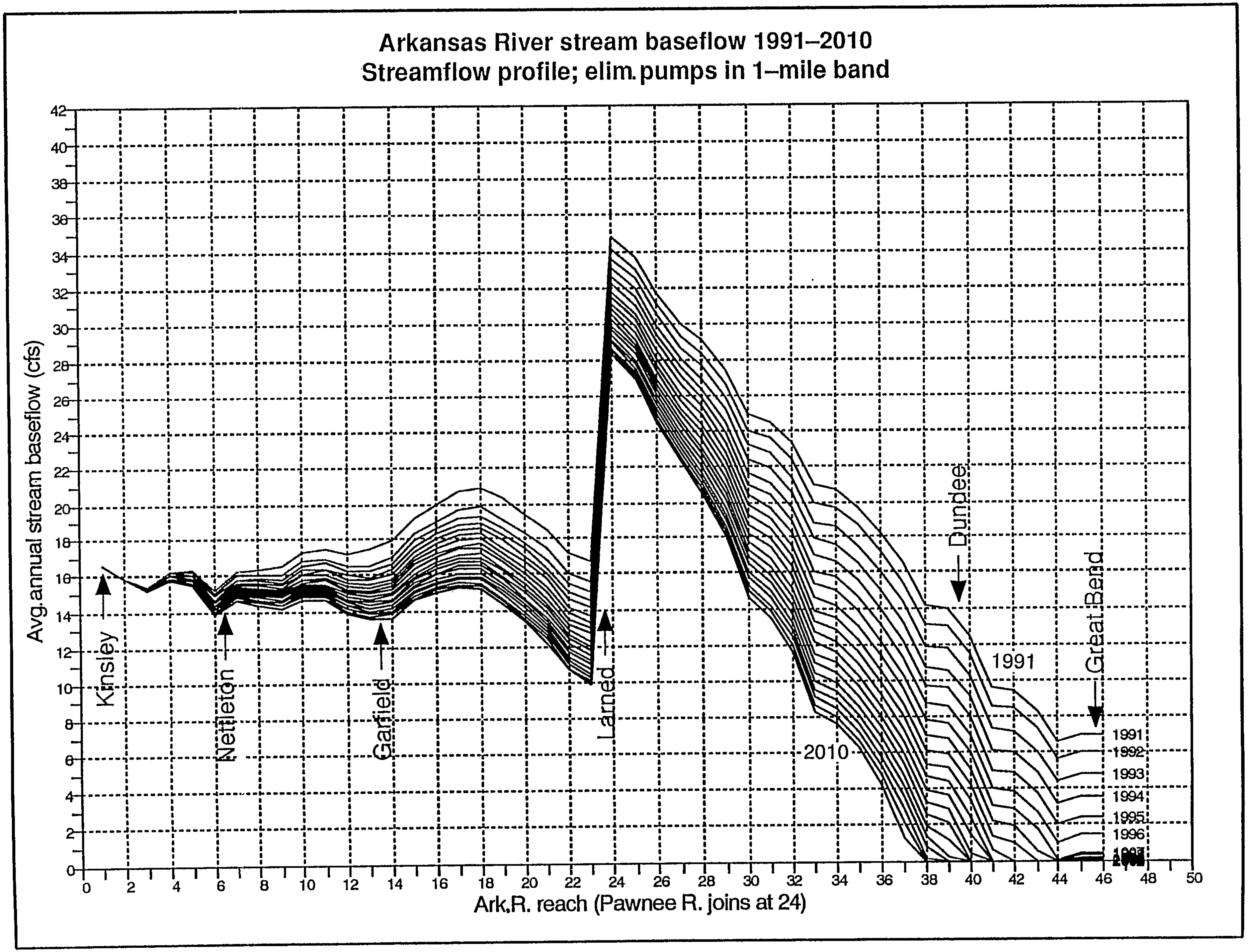


Figure 46. Model-predicted streamflows for the next 20 years assuming 1988–1990 calendar-year average incoming streamflows at Kinsley and Larned and no ground-water pumpage along a 1-mile corridor around the Arkansas River.

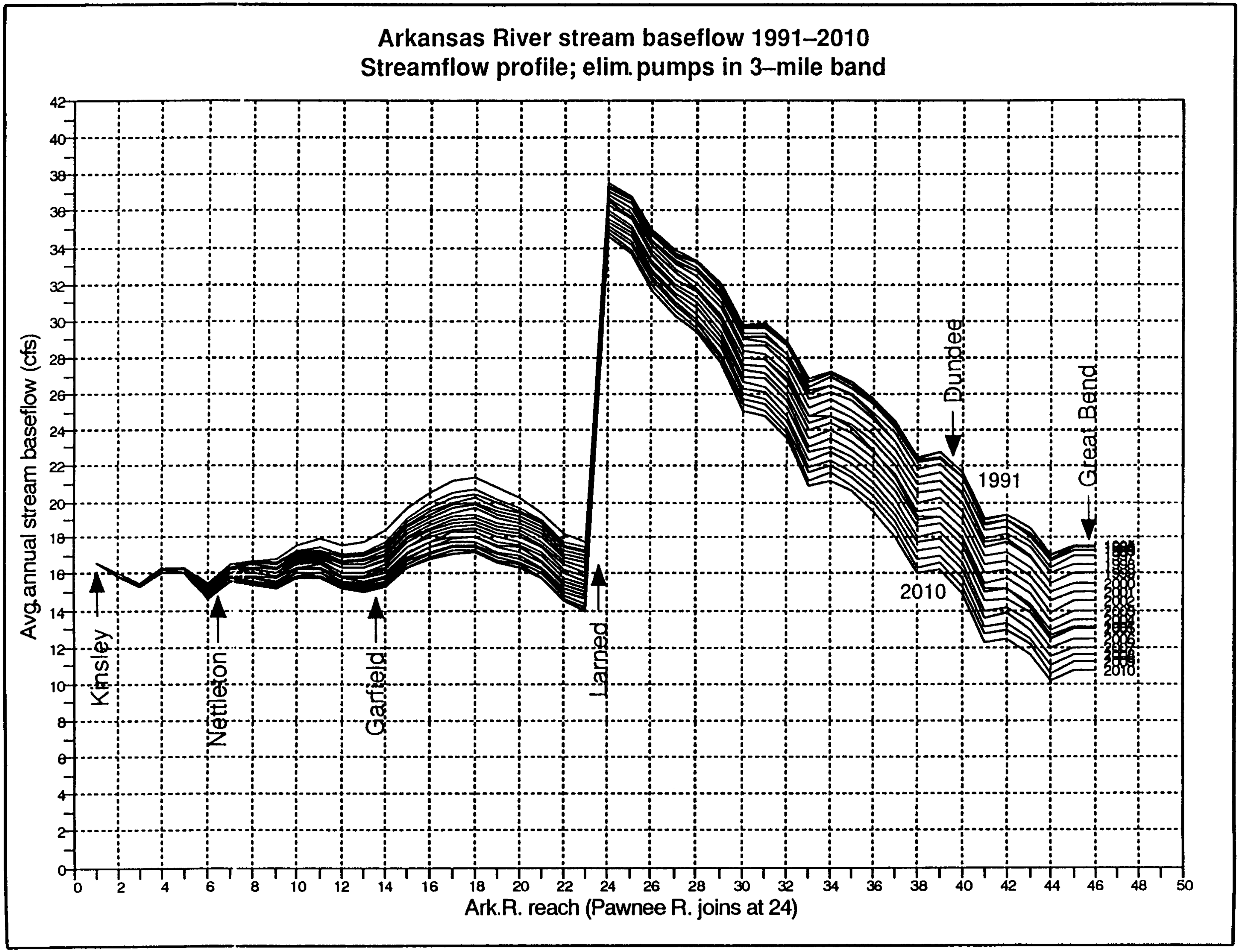


Figure 47. Model-predicted streamflows for the next 20 years assuming 1988–1990 calendar-year average incoming streamflows at Kinsley and Larned and no ground-water pumpage along a 3-mile corridor around the Arkansas River

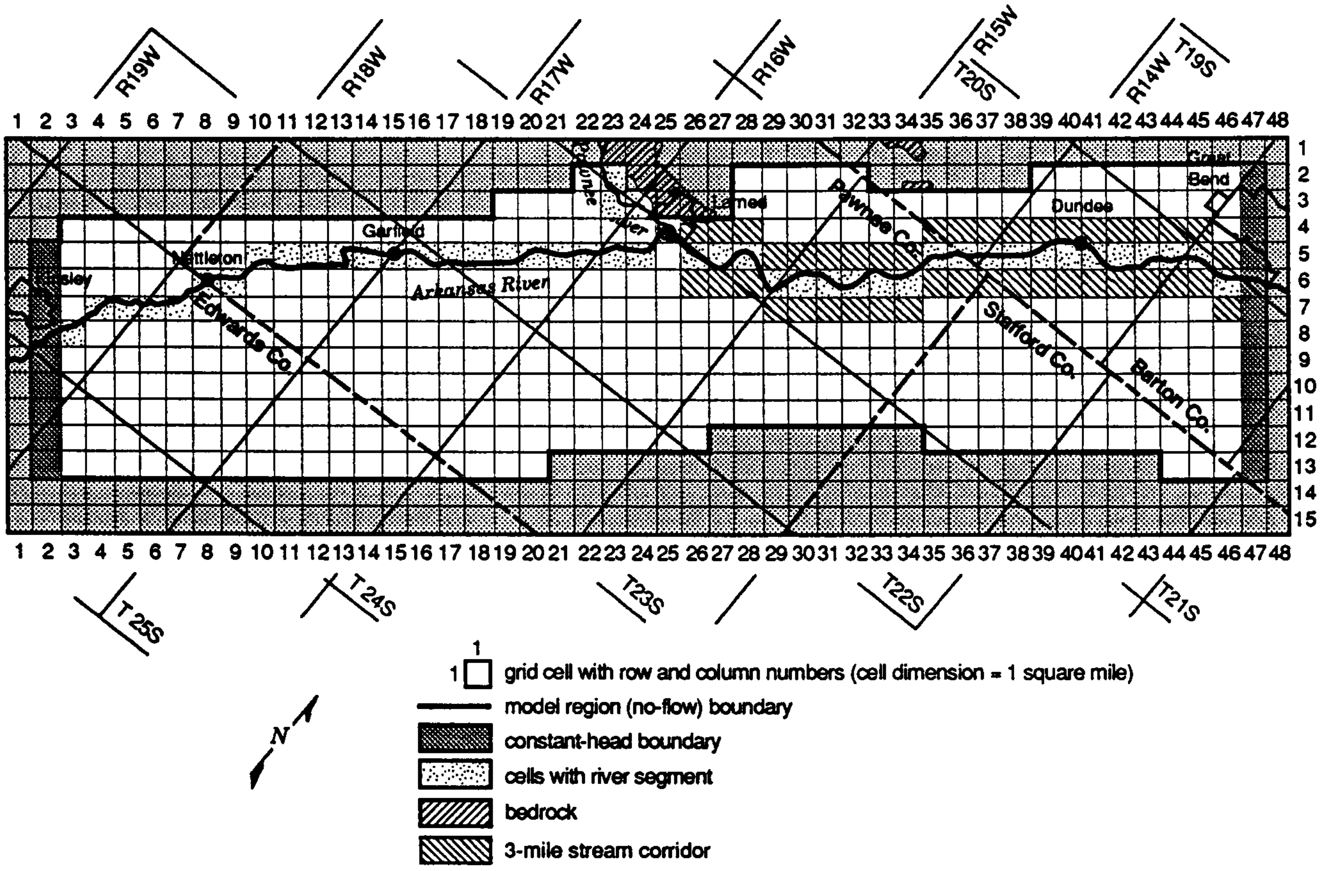


Figure 48. Partial 3-mile stream corridor along the Arkansas River between Larned and Great Bend.

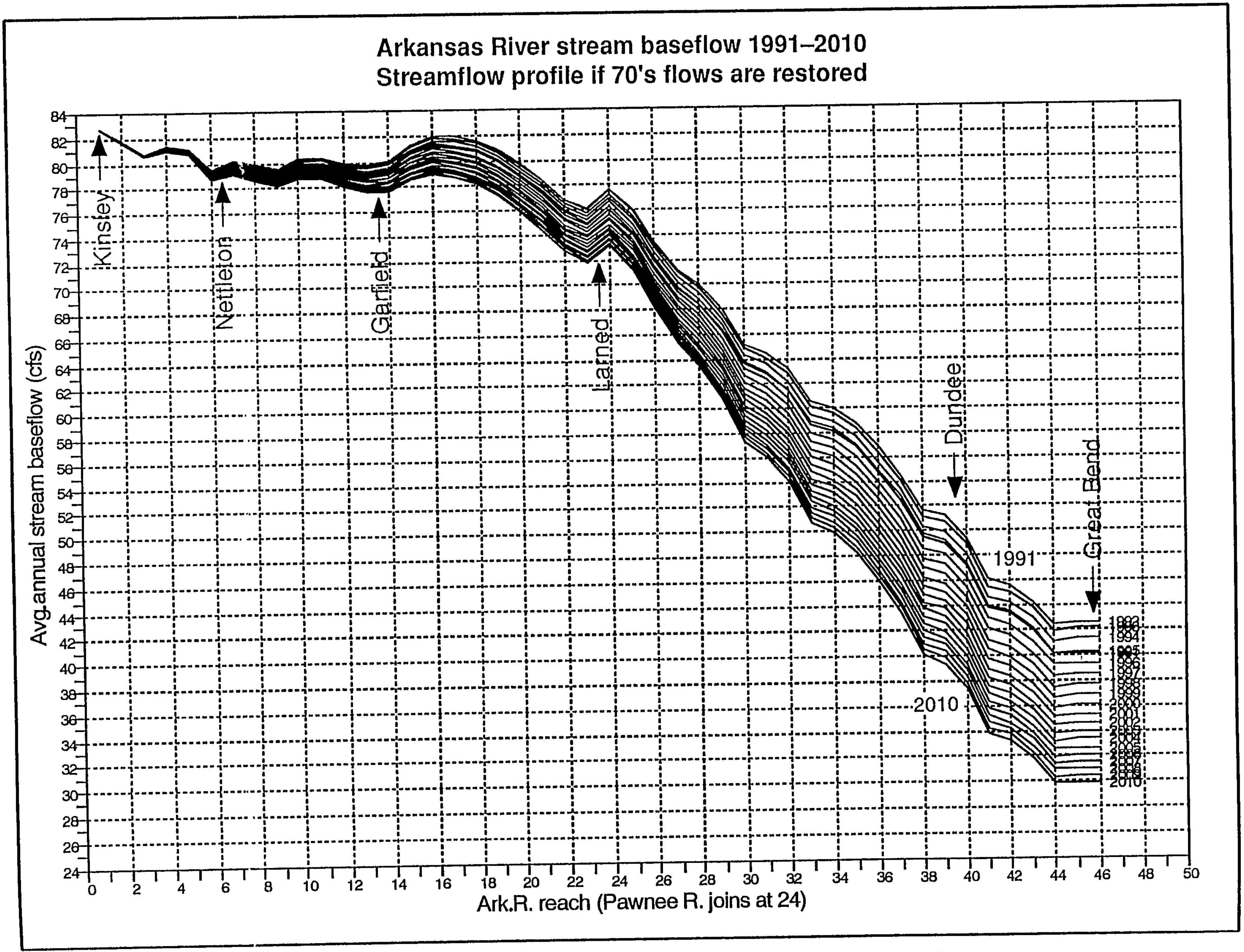
near zero otherwise) over the next 20 years, assuming that present-day pumpage remains unchanged during that period.

For the next series of management alternatives simulations the base case (fig. 50) is identical to the one used previously (fig. 44) except that instead of using the 1988–1990 calendar-year average streamflows in projecting for the next 20 years, the slightly higher 1988–1990 water-year average streamflows at Kinsley (20.66 cfs) and Larned (17.63 cfs) are used. The purpose of these simulations is primarily to evaluate what could be done to restore streamflows in the critical Larned to Great Bend reach of the Arkansas River.

Figure 51 displays the effects of several alternative pumping reductions throughout the model area on the streamflows of the Arkansas River. These pumping reductions range fro 0% (.8Q; base case 2 "status quo"), through 37.5% (.5Q) and 50% (.4Q) pumping reductions to 75% (.2Q). Streamflows along the entire Kinsley to Great Bend reach will be significantly improved (except for the 0% pumping reduction). The 37.5% pumping reduction would result in a minimum annual streamflow at Great Bend of 11 cfs by 2010.

Figure 52 depicts the Arkansas River streamflow profiles for the next 20 years if a 3-mile ground-water pumpage restriction corridor were established around the river from Larned to Great Bend only. Figure 52a shows the predicted effects on streamflows of a 50% pumpage reduction, fig. 52b the effects of an 80% pumpage reduction, and fig. 52c the effects of a complete pumpage moratorium on a 3-mile corridor around the stream. Only the last alternative would result in no dry stream cell in the critical Larned to Great Bend stream reach.

Figure 53 shows a similar situation to the one depicted in fig. 52 except that instead of employing a corridor around the stream, the entire model area below the confluence with the Pawnee River is subjected to (a) 50%, (b) 80% and (c) complete ground-water pumpage reductions. All cases would result in a no-dry-stream cell in the critical Larned to Great Bend reach of the Arkansas River. Case (a) would result in a minimum streamflow of approximately 6 cfs just west of Great Bend in the 20-year projection period, whereas cases (b) and (c) will completely stabilize or reverse the declining streamflow trend in that critical stretch of the Arkansas River.



Arkansas River stream baseflow 1991–2010
Streamflow profile if 70's flows are restored

Figure 49. Model-predicted streamflows for the next 20 years assuming 1970–1979 calendar-year average incoming streamflows at Kinsley and Larned and 1990 ground-water pumpage.

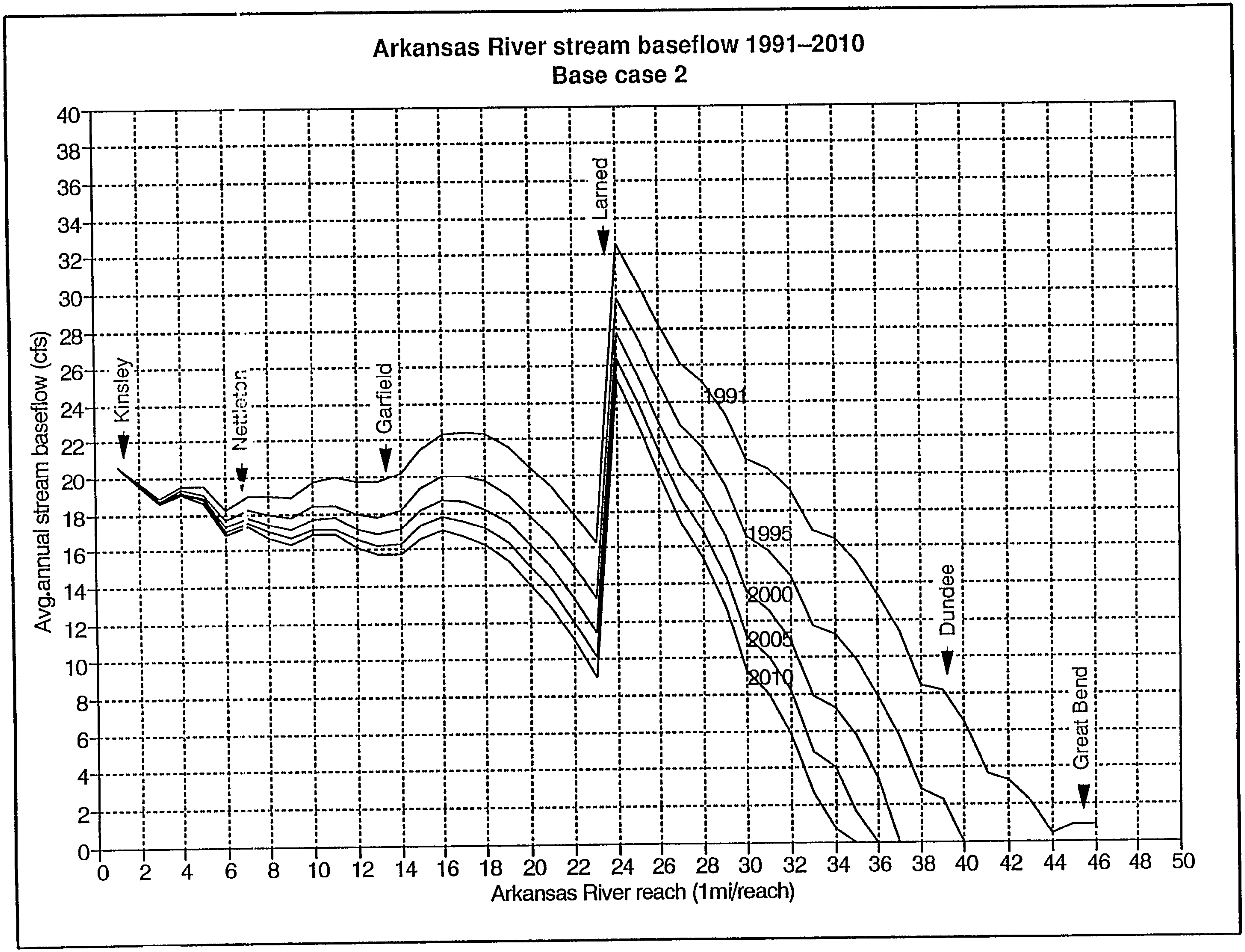


Figure 50. Model-predicted streamflows for the next 20 years assuming 1988–1990 water-year average incoming streamflows at Kinsley and Larned and 1990 ground-water pumpage. Base case 2.

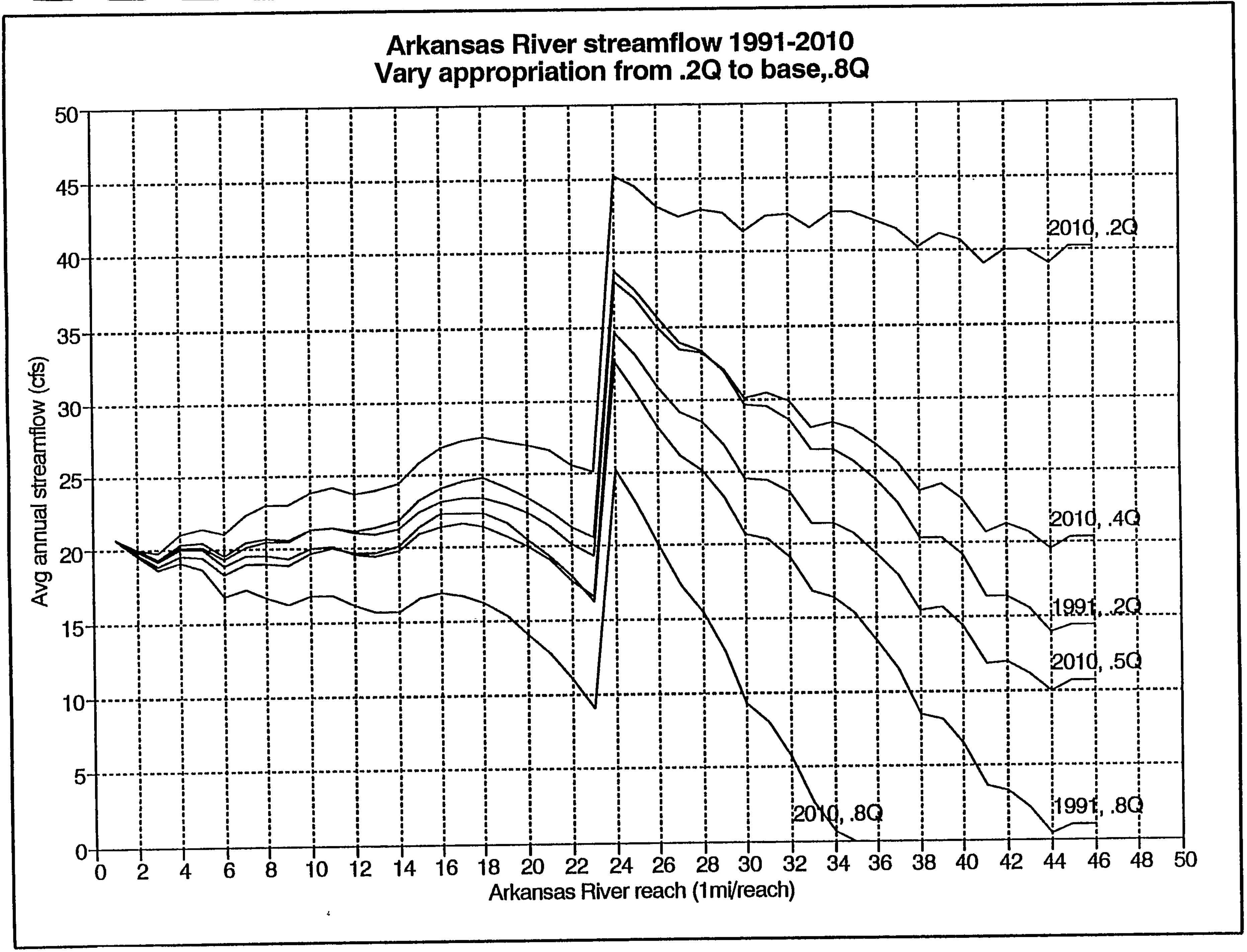


Figure 51. Model-predicted streamflows assuming 1988–1990 water-year average incoming streamflows at Kinsley and Larned and several alternative pumping reductions throughout the model area, ranging from 0% (.8Q) through 37.5% (.5Q) and 50% (.4Q) pumping reductions to 75% (.2Q).

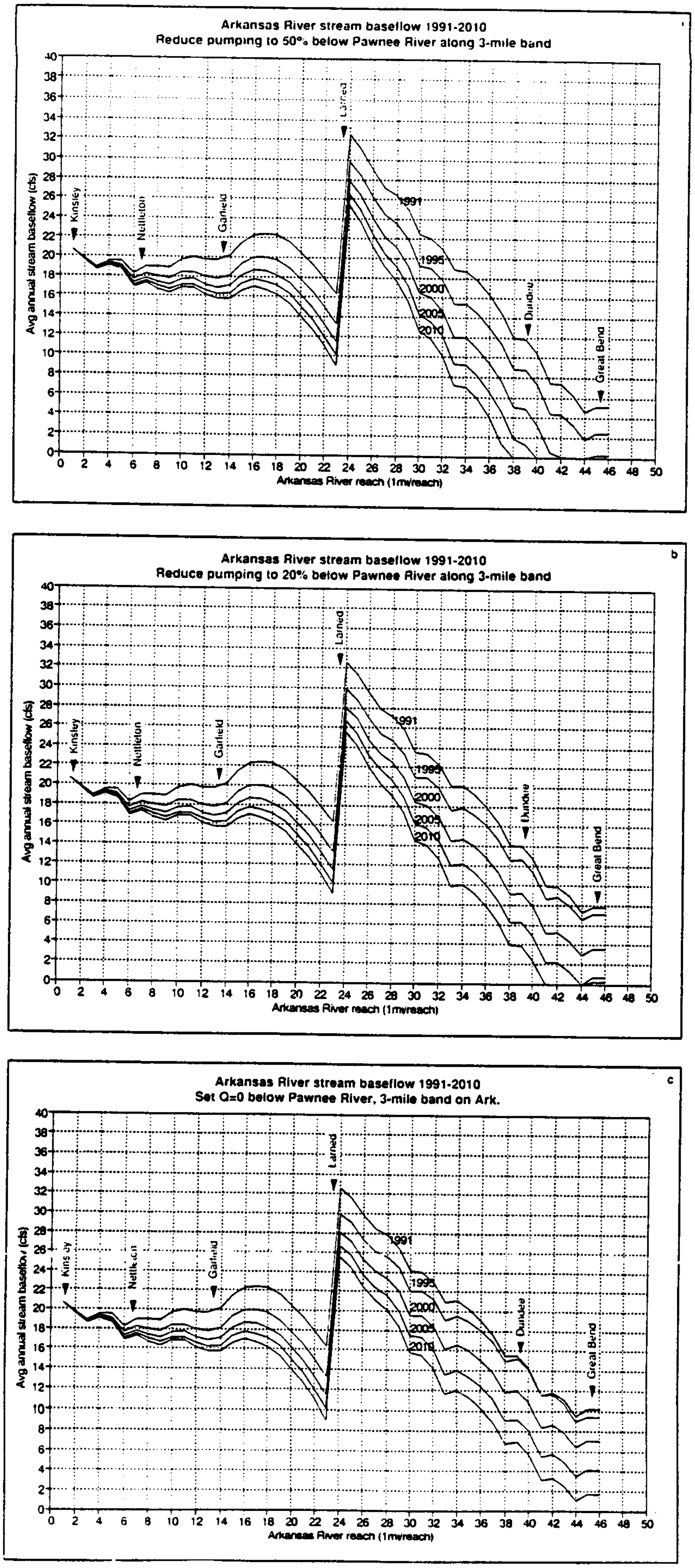
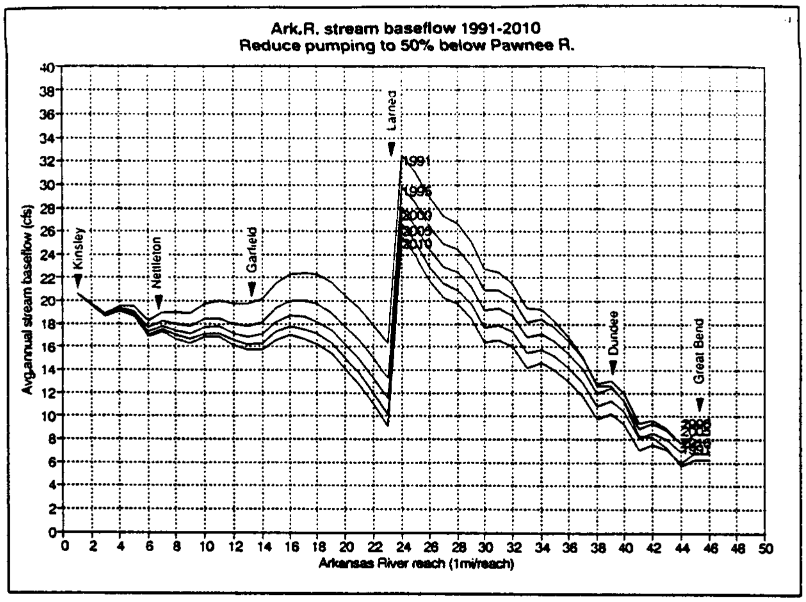
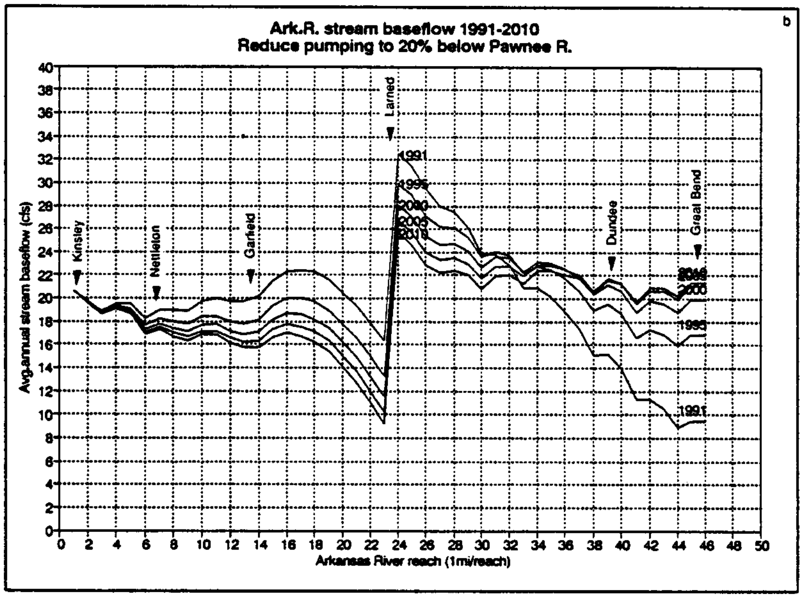


Figure 52. Model-predicted streamflows for the next 20 years assuming 1988–1990 water-year average incoming streamflows at Kinsley and Larned and (a) 50% reduction in 1990 ground-water pumpage along a 3-mile corridor around the Arkansas River from Larned to Great Bend, (b) 80% pumpage reduction, and (c) complete pumpage moratorium along the same corridor.





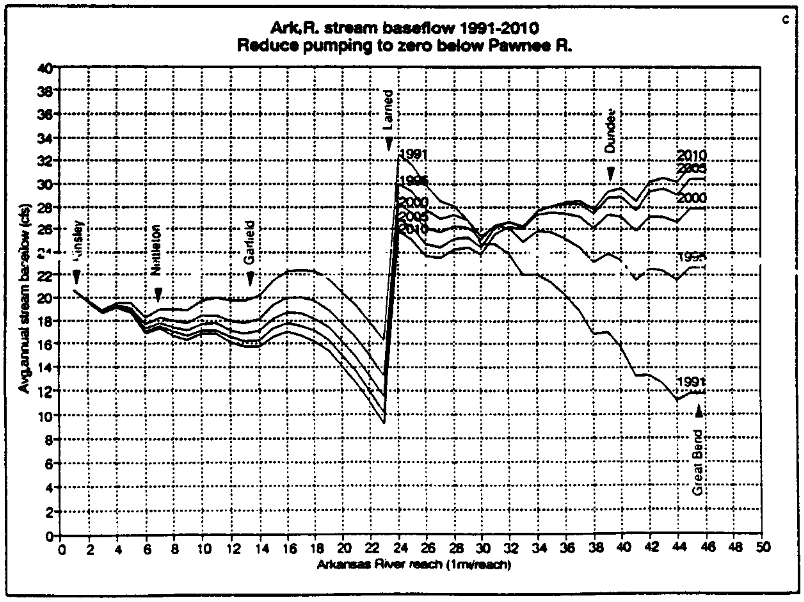


Figure 53. Model-predicted streamflows for the next 20 years assuming 1988–1990 water-year average incoming streamflows at Kinsley and Larned and (a) 50% reduction in 1990 ground-water pumpage in the entire model area below the confluence with the Pawnee River, (b) 80% pumpage reduction, and (c) complete pumpage moratorium over the same area.

Effect of climatic fluctuations on the Kinsley to Great Bend stream-aquifer system

To simulate flood-drought cycles and their effects on the stream-aquifer system, we examined the Arkansas River and Pawnee River streamflow records to identify annual flood and drought flows. For flooding conditions we selected the 1987 calendar year streamflow for the Arkansas River at Kinsley (334.02 cfs), and the 1973 calendar year streamflow for the Pawnee River near Larned (140.45 cfs). For drought conditions we selected the 1989 calendar year Arkansas River streamflow of 1.72 cfs at Kinsley, and for the Pawnee River the 1988 calendar year streamflow of 2.46 cfs near Larned. The average annual water-year streamflows during the 1988–1990 period of 20.66 cfs for the Arkansas River at Kinsley, and 17.62 cfs for the Pawnee River near Larned were taken as the normal streamflows (base case 2). Thus a 10-year cycle of the above-mentioned flood-drought or drought-flood streamflows of 5-year duration each was simulated, followed by normal streamflows for the last 10 years of a 20-year total simulation run. During flooding periods, recharge was increased by 100% and actual pumping (i.e. 80% of appropriations) was reduced by 50%. During droughts, recharge was reduced by 100% and pumpage was increased to the nominal appropriated amounts.

Figure 54 displays both the flood-drought and drought-flood cycle streamflows at the model entry points at Kinsley (a) and Larned (b). The resulting streamflow hydrographs at Dundee (a) and Great Bend (b) are shown in fig. 55. The effect of these climatic fluctuations on the aquifer are shown in fig. 56 for an area near Larned [node (8, 24)] and Great Bend [node (7, 42)]. The results show that the sequence drought-flood-normal ends up in higher ground-water levels by the end of the climatic fluctuation cycle than the flood-drought-normal cycle.

VI. Summary and conclusions

This study was undertaken to address concerns with declining streamflows and to explore possible management options to remedy this situation. The approach we followed was to analyze the stream-aquifer system as a unit in the Arkansas River valley from Kinsley to Great Bend. A two-dimensional stream-aquifer model coupled with parameter estimation and optimization

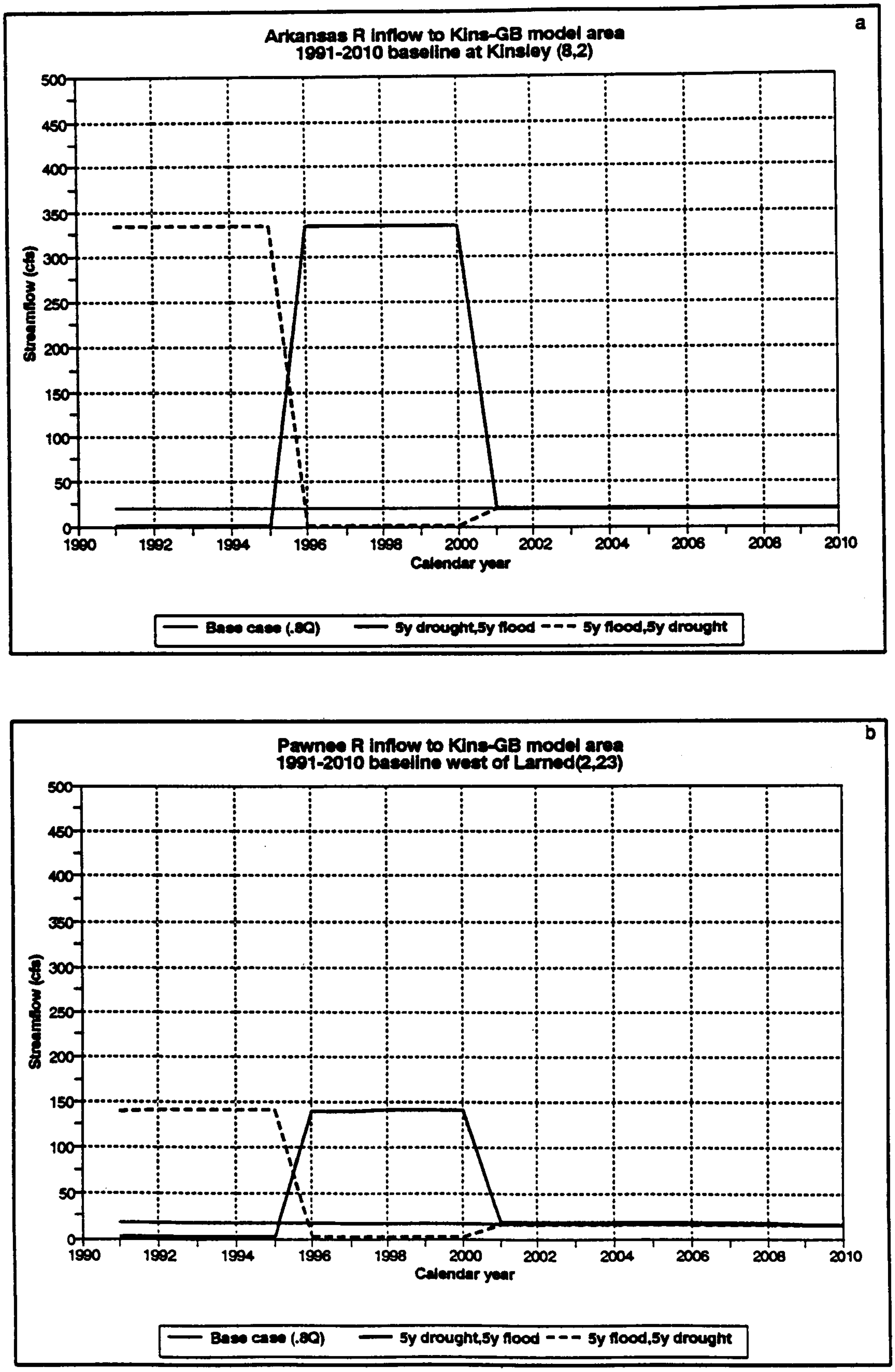


Figure 54. Flood/drought- and drought/flood-cycle incoming streamflows at (a) Kinsley and (b) Larned.

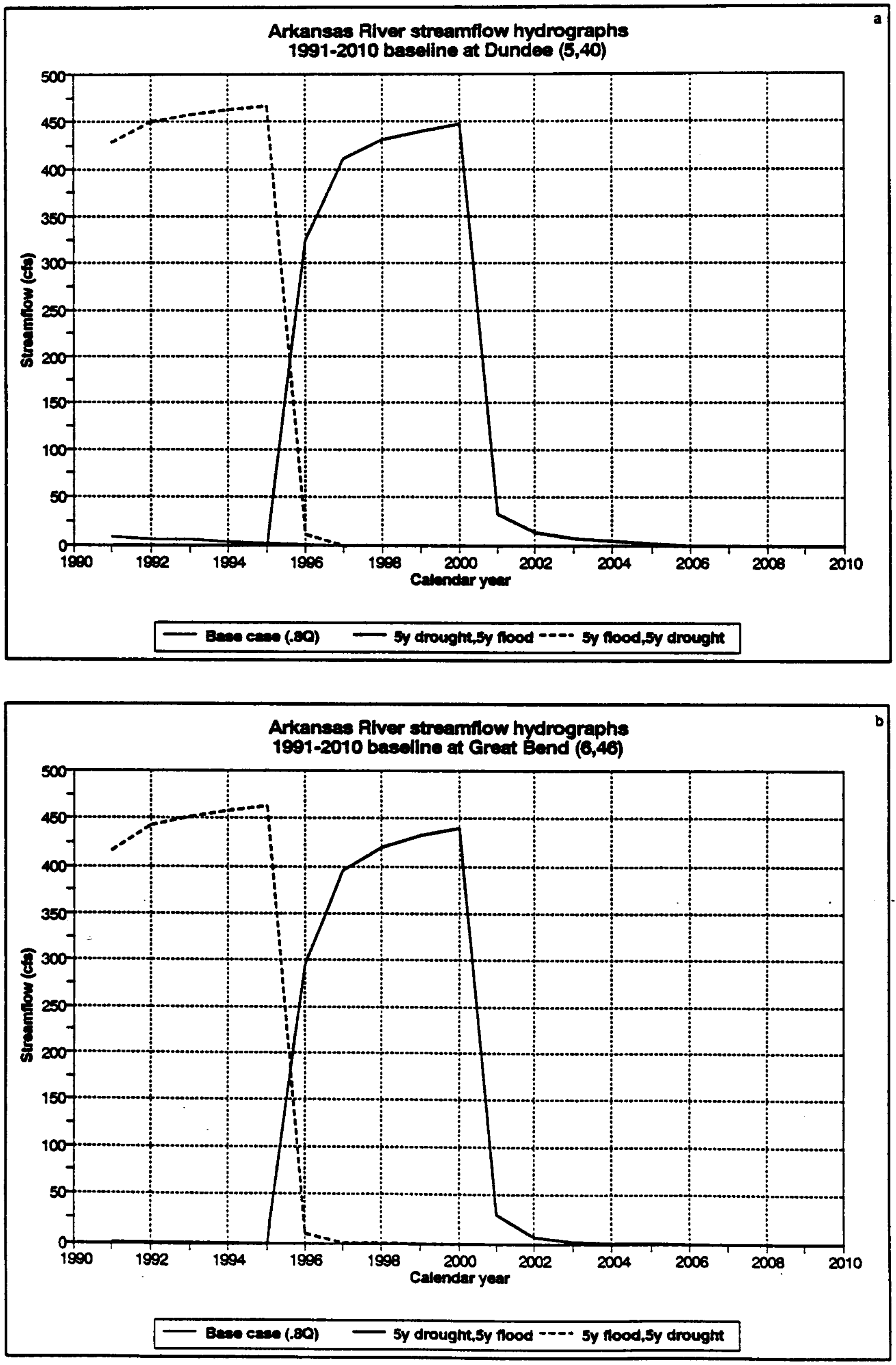
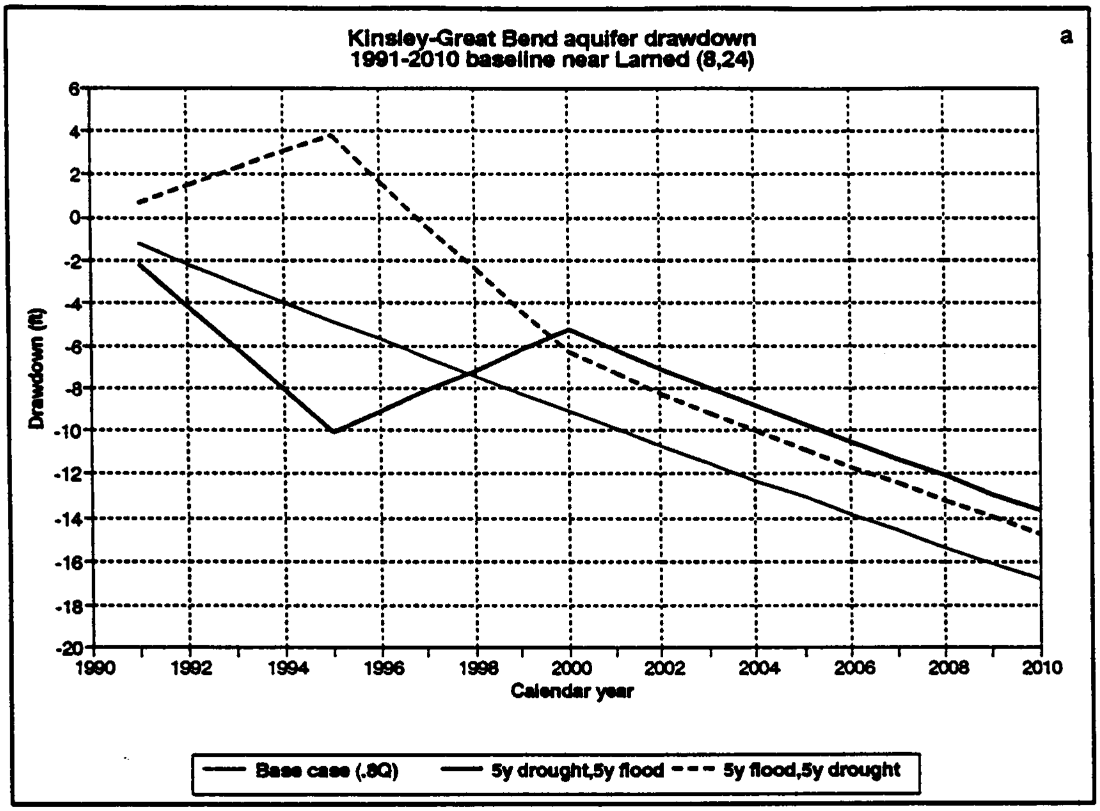


Figure 55. Model predicted flood/drought- and drought/flood-cycle streamflows at (a) Dundee and (b) Great Bend.



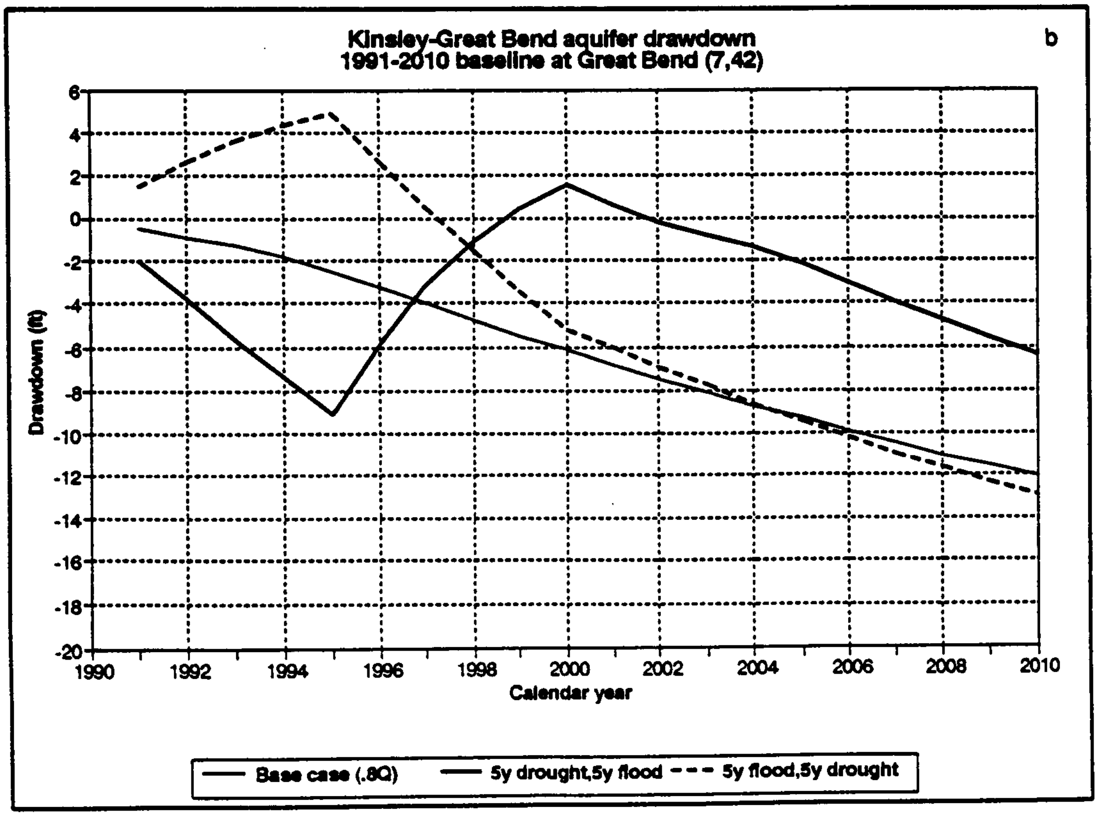


Figure 56. Effect of streamflow climatic cycles shown in figs. 54 and 55 on aquifer near (a) Larned and (b) Great Bend.

modeling was implemented in the study area and proved to be an effective and efficient approach in addressing the stream-aquifer problem. The model was field-calibrated for both predevelopment (c. 1955) and development periods (1955–1985) and was validated using stresses (1985–1990 pumping and streamflows) different from those used in the calibration (1955–1985).

Hydrologic budgets for both predevelopment and developed conditions indicate significant differences in the hydrologic components resulting from development. Such computer simulations provide insight into the changes in recharge and discharge resulting from development. The predevelopment budgets give us an estimate of natural recharge, that is, water moving through the ground-water system under the boundary conditions imposed by natural topography, geology, and climate, whereas the developed-conditions budgets give us an estimate of induced recharge, that is, water added to the natural ground-water system in response to artificial boundary conditions imposed at well fields, farm ponds, drains, reservoirs, and other boundary conditions. Natural recharge balances natural discharge as baseflow of streams or outflow to springs and wetlands and does not enter the water account for artificial ground-water diversions. Induced recharge and ground-water storage are the two sources of water to balance artificial ground-water withdrawals. The effects of concern to water policy are primarily aquifer drawdown and surface-water depletion. Both are functionally related to pumping rate, aquifer diffusivity, location, and time of pumpage. Thus the natural recharge rate is not directly related to any parameters controlling these primary water policy concerns and should not be used as a measure of the magnitude of ground-water development that will lead to stable, nondepleting ground-water levels. As Bredehoeft et al. (1982) noted, the suggestion that the safe yield of a ground-water basin be defined as the annual extraction of water that does not exceed the average annual ground-water recharge is misleading. As the comparison of the steady-state and transient-state water budgets for both model areas shows, major ground-water development, such as the one in the GMD5 region, significantly changes the recharge-discharge regime with time. The yield of the ground-water basin depends on both the manner in which the effects of withdrawal are transmitted throught he aquifer and the changes in rates of recharge and discharge induced by the withdrawals.

We used sensitivity analysis to identify parameters to which the transient-state model is most sensitive. Ground-water pumpage has the largest effect on aquifer water levels and streamflows, followed by recharge, aquifer storativity, and hydraulic conductivity, in order of decreasing sensitivity. These parameters are much more sensitive than stream-related parameters (streambed conductance, Manning's roughness coefficient, stream slope, and stream width).

The calibrated model provides a predictive tool that explains the connections between well field withdrawals and surface-water depletion. such causal hydrologic models also link proposed actions to hydrologic effects, as clearly demonstrated by the effects of various management alternatives on the streamflows of the Arkansas River. The hydrologic effectiveness of protective stream corridors with restricted ground-water extraction is demonstrated for the study area, thus providing a possible means of restoring streamflows in the Arkansas River between Kinsley and Great Bend.

The results from this study indicate that the present level of ground-water pumpage in the area is not sustainable over the long term and that desirable streamflows cannot be maintained unless severe measures along the lines indicated in this study area are taken to protect and conserve the water resources of the region. In view of the possible significant impact such studies might have on water management policies in the GMD5 region, the irrigators of the area were organized to protect their rights and contest any unfavorable results from this study. It is hoped that hydrologic studies such as this one will raise people's awareness of hydrologic reality and will encourage opne discussion and improve understanding concerning the important issues we are addressing and their significance to all concerned.

Acknowledgments

The cooperation and field assistance of GMD5 in ground water-level surveying and stream gaging is gratefully acknowledged. The Division of Water Resources Stafford Field Office, the Kansas Water Office, and the Kansas Department of Wildlife and Parks assisted with stream-gaging the Kinsley to Great Bend reach of the Arkansas River. Tom McClain and other KGS employees were instrumental in the 1985 water-level survey of the area. Feng Zhaodong, Alan Stern, and Chong Chung, KGS graduate student assistants, were particularly helpful in getting all geographic-related data into map form. Mark Schoneweis drafted a number of the figures; Mimi Braverman edited the manuscript; and Anna Kraxner and Shan Chen typed and formatted the text. Kansas Water Office funding of this project is gratefully acknowledged.

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Appendix 1. Ground-Water Rights in the Kinsley to Great Bend Area (1990)

Appendix 1. Ground-Water Rights in the Kinsley to Great Bend Study Area (1990).

Key to Table Columns:

(a) Location of each well (or grid corner) using the Public Land Survey System. Well identification number is listed first, followed by township number (all south of the 40th parallel), range, section number, and quarter-section identifier.

(b) Pumpage rate in gallons per minute.

(c) Water rights appropriation amount in acre-feet per year.

(d, e) Well-use codes: (1) domestic, (2) industrial, (3) irrigation, (4) municipal, (5) recreation, (6) stock watering. G = ground-water right, V = vested right, A . . = appropriated right and year established (e.g., A54 = appropriated 1954).

(f, g) Conversion to longitude, latitude (deg) from legal coordinates, automated by LEO I-PC (C. G. Ross, KGS Open-File Report 91-37, September 1991).

(h, i) Albers projection (x, y) coordinates are with respect to origin (0, 0) located at 36.8750° N latitude, 98.3125° W longitude. Albers projection is based on meridian at 98.3215° W, parallels at 34.0° N and 44.0° N, and earth radius 6,371,007 m (weighted average based on the geodetic reference spheroid WGS-72).

(j, k) Wells are located on a 15 mi × 48 mi rectangle with a regular 1-mile grid of rows and columns. The study-area rectangle's corners are listed at the beginning of the table. Row axis (parallel to rows) passes from NW to NE corner and has a bearing of 38.2 deg counterclockwise with respect to east. Column axis passes from NW to SW corner.

(l, m) Integer values for row and column denote the cell in which the well lies.

(n) Cell activity: 0 = outside model area; −1 = constant-head cell; 1 = active model cell.

Study-area grid corners

Grid corner	Township, range, section, quarter-section	Longitude (deg)	Latitude (deg)	Albers *x* (m)	Albers *y* (m)	Grid row	Grid column
SW corner	2420W 3 DADD	-99.4967	37.9898	-103403.	125047.	0	0
SE corner	2618W 6 AADD	-99.3232	37.8215	-88464.	106086.	15	0
NE corner	1913W 6 CDBB	-98.8056	38.4227	-42795.	172800.	0	48
NW corner	2112W 3 CBAA	-98.6327	38.2534	-27856.	153839.	15	48

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Appendix 1. Well data

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
029157-IR	19	13W	7	CDCA	800.00	53.00	3	G	V	-98.8048	38.4066	-42736.	171008.	0.90	47.34	1	48	0
BT0012-00	19	13W	18	DBAC	2200.00	780.00	3	G	V	-98.7992	38.3967	-42254.	169895.	1.63	47.15	2	48	0
BT0004-00	19	13W	28	CDAA	500.00	214.00	4	G	V	-98.7652	38.3649	-39318.	166340.	4.49	47.21	5	48	0
BT0030-00	19	13W	33	BDA	165.00	111.00	2	G	V	-98.7658	38.3573	-39375.	165484.	4.89	46.85	5	47	-1
BT0028-00	19	13W	33	CCDC	400.00	613.77	2	G	V	-98.7711	38.3479	-39846.	164437.	5.22	46.22	6	47	-1
BT0017-00	19	14W	22	ACB	1000.00	92.00	3	G	V	-98.8561	38.3862	-47203.	168753.	0.28	44.29	1	45	0
BT0018-00	19	14W	23	BBCA	1350.00	100.00	3	G	V	-98.8464	38.3884	-46356.	169000.	0.49	44.80	1	45	0
BT0032-00	19	14W	25	DDD	100.00	33.80	2	G	V	-98.8121	38.3627	-43395.	166106.	3.04	45.13	4	46	1
BT0019-00	19	14W	26	CBDB	1200.00	160.00	3	G	V	-98.8450	38.3667	-46249.	166573.	1.71	43.92	2	44	1
BT0005-00	19	14W	32	DABB	750.00	105.00	3	G	V	-98.8887	38.3540	-50059.	165185.	0.92	41.52	1	42	0
008764-IR	20	14W	9	DCC	570.00	12.00	3	G	V	-98.8741	38.3190	-48815.	161268.	3.31	40.62	4	41	1
BT0021-00	20	15W	35	ACBB	800.00	67.00	3	G	V	-98.9484	38.2717	-55306.	156025.	3.38	35.43	4	36	1
BT0022-00	20	15W	35	CBBB	1400.00	93.00	3	G	V	-98.9576	38.2681	-56110.	155629.	3.26	34.88	4	35	1
PN0082-00	21	15W	5	CBCC	800.00	45.00	3	G	V	-99.0038	38.2512	-60147.	153771.	2.62	32.20	3	33	1
PN0002-00	21	15W	18	DCDC	1000.00	105.00	3	G	V	-99.0102	38.2186	-60728.	150140.	4.16	30.51	5	31	1
018530-RE	21	15W	28	DAA	0.00	30.00	5	G	V	-98.9685	38.1956	-57117.	147546.	6.82	31.28	7	32	1
018530-IR	21	15W	28	DAA	1500.00	180.00	3	G	V	-98.9685	38.1956	-57117.	147546.	6.82	31.28	7	32	1
PN0003-00	21	16W	15	ACAC	400.00	20.00	3	G	V	-99.0650	38.2274	-65487.	151166.	1.83	28.58	2	29	1
PN0004-00	21	16W	26	CBDB	1200.00	75.00	3	G	V	-99.0558	38.1939	-64716.	147420.	3.96	27.52	4	28	1
PN0005-00	21	16W	27	ABDA	1000.00	82.00	3	G	V	-99.0638	38.2012	-65409.	148234.	3.29	27.49	4	28	1
PN0006-00	21	16W	27	BADC	1500.00	45.00	3	G	V	-99.0694	38.2002	-65901.	148135.	3.15	27.21	4	28	1
PN0007-00	21	16W	33	BCA	600.00	22.00	3	G	V	-99.0918	38.1843	-67864.	146374.	3.26	25.58	4	26	1
PN0001-00	21	16W	33	CDDB	1000.00	300.00	4	G	V	-99.0878	38.1757	-67524.	145409.	3.86	25.37	4	26	1
033973-B	22	15W	33	AACB	300.00	72.00	3	G	V	-98.9713	38.0997	-57437.	136845.	11.92	27.00	12	28	0
PN0045-00	22	16W	3	BBDC	1700.00	225.00	3	G	V	-99.0740	38.1712	-66323.	144894.	4.57	25.76	5	26	1
PN0046-00	22	16W	3	CBCD	400.00	20.00	3	G	V	-99.0751	38.1639	-66425.	144084.	4.93	25.40	5	26	1
PN0047-00	22	16W	4	BAA	1000.00	40.00	3	G	V	-99.0872	38.1734	-67476.	145156.	4.00	25.30	5	26	1
PN0050-00	22	16W	6	BBDA	1750.00	127.00	3	G	V	-99.1275	38.1721	-70985.	145034.	2.71	23.54	3	24	1
PN0081-00	22	16W	8	BBCA	60.00	15.34	2	G	V	-99.1118	38.1576	-69633.	143404.	4.03	23.57	5	24	1
PN0052-00	22	16W	23	AAAB	500.00	40.00	3	G	V	-99.0417	38.1305	-63547.	140335.	7.87	25.36	8	26	1
016111-IN	22	16W	27	BCD	770.00	39.98	2	G	V	-99.0733	38.1099	-66317.	138053.	7.91	23.13	8	24	1
PN0079-00	22	16W	29	ADD	150.00	20.00	3	G	V	-99.0963	38.1098	-68324.	138057.	7.14	22.15	8	23	1
PN0076-00	22	17W	2	DCA	500.00	377.47	4	G	V	-99.1555	38.1626	-73429.	143996.	2.28	21.94	3	22	1
PN0054-00	22	17W	12	CCDA	1000.00	50.00	3	G	V	-99.1459	38.1467	-72610.	142214.	3.46	21.66	4	22	1
PN0055-00	22	17W	18	AADA	900.00	100.00	3	G	V	-99.2235	38.1429	-79378.	141857.	1.03	18.21	2	19	0

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Appendix 1. Well data (cont)

(a)					(b)	(c)	(d)		(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section					Rate (gpm)	Approp (ac-ft)	Use code		Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
PN0072-00	23	16W	12	BDC	1000.00	210.00	3	G	V	-99.0342	38.0664	-62954.	133170.	11.59	22.89	12	23	1
PN0073-00	23	18W	36	DACC	1200.00	184.00	3	G	V	-99.2444	38.0041	-81352.	126382.	7.83	11.29	8	12	1
ED0006-00	24	17W	16	CCC	1200.00	45.00	3	G	V	-99.2039	37.9570	-77871.	121092.	11.75	10.95	12	11	1
ED0008-00	24	17W	20	ADCC	1600.00	45.00	3	G	V	-99.2090	37.9493	-78330.	120235.	11.99	10.40	12	11	1
ED0002-00	24	18W	25	CACB	650.00	46.03	4	G	V	-99.2538	37.9322	-82260.	118372.	11.39	7.76	12	8	1
ED0010-00	24	19W	22	DCA	1150.00	210.00	3	G	V	-99.3922	37.9453	-94336.	119963.	5.97	2.47	6	3	1
ED0011-00	24	19W	28	CCB	50.00	30.00	3	G	V	-99.4217	37.9306	-96936.	118362.	5.75	0.59	6	1	0
ED0026-00	24	19W	29	DCA	700.00	100.00	3	G	V	-99.4286	37.9306	-97534.	118369.	5.52	0.30	6	1	0
ED0003-00	24	19W	33	DCAD	1200.00	368.26	4	G	V	-99.4098	37.9158	-95917.	116690.	6.96	0.44	7	1	0
ED0013-00	24	19W	34	CCB	800.00	58.00	3	G	V	-99.4036	37.9162	-95367.	116733.	7.15	0.73	8	1	0
ED0016-00	24	19W	35	BDDB	1200.00	45.00	3	G	V	-99.3790	37.9220	-93216.	117351.	7.67	2.02	8	3	1
000294-00	19	14W	22	ACB	1000.00	170.50	3	G	A49	-98.8561	38.3862	-47203.	168753.	0.28	44.29	1	45	0
000288-00	19	14W	23	BBCA	1700.00	300.00	3	G	A49	-98.8464	38.3884	-46356.	169000.	0.49	44.80	1	45	0
000298-00	19	14W	24	CCB	1346.00	105.00	3	G	A49	-98.8286	38.3789	-44818.	167926.	1.60	45.14	2	46	1
000291-00	19	14W	36	CBC	1600.00	120.00	3	G	A49	-98.8281	38.3517	-44792.	164896.	3.09	43.98	4	44	1
000378-00	20	14W	5	CCBC	1300.00	120.00	3	G	A49	-98.9024	38.3348	-51258.	163049.	1.50	40.11	2	41	1
000588-05	21	15W	17	BADA	75.00	25.19	1	G	A50	-98.9957	38.2305	-59453.	151462.	4.01	31.65	5	32	1
001096-00	24	18W	28	DDBB	980.00	360.00	3	G	A53	-99.2995	37.9307	-86252.	118249.	9.91	5.76	10	6	1
001623-00	19	13W	28	DCCA	570.00	250.00	4	G	A54	-98.7628	38.3631	-39116.	166135.	4.67	47.23	5	48	0
001751-00	19	13W	30	DCBD	550.00	340.00	4	G	A54	-98.7999	38.3641	-42339.	166259.	3.37	45.70	4	46	1
001194-00	20	13W	17	ABCB	920.00	120.00	3	G	A54	-98.7827	38.3166	-40867.	160957.	6.52	44.38	7	45	1
002065-00	23	16W	31	DBBB	510.00	71.00	3	G	A54	-99.1221	38.0067	-70680.	126574.	11.84	16.58	12	17	1
001437-00	24	18W	12	CDBB	731.00	320.00	3	G	A54	-99.2535	37.9741	-82183.	123050.	9.14	9.60	10	10	1
003170-00	19	14W	36	DCAB	1000.00	190.00	3	G	A55	-98.8171	38.3504	-43841.	164743.	3.53	44.39	4	45	1
002872-00	21	16W	33	CDA	800.00	182.00	4	G	A55	-99.0872	38.1771	-67472.	145561.	3.81	25.46	4	26	1
003078-00	24	18W	10	ADAB	850.00	446.00	3	G	A55	-99.2786	37.9815	-84370.	123898.	7.88	8.86	8	9	1
002341-00	25	18W	18	DABB	745.00	288.00	3	G	A55	-99.3358	37.8760	-89494.	112173.	11.63	1.84	12	2	-1
004319-00	19	13W	20	BCC	1400.00	127.00	3	G	A56	-98.7915	38.3845	-41595.	168532.	2.54	46.94	3	47	-1
003726-00	20	14W	24	CACC	820.00	240.00	3	G	A56	-98.8241	38.2941	-44483.	158460.	6.35	41.65	7	42	1
003426-00	22	15W	11	ABC	920.00	222.00	3	G	A56	-98.9385	38.1573	-54536.	143252.	9.91	30.89	10	31	1
003425-00	22	15W	11	BDB	1000.00	83.00	3	G	A56	-98.9431	38.1555	-54935.	143055.	9.85	30.62	10	31	1
004615-00	22	16W	6	CCC	1305.00	240.00	3	G	A56	-99.1303	38.1607	-71240.	143772.	3.23	22.93	4	23	1
003430-00	22	17W	18	AADA	30.00	60.00	3	G	A56	-99.2235	38.1429	-79378.	141857.	1.03	18.21	2	19	0
003664-00	23	16W	16	BAB	85.00	12.00	3	G	A56	-99.0895	38.0571	-67785.	132179.	10.22	20.15	11	21	1
003401-00	23	18W	12	BDBB	325.00	22.00	3	G	A56	-99.2535	38.0685	-82074.	133581.	4.04	13.71	5	14	1

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Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code		(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
003326-00	25	18W	3	ADBB	975.00	240.00	3	G	A56	-99.2814	37.9087	-84696.	115778.	11.72	5.57	12	6	1
005246-00	19	13W	20	BBD	538.00	109.00	3	G	A57	-98.7893	38.3881	-41405.	168932.	2.42	47.19	3	48	0
005106-00	19	13W	20	CCB	1056.00	66.00	3	G	A57	-98.7913	38.3791	-41582.	167928.	2.84	46.72	3	47	-1
005699-00	19	13W	28	CDAA	500.00	214.00	4	G	A57	-98.7652	38.3649	-39318.	166340.	4.49	47.21	5	48	0
005062-00	19	13W	29	DCC	500.00	705.00	4	G	A57	-98.7819	38.3627	-40777.	166099.	4.05	46.41	5	47	-1
005899-00	19	14W	13	BADB	280.00	105.00	3	G	A57	-98.8221	38.4030	-44237.	170610.	0.51	46.45	1	47	0
006338-00	19	14W	25	ACAD	200.00	33.00	3	G	A57	-98.8163	38.3712	-43759.	167066.	2.43	45.32	3	46	1
005085-00	19	14W	25	BBBC	1065.00	114.00	3	G	A57	-98.8291	38.3748	-44869.	167471.	1.80	44.93	2	45	1
005105-00	19	14W	33	BDD	990.00	82.00	3	G	A57	-98.8765	38.3554	-49000.	165329.	1.26	42.09	2	43	1
005145-00	20	13W	2	BCBC	605.00	63.00	3	G	A57	-98.7365	38.3425	-36839.	163821.	6.67	47.45	7	48	0
006204-00	20	13W	30	CAB	800.00	120.00	3	G	A57	-98.8052	38.2818	-42844.	157081.	7.65	41.92	8	42	1
005093-00	20	14W	15	ACBC	1140.00	190.00	3	G	A57	-98.8563	38.3135	-47265.	160644.	4.21	41.14	5	42	1
005537-00	20	15W	33	ADDB	500.00	47.00	3	G	A57	-98.9783	38.2699	-57910.	155846.	2.46	34.09	3	35	1
005294-00	20	15W	34	DCB	415.00	81.00	3	G	A57	-98.9662	38.2640	-56866.	155181.	3.19	34.34	4	35	1
006460-00	21	13W	23	DBBB	2500.00	240.00	3	G	A57	-98.7196	38.2092	-35435.	148945.	14.47	42.41	15	43	0
005428-00	21	15W	17	CDCD	860.00	315.00	3	G	A57	-98.9978	38.2187	-59651.	150143.	4.58	31.04	5	32	1
006233-00	21	16W	10	DCDA	396.00	60.00	3	G	A57	-99.0639	38.2338	-65385.	151871.	1.53	28.90	2	29	1
005905-00	22	15W	19	DCDC	1090.00	135.00	3	G	A57	-99.0100	38.1170	-60796.	138797.	9.67	26.11	10	27	1
005017-00	22	17W	4	BDBC	995.00	160.00	3	G	A57	-99.1995	38.1693	-77255.	144780.	0.42	20.37	1	21	0
005704-00	22	17W	11	BCC	2000.00	490.00	3	G	A57	-99.1664	38.1536	-74391.	143003.	2.39	21.09	3	22	1
006363-00	23	18W	11	ACDB	1000.00	160.00	3	G	A57	-99.2650	38.0668	-83078.	133398.	3.74	13.15	4	14	1
006360-00	23	18W	21	CBDC	119.00	22.00	3	G	A57	-99.3108	38.0336	-87116.	129735.	3.98	9.76	4	10	1
006530-00	24	18W	34	CAD	1345.00	317.00	3	G	A57	-99.2876	37.9174	-85229.	116755.	11.04	5.69	12	6	1
006437-00	25	18W	2	CAA	1200.00	240.00	3	G	A57	-99.2694	37.9046	-83654.	115303.	12.35	5.90	13	6	1
006438-00	25	18W	4	BDBB	890.00	196.00	3	G	A57	-99.3086	37.9089	-87078.	115819.	10.78	4.42	11	5	1
007322-00	21	13W	5	CBDC	570.00	117.00	3	G	A58	-98.7816	38.2507	-40815.	153600.	10.13	41.58	11	42	1
007286-00	22	15W	25	ADBB	1180.00	213.00	3	G	A58	-98.9164	38.1124	-52638.	138228.	13.09	29.88	14	30	0
007430-00	22	17W	15	DDB	6000.00	1040.00	3	G	A58	-99.1714	38.1336	-74851.	140770.	3.31	20.01	4	21	1
006817-00	22	17W	27	BACB	660.00	86.00	3	G	A58	-99.1811	38.1139	-75715.	138587.	4.04	18.74	5	19	1
007564-00	23	16W	2	DACB	800.00	240.00	3	G	A58	-99.0440	38.0778	-63795.	134447.	10.64	22.97	11	23	1
006819-00	23	17W	33	CACC	830.00	136.00	3	G	A58	-99.1997	38.0039	-77458.	126323.	9.36	13.17	10	14	1
007004-00	24	18W	35	CCB	1005.00	360.00	3	G	A58	-99.2762	37.9155	-84236.	116533.	11.53	6.09	12	7	1
006984-00	24	19W	35	DBD	210.00	16.00	3	G	A58	-99.3740	37.9178	-92779.	116884.	8.07	2.05	9	3	1
007399-00	25	18W	1	AABC	1000.00	240.00	3	G	A58	-99.2447	37.9114	-81487.	116037.	12.83	7.24	13	8	1
007111-00	25	18W	7	ADBB	1000.00	178.00	3	G	A58	-99.3358	37.8942	-89474.	114208.	10.65	2.63	11	3	1

[redacted]

Appendix 1. Well data (cont)

(a)	(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section	Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
006631-00 25 18W 20 BDBB	680.00	115.00	3	G A58	-99.3267	37.8650	-88711.	110937.	12.54	1.75	13	2	-1
006619-00 25 18W 28 DCAA	525.00	91.00	3	G A58	-99.3007	37.8431	-86469.	108470.	14.60	1.89	15	2	0
008032-00 21 13W 9 DBC	615.00	111.00	3	G A60	-98.7558	38.2365	-38573.	152001.	11.78	42.06	12	43	1
008054-00 23 18W 12 BDBB	0.00	38.00	3	G A60	-99.2535	38.0685	-82074.	133581.	4.04	13.71	5	14	1
008328-00 22 15W 22 DABC	275.00	119.00	3	G A61	-98.9529	38.1224	-55813.	139369.	11.31	28.77	12	29	0
008791-00 20 14W 6 CCDD	943.00	165.00	3	G A62	-98.9173	38.3330	-52558.	162856.	1.10	39.40	2	40	1
008705-00 21 16W 33 DBD	1200.00	120.00	3	G A62	-99.0826	38.1789	-67067.	145760.	3.86	25.73	4	26	1
009378-00 19 14W 28 AAAA	590.00	64.43	2	G A64	-98.8669	38.3758	-48152.	167600.	0.48	43.38	1	44	0
009342-00 20 14W 28 ADC	850.00	50.00	3	G A64	-98.8697	38.2838	-48452.	157334.	5.37	39.28	6	40	1
009119-00 20 15W 13 AADD	1160.00	240.00	3	G A64	-98.9219	38.3149	-52968.	160839.	1.93	38.42	2	39	0
009185-00 20 15W 36 AAC	470.00	111.00	3	G A64	-98.9248	38.2729	-53255.	156151.	4.10	36.48	5	37	1
009366-00 23 17W 32 BDBB	660.00	243.00	3	G A64	-99.2180	38.0103	-79042.	127059.	8.39	12.68	9	13	1
009455-00 25 18W 10 BCA	1040.00	328.00	3	G A64	-99.2921	37.8937	-85649.	114109.	12.17	4.46	13	5	1
009847-00 19 14W 23 BBCA	550.00	400.00	3	G A65	-98.8464	38.3884	-46356.	169000.	0.49	44.80	1	45	0
010539-00 19 14W 32 CABC	725.00	199.00	3	G A65	-98.8979	38.3531	-50859.	165088.	0.66	41.09	1	42	0
010470-00 21 13W 31 DCCB	655.00	31.00	3	G A65	-98.7930	38.1755	-41845.	145210.	13.83	37.84	14	38	0
009737-00 22 14W 16 BDBB	2500.00	378.00	3	G A65	-98.8708	38.1412	-48645.	141416.	13.07	33.06	14	34	0
010184-00 22 16W 7 DBD	675.00	104.00	3	G A65	-99.1191	38.1499	-70277.	142550.	4.20	22.93	5	23	1
009776-00 22 16W 16 DCAD	510.00	240.00	3	G A65	-99.0819	38.1330	-67053.	140643.	6.37	23.77	7	24	1
009901-00 25 18W 2 CAA	10.00	20.00	3	G A65	-99.2694	37.9046	-83654.	115303.	12.35	5.90	13	6	1
011297-00 19 14W 25 DDD	500.00	79.80	2	G A66	-98.8121	38.3627	-43395.	166106.	3.04	45.13	4	46	1
011492-00 21 13W 14 CBD	2500.00	237.00	3	G A66	-98.7258	38.2216	-35976.	150330.	13.59	42.68	14	43	0
010958-00 21 15W 3 ACDD	685.00	141.00	3	G A66	-98.9544	38.2547	-55839.	154136.	4.09	34.44	5	35	1
010855-00 21 15W 9 DDAB	987.00	120.00	3	G A66	-98.9692	38.2362	-57148.	152077.	4.59	33.01	5	34	1
011480-00 21 16W 22 ACCB	970.00	180.00	3	G A66	-99.0672	38.2120	-65695.	149449.	2.59	27.82	3	28	1
011339-00 21 16W 33 DBD	300.00	8.00	3	G A66	-99.0826	38.1789	-67067.	145760.	3.86	25.73	4	26	1
011340-00 21 16W 33 DBD	0.00	16.00	3	G A66	-99.0826	38.1789	-67067.	145760.	3.86	25.73	4	26	1
010782-00 24 17W 28 ADBB	1430.00	212.00	3	G A66	-99.1909	37.9374	-76754.	118900.	13.25	10.66	14	11	0
010952-00 25 19W 1 ACDA	851.00	181.98	4	G A66	-99.3552	37.9072	-91153.	115678.	9.28	2.38	10	3	1
012254-00 19 13W 19 ACB	1635.00	218.00	3	G A67	-98.8008	38.3863	-42401.	168735.	2.14	46.63	3	47	-1
011856-00 19 13W 33 CCDC	100.00	192.72	2	G A67	-98.7711	38.3479	-39846.	164437.	5.22	46.22	6	47	-1
012086-00 19 14W 24 CCB	820.00	93.00	3	G A67	-98.8286	38.3789	-44818.	167926.	1.60	45.14	2	46	1
011866-00 21 13W 1 BCB	390.00	86.00	3	G A67	-98.7094	38.2563	-34528.	154189.	12.26	44.87	13	45	1
012220-00 21 15W 7 DBB	1225.00	120.00	3	G A67	-99.0121	38.2390	-60874.	152416.	3.00	31.32	3	32	1
012409-00 21 15W 7 DCCB	1059.00	120.00	3	G A67	-99.0126	38.2340	-60924.	151859.	3.25	31.08	4	32	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
012410-00	21	15W	17	ABC	900.00	339.00	3	G	A67	-98.9939	38.2301	-59303.	151412.	4.09	31.70	5	32	1
011916-00	21	16W	15	BDC	1200.00	198.00	3	G	A67	-99.0712	38.2261	-66031.	151016.	1.70	28.26	2	29	1
012313-00	22	15W	26	ADAB	450.00	119.00	3	G	A67	-98.9322	38.1124	-54022.	138239.	12.55	29.21	13	30	0
012270-00	22	16W	26	BCDC	1045.00	219.00	3	G	A67	-99.0554	38.1095	-64762.	137999.	8.54	23.87	9	24	1
011601-00	22	16W	28	CCA	1370.00	264.00	3	G	A67	-99.0917	38.1044	-67928.	137450.	7.59	22.11	8	23	1
012143-00	23	16W	23	ACA	1000.00	227.00	3	G	A67	-99.0458	38.0392	-63983.	130145.	12.67	21.23	13	22	0
012212-00	24	19W	35	BDDB	400.00	115.00	3	G	A67	-99.3790	37.9220	-93216.	117351.	7.67	2.02	8	3	1
012841-00	19	14W	21	DDCD	575.00	91.00	3	G	A68	-98.8693	38.3767	-48353.	167702.	0.35	43.32	1	44	0
013357-00	19	14W	24	BBD	1235.00	77.00	3	G	A68	-98.8262	38.3880	-44604.	168941.	1.19	45.63	2	46	1
013321-00	19	14W	28	ACA	1570.00	233.00	3	G	A68	-98.8721	38.3717	-48602.	167146.	0.53	42.99	1	43	0
013061-00	20	13W	20	BCDD	965.00	219.00	3	G	A68	-98.7885	38.2976	-41387.	158836.	7.36	43.31	8	44	1
013420-00	20	14W	2	DBAC	1035.00	98.00	3	G	A68	-98.8353	38.3386	-45430.	163427.	3.56	43.10	4	44	1
012689-00	20	14W	17	BBD	1000.00	239.00	3	G	A68	-98.8995	38.3153	-51024.	160871.	2.66	39.39	3	40	1
013299-00	20	14W	22	DCBC	1435.00	84.00	3	G	A68	-98.8563	38.2924	-47283.	158289.	5.36	40.22	6	41	1
014050-00	20	14W	23	ADBB	850.00	221.00	3	G	A68	-98.8333	38.3005	-45277.	159176.	5.70	41.54	6	42	1
013246-00	21	14W	32	ADBB	1215.00	180.00	3	G	A68	-98.8800	38.1848	-49420.	146292.	10.39	34.56	11	35	1
013965-00	21	15W	5	ADC	1050.00	149.00	3	G	A68	-98.9895	38.2552	-58894.	154210.	2.88	32.98	3	33	1
013518-00	22	13W	5	CBC	400.00	40.00	5	G	A68	-98.7834	38.1641	-41015.	143937.	14.77	37.76	15	38	0
013554-00	22	14W	6	DCAA	975.00	221.00	3	G	A68	-98.8993	38.1631	-51116.	143880.	10.92	32.80	11	33	1
013553-00	22	14W	7	ADBB	905.00	214.00	3	G	A68	-98.8982	38.1558	-51024.	143066.	11.35	32.53	12	33	0
013260-00	22	14W	15	DDBC	610.00	150.00	3	G	A68	-98.8432	38.1328	-46246.	140472.	14.45	33.87	15	34	0
012946-00	22	15W	17	BDC	1740.00	207.00	3	G	A68	-98.9982	38.1392	-59752.	141274.	8.87	27.58	9	28	1
013084-00	22	15W	17	DCBB	1700.00	176.00	3	G	A68	-98.9942	38.1342	-59409.	140714.	9.27	27.53	10	28	1
012780-00	22	16W	33	CDBD	1260.00	180.00	3	G	A68	-99.0889	38.0894	-67697.	135780.	8.49	21.58	9	22	1
014251-00	23	17W	10	CADC	600.00	77.00	3	G	A68	-99.1791	38.0621	-75598.	132797.	6.91	16.57	7	17	1
012910-00	23	18W	18	ADDD	745.00	196.00	3	G	A68	-99.3327	38.0518	-89002.	131794.	2.24	9.63	3	10	0
013828-00	24	17W	31	DDBB	960.00	196.00	3	G	A68	-99.2272	37.9158	-79954.	116517.	13.18	8.17	14	9	0
014678-00	20	13W	24	DCBB	4000.00	240.00	3	G	A69	-98.7090	38.2931	-34478.	158304.	10.27	46.48	11	47	-1
014594-00	20	14W	16	DABB	2000.00	168.00	3	G	A69	-98.8701	38.3108	-48469.	160348.	3.90	40.43	4	41	1
015699-00	20	14W	17	DDBC	705.00	78.00	3	G	A69	-98.8886	38.3056	-50080.	159779.	3.55	39.43	4	40	1
015155-00	20	14W	30	ACAB	545.00	93.00	3	G	A69	-98.9093	38.2852	-51898.	157512.	3.96	37.67	4	38	1
015937-00	20	15W	12	DAD	900.00	90.00	3	G	A69	-98.9225	38.3227	-53014.	161704.	1.49	38.74	2	39	0
015811-00	20	15W	13	DDBA	835.00	216.00	3	G	A69	-98.9241	38.3069	-53172.	159947.	2.28	37.98	3	38	1
015969-00	20	15W	25	ADBC	1420.00	177.00	3	G	A69	-98.9253	38.2846	-53292.	157459.	3.45	36.96	4	37	1
014619-00	21	13W	27	CDBC	800.00	120.00	3	G	A69	-98.7427	38.1904	-37457.	146854.	14.72	40.62	15	41	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
014911-00	21	15W	5	CBCC	1300.00	99.00	3	G A69	-99.0038	38.2512	-60147.	153771.	2.62	32.20	3	33	1
015561-00	21	15W	18	CCBB	690.00	137.00	3	G A69	-99.0213	38.2212	-61692.	150444.	3.64	30.16	4	31	1
014348-00	21	15W	18	DCDC	170.00	48.00	3	G A69	-99.0102	38.2186	-60728.	150140.	4.16	30.51	5	31	1
015245-00	21	15W	34	ADBB	945.00	195.00	3	G A69	-98.9529	38.1850	-55766.	146358.	7.92	31.48	8	32	1
014973-00	21	15W	34	BDBB	900.00	240.00	3	G A69	-98.9621	38.1851	-56570.	146371.	7.60	31.09	8	32	1
015470-00	21	16W	2	DCCC	100.00	26.00	3	G A69	-99.0490	38.2473	-64083.	153376.	1.29	30.12	2	31	1
015773-00	21	16W	10	DDDC	0.00	31.00	3	G A69	-99.0604	38.2329	-65088.	151770.	1.69	29.01	2	30	1
015087-00	21	16W	13	CCDC	620.00	198.00	3	G A69	-99.0373	38.2184	-63085.	150142.	3.26	29.36	4	30	1
014442-00	22	14W	29	BABB	1195.00	117.00	3	G A69	-98.8891	38.1159	-50262.	138609.	13.82	31.19	14	32	0
015802-00	22	15W	9	CCAA	1660.00	240.00	3	G A69	-98.9816	38.1487	-58295.	142325.	8.91	28.69	9	29	1
014633-00	22	15W	20	CDCC	1895.00	240.00	3	G A69	-98.9988	38.1170	-59817.	138794.	10.05	26.59	11	27	1
015053-00	22	15W	27	CBBB	200.00	66.00	3	G A69	-98.9666	38.1088	-57022.	137861.	11.58	27.60	12	28	0
014674-00	22	15W	29	ACA	1665.00	240.00	3	G A69	-98.9913	38.1120	-59169.	138232.	10.58	26.69	11	27	1
015782-00	22	16W	2	DDBB	1700.00	240.00	3	G A69	-99.0440	38.1632	-63721.	143987.	6.02	26.68	7	27	1
014407-00	22	16W	9	BDBC	1065.00	218.00	3	G A69	-99.0900	38.1549	-67736.	143087.	4.91	24.37	5	25	1
015919-00	22	16W	13	AAAB	580.00	29.00	3	G A69	-99.0234	38.1451	-61937.	141952.	7.70	26.77	8	27	1
015924-00	22	16W	14	AAAB	800.00	126.00	3	G A69	-99.0417	38.1450	-63536.	141951.	7.08	25.99	8	26	1
014697-00	22	16W	19	BBDA	435.00	85.00	3	G A69	-99.1275	38.1284	-71030.	140159.	5.07	21.64	6	22	1
015287-00	22	17W	1	ACDB	635.00	111.00	3	G A69	-99.1378	38.1684	-71880.	144636.	2.56	22.95	3	23	1
015217-00	22	17W	12	ABB	1250.00	300.00	3	G A69	-99.1395	38.1589	-72046.	143577.	3.01	22.46	4	23	1
014690-00	22	17W	12	CBB	780.00	168.00	3	G A69	-99.1488	38.1517	-72856.	142775.	3.09	21.75	4	22	1
015530-00	22	17W	14	CDA	900.00	213.00	3	G A69	-99.1601	38.1335	-73860.	140758.	3.69	20.48	4	21	1
015225-00	22	17W	16	BACC	600.00	211.00	3	G A69	-99.1993	38.1420	-77274.	141740.	1.90	19.19	2	20	0
015226-00	22	17W	17	BAAD	675.00	221.00	3	G A69	-99.2143	38.1438	-78577.	141952.	1.30	18.64	2	19	0
015685-00	23	16W	35	ADBB	2500.00	473.00	3	G A69	-99.0441	38.0106	-63865.	126951.	14.28	20.05	15	21	0
014321-00	23	18W	29	BACC	1300.00	338.00	3	G A69	-99.3269	38.0265	-88528.	128962.	3.81	8.78	4	9	1
014574-00	24	17W	1	CBCC	1505.00	225.00	3	G A69	-99.1497	37.9892	-73106.	124643.	11.85	14.65	12	15	1
015293-00	24	17W	10	BDBB	788.00	166.00	3	G A69	-99.1816	37.9809	-75901.	123748.	11.21	12.94	12	13	1
014575-00	24	17W	12	ABDD	925.00	174.00	3	G A69	-99.1371	37.9820	-72012.	123832.	12.66	14.87	13	15	1
015405-00	24	18W	14	ABCC	1110.00	205.00	3	G A69	-99.2672	37.9679	-83389.	122368.	9.00	8.75	10	9	1
016073-00	19	14W	14	DCAB	800.00	98.00	3	G A70	-98.8360	38.3939	-45451.	169603.	0.54	45.47	1	46	0
016718-00	19	14W	26	ABB	1720.00	174.00	3	G A70	-98.8377	38.3753	-45614.	167527.	1.49	44.59	2	45	1
016596-00	19	14W	27	BBDD	1035.00	234.00	3	G A70	-98.8623	38.3731	-47750.	167293.	0.78	43.46	1	44	0
016765-00	19	14W	32	BACC	845.00	173.00	3	G A70	-98.8980	38.3586	-50861.	165693.	0.37	41.32	1	42	0
016747-00	20	12W	30	BCAA	780.00	182.00	3	G A70	-98.6963	38.2858	-33372.	157485.	11.10	46.71	12	47	-1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
016598-00 20 13W 17 DDCC	1500.00	201.00	3	G A70	-98.7781	38.3048	-40478.	159631.	7.32	44.06	8	45	1
016599-00 20 13W 19 BCDC	1000.00	102.00	3	G A70	-98.8080	38.2977	-43080.	158853.	6.70	42.49	7	43	1
016839-00 20 15W 26 CCCC	385.00	47.00	3	G A70	-98.9575	38.2762	-56096.	156537.	2.82	35.24	3	36	1
016833-00 21 14W 1 ACAA	900.00	221.00	3	G A70	-98.8077	38.2571	-43076.	154320.	8.91	40.75	9	41	1
016032-00 22 14W 9 BCAC	1200.00	222.00	3	G A70	-98.8731	38.1548	-48838.	142938.	12.25	33.55	13	34	0
016594-00 22 14W 22 BAD	44.00	47.20	2	G A70	-98.8495	38.1279	-46796.	139924.	14.51	33.39	15	34	0
016276-00 22 15W 13 ADBB	900.00	240.00	3	G A70	-98.9163	38.1414	-52608.	141468.	11.52	31.14	12	32	0
016600-00 22 15W 13 DDBB	900.00	240.00	3	G A70	-98.9163	38.1341	-52619.	140658.	11.91	30.83	12	31	0
016238-00 22 15W 32 CDB	1200.00	236.00	3	G A70	-98.9982	38.0901	-59793.	135794.	11.53	25.45	12	26	1
016237-00 22 15W 32 DBD	1200.00	240.00	3	G A70	-98.9913	38.0919	-59191.	135995.	11.66	25.82	12	26	1
016013-00 22 16W 13 CCAA	1005.00	185.00	3	G A70	-99.0360	38.1342	-63044.	140738.	7.86	25.76	8	26	1
016020-00 22 16W 16 CDA	470.00	65.00	3	G A70	-99.0871	38.1335	-67503.	140697.	6.17	23.57	7	24	1
016668-00 22 16W 21 CACC	690.00	197.00	3	G A70	-99.0900	38.1202	-67764.	139220.	6.79	22.87	7	23	1
016117-00 22 16W 26 CDBB	1000.00	240.00	3	G A70	-99.0531	38.1050	-64566.	137491.	8.86	23.77	9	24	1
016125-00 22 16W 28 DAAB	800.00	195.00	3	G A70	-99.0784	38.1085	-66770.	137901.	7.81	22.85	8	23	1
016734-00 22 17W 1 DCAB	810.00	140.00	3	G A70	-99.1378	38.1630	-71889.	144030.	2.85	22.71	3	23	1
016789-00 22 17W 24 CBCC	905.00	272.00	3	G A70	-99.1492	38.1203	-72927.	139268.	4.78	20.37	5	21	1
016790-00 22 17W 25 BACC	895.00	224.00	3	G A70	-99.1446	38.1130	-72536.	138450.	5.33	20.24	6	21	1
016844-00 23 16W 24 CDBB	1200.00	240.00	3	G A70	-99.0348	38.0324	-63035.	129376.	13.41	21.39	14	22	0
016355-00 23 16W 25 ADBB	4800.00	960.00	3	G A70	-99.0256	38.0251	-62238.	128562.	14.12	21.47	15	22	0
016335-00 23 16W 35 BDBB	1100.00	233.00	3	G A70	-99.0533	38.0106	-64668.	126958.	13.96	19.66	14	20	0
016334-00 23 16W 35 CDBB	1100.00	240.00	3	G A70	-99.0533	38.0033	-64675.	126149.	14.36	19.35	15	20	0
016756-00 24 17W 28 BDBB	585.00	237.00	3	G A70	-99.2000	37.9374	-77551.	118906.	12.94	10.27	13	11	1
016105-00 24 18W 35 BDBB	975.00	189.00	3	G A70	-99.2721	37.9232	-83871.	117387.	11.25	6.60	12	7	1
016205-00 25 18W 13 BDBB	860.00	221.00	3	G A70	-99.2538	37.8795	-82319.	112495.	14.24	5.47	15	6	0
017294-00 19 13W 18 ACA	2000.00	504.06	6	G A71	-98.7986	38.4007	-42201.	170350.	1.42	47.35	2	48	0
016896-00 19 14W 25 ACAD	0.00	51.00	3	G A71	-98.8163	38.3712	-43759.	167066.	2.43	45.32	3	46	1
017162-00 20 13W 21 DCAD	550.00	107.00	3	G A71	-98.7609	38.2922	-38985.	158222.	8.58	44.25	9	45	1
017113-00 20 14W 6 AACC	1060.00	221.00	3	G A71	-98.9070	38.3440	-51655.	164077.	0.85	40.31	1	41	0
017300-00 20 14W 9 ABDD	1800.00	233.00	3	G A71	-98.8711	38.3295	-48544.	162437.	2.85	41.20	3	42	1
017369-00 20 14W 23 BCAA	1000.00	240.00	3	G A71	-98.8436	38.3006	-46174.	159192.	5.34	41.11	6	42	1
017535-00 20 15W 24 DDCB	1500.00	180.00	3	G A71	-98.9253	38.2907	-53285.	158136.	3.12	37.23	4	38	1
017493-00 21 15W 9 DCAB	1125.00	120.00	3	G A71	-98.9738	38.2361	-57549.	152076.	4.44	32.81	5	33	1
017706-00 21 15W 31 ADBB	800.00	206.00	3	G A71	-99.0079	38.1852	-60554.	146409.	6.05	29.16	7	30	1
017001-00 21 16W 15 ACAC	350.00	104.00	3	G A71	-99.0650	38.2274	-65487.	151166.	1.83	28.58	2	29	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code		(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
017707-00	21	16W	23	ABDD	1065.00	150.00	3	G	A71	-99.0453	38.2148	-63790.	149741.	3.18	28.86	4	29	1
017083-00	21	16W	25	BCAA	920.00	221.00	3	G	A71	-99.0361	38.1994	-62997.	148014.	4.33	28.59	5	29	1
017084-00	21	16W	26	DDBB	860.00	213.00	3	G	A71	-99.0442	38.1921	-63708.	147205.	4.45	27.93	5	28	1
017122-00	21	16W	27	CDDD	100.00	14.00	3	G	A71	-99.0683	38.1894	-65810.	146920.	3.78	26.79	4	27	1
017018-00	22	15W	3	BCB	1600.00	224.00	3	G	A71	-98.9660	38.1701	-56916.	144698.	8.29	30.28	9	31	1
016899-00	22	15W	8	DACC	1350.00	159.00	3	G	A71	-98.9896	38.1497	-58992.	142433.	8.59	28.39	9	29	1
017129-00	22	15W	10	ADBB	2000.00	233.00	3	G	A71	-98.9528	38.1560	-55782.	143116.	9.49	30.23	10	31	1
017017-00	22	15W	36	BDBB	1600.00	240.00	3	G	A71	-98.9256	38.0979	-53452.	136617.	13.56	28.86	14	29	0
016948-00	22	16W	4	BBDC	700.00	107.00	3	G	A71	-99.0924	38.1712	-67929.	144907.	3.95	24.98	4	25	1
016977-00	22	16W	10	DDAA	540.00	188.00	3	G	A71	-99.0590	38.1486	-65041.	142363.	6.30	25.41	7	26	1
017671-00	22	16W	12	CACC	880.00	215.00	3	G	A71	-99.0348	38.1496	-62932.	142459.	7.07	26.48	8	27	1
016978-00	22	16W	22	DDAA	645.00	217.00	3	G	A71	-99.0589	38.1195	-65053.	139117.	7.88	24.16	8	25	1
016962-00	22	16W	23	CBBB	2000.00	480.00	3	G	A71	-99.0577	38.1232	-64952.	139524.	7.72	24.36	8	25	1
017410-00	22	16W	23	DCBB	1100.00	120.00	3	G	A71	-99.0485	38.1195	-64153.	139112.	8.23	24.59	9	25	1
017085-00	22	16W	25	DDBB	2000.00	414.00	3	G	A71	-99.0256	38.1051	-62164.	137481.	9.79	24.94	10	25	1
017091-00	22	16W	28	BCDD	720.00	187.00	3	G	A71	-99.0911	38.1093	-67874.	138005.	7.34	22.35	8	23	1
017125-00	22	16W	30	BBAC	750.00	47.00	3	G	A71	-99.1287	38.1148	-71141.	138642.	5.77	21.00	6	21	1
017140-00	23	15W	6	BDBB	800.00	140.00	3	G	A71	-99.0167	38.0832	-61408.	135039.	11.27	24.37	12	25	1
016892-00	23	16W	36	ADBB	1000.00	240.00	3	G	A71	-99.0257	38.0107	-62253.	126948.	14.90	20.84	15	21	0
017560-00	23	16W	36	CDBB	1500.00	240.00	3	G	A71	-99.0349	38.0034	-63070.	126141.	14.98	20.13	15	21	0
017455-00	25	17W	8	BDBB	840.00	216.00	3	G	A71	-99.2184	37.8940	-79209.	114075.	14.66	7.60	15	8	0
018540-00	20	13W	19	BCBA	1655.00	114.00	3	G	A72	-98.8091	38.3004	-43178.	159160.	6.51	42.56	7	43	1
018541-00	20	13W	19	CCBB	1590.00	238.00	3	G	A72	-98.8103	38.2931	-43283.	158346.	6.87	42.20	7	43	1
018200-00	20	14W	1	DBAB	600.00	50.00	3	G	A72	-98.8170	38.3395	-43835.	163520.	4.13	43.92	5	44	1
018490-00	20	14W	6	BADD	170.00	46.00	3	G	A72	-98.9127	38.3440	-52153.	164080.	0.66	40.07	1	41	0
018519-00	20	14W	8	DDBB	1270.00	234.00	3	G	A72	-98.8885	38.3212	-50066.	161521.	2.71	40.10	3	41	1
018517-00	20	14W	9	CABB	2142.00	309.00	3	G	A72	-98.8793	38.3249	-49257.	161923.	2.82	40.66	3	41	1
018599-00	20	14W	10	AAAC	940.00	77.00	3	G	A72	-98.8491	38.3314	-46632.	162631.	3.49	42.21	4	43	1
017906-00	20	14W	18	BDBB	785.00	224.00	3	G	A72	-98.9161	38.3140	-52470.	160731.	2.17	38.63	3	39	1
018352-00	20	14W	32	BDCB	895.00	194.00	3	G	A72	-98.9005	38.2697	-51145.	155779.	5.10	37.37	6	38	1
018148-00	20	14W	35	ADBA	1300.00	213.00	3	G	A72	-98.8322	38.2715	-45204.	155940.	7.30	40.33	8	41	1
018639-00	20	15W	24	DDCD	690.00	32.00	3	G	A72	-98.9242	38.2897	-53186.	158025.	3.22	37.23	4	38	1
018421-00	21	13W	13	ADBC	890.00	101.00	3	G	A72	-98.6964	38.2265	-33413.	150866.	14.31	44.14	15	45	0
018388-00	21	14W	32	BACC	1350.00	180.00	3	G	A72	-98.8892	38.1857	-50219.	146401.	10.03	34.21	11	35	1
018112-00	21	15W	4	ACAA	630.00	113.00	3	G	A72	-98.9728	38.2574	-57439.	154448.	3.33	33.78	4	34	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
018128-00	21	15W	6	DCBB	785.00	138.00	3	G A72	-99.0127	38.2502	-60916.	153671.	2.37	31.78	3	32	1
018362-00	21	15W	7	DBB	25.00	120.00	3	G A72	-99.0121	38.2390	-60874.	152416.	3.00	31.32	3	32	1
018305-00	21	15W	18	ADCB	485.00	120.00	3	G A72	-99.0081	38.2268	-60539.	151051.	3.79	30.96	4	31	1
018333-00	21	16W	23	BBCC	1040.00	165.00	3	G A72	-99.0582	38.2148	-64905.	149750.	2.75	28.32	3	29	1
018129-00	22	14W	14	CACC	900.00	195.00	3	G A72	-98.8340	38.1346	-45444.	140666.	14.67	34.33	15	35	0
018366-00	22	15W	6	BDBA	1040.00	151.00	3	G A72	-99.0155	38.1706	-61234.	144785.	6.58	28.20	7	29	1
018003-00	22	15W	13	CDBB	680.00	178.00	3	G A72	-98.9255	38.1342	-53418.	140665.	11.60	30.44	12	31	0
018611-00	22	15W	16	BDBB	1420.00	225.00	3	G A72	-98.9805	38.1415	-58204.	141513.	9.35	28.43	10	29	1
017839-00	22	15W	26	BAD	1500.00	240.00	3	G A72	-98.9408	38.1138	-54766.	138397.	12.19	28.91	13	29	0
018548-00	22	16W	20	DCCC	860.00	189.00	3	G A72	-99.1037	38.1166	-68965.	138824.	6.52	22.13	7	23	1
018061-00	22	16W	33	DACA	740.00	195.00	3	G A72	-99.0797	38.0922	-66892.	136081.	8.66	22.09	9	23	1
018550-00	22	17W	5	DADA	1256.00	301.00	3	G A72	-99.2052	38.1647	-77756.	144277.	0.48	19.94	1	20	0
018669-00	23	15W	1	ABBB	780.00	221.00	3	G A72	-98.9211	38.0870	-53071.	135397.	14.30	28.58	15	29	0
018670-00	23	15W	1	BBDD	1000.00	214.00	3	G A72	-98.9268	38.0842	-53572.	135095.	14.26	28.22	15	29	0
017917-00	23	15W	8	DDBB	785.00	221.00	3	G A72	-98.9898	38.0615	-59078.	132594.	13.36	24.56	14	25	0
017901-00	23	15W	9	ADBB	1015.00	221.00	3	G A72	-98.9715	38.0687	-57481.	133392.	13.59	25.65	14	26	0
018304-00	23	15W	18	DDBB	1045.00	221.00	3	G A72	-99.0077	38.0470	-60657.	130985.	13.54	23.17	14	24	0
018671-00	23	15W	19	BABC	750.00	172.00	3	G A72	-99.0166	38.0424	-61436.	130482.	13.49	22.60	14	23	0
018119-00	23	16W	11	CCDC	350.00	82.00	3	G A72	-99.0555	38.0587	-64815.	132325.	11.29	21.66	12	22	1
018321-00	23	16W	26	CDBB	1000.00	240.00	3	G A72	-99.0533	38.0178	-64660.	127768.	13.57	19.98	14	20	0
018322-00	23	16W	36	BDBB	1200.00	240.00	3	G A72	-99.0349	38.0106	-63059.	126947.	14.59	20.45	15	21	0
018082-00	23	17W	32	CBDB	450.00	68.00	3	G A72	-99.2203	38.0048	-79254.	126448.	8.60	12.34	9	13	1
017820-00	24	17W	30	CDBB	1000.00	330.00	3	G A72	-99.2358	37.9303	-80689.	118138.	12.11	8.44	13	9	1
017817-00	24	17W	30	DABB	770.00	143.00	3	G A72	-99.2271	37.9339	-79925.	118536.	12.21	8.97	13	9	1
017726-00	25	17W	7	CDBB	730.00	185.00	3	G A72	-99.2359	37.8868	-80746.	113287.	14.45	6.54	15	7	0
017727-00	25	17W	7	DDBB	650.00	204.00	3	G A72	-99.2273	37.8868	-79996.	113280.	14.75	6.91	15	7	0
017728-00	25	17W	18	BDBB	870.00	166.00	3	G A72	-99.2359	37.8795	-80757.	112479.	14.84	6.23	15	7	0
019611-00	19	14W	13	DABC	1038.00	240.00	3	G A73	-98.8151	38.3966	-43641.	169901.	1.09	46.47	2	47	-1
019083-00	19	14W	24	DCBD	715.00	28.00	3	G A73	-98.8187	38.3785	-43964.	167875.	1.95	45.53	2	46	1
019612-00	19	14W	31	AADD	1110.00	85.20	3	G A73	-98.9037	38.3586	-51361.	165696.	0.17	41.08	1	42	0
019251-00	19	14W	35	DCBB	2000.00	195.00	3	G A73	-98.8378	38.3504	-45641.	164749.	2.84	43.51	3	44	1
019670-00	20	13W	21	BCAA	1030.00	195.00	3	G A73	-98.7701	38.3003	-39780.	159126.	7.83	44.21	8	45	1
019747-00	20	14W	8	BBBB	830.00	165.00	3	G A73	-98.9023	38.3321	-51258.	162742.	1.65	39.99	2	40	1
019072-00	20	14W	25	BDBB	1800.00	240.00	3	G A73	-98.8241	38.2859	-44490.	157550.	6.79	41.30	7	42	1
019615-00	21	12W	5	DDBB	920.00	195.00	3	G A73	-98.6598	38.2495	-30217.	153414.	14.30	46.68	15	47	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
019801-00 21 14W 17 DDBB	820.00	195.00	3	G A73	-98.8801	38.2211	-49404.	150345.	8.42	36.13	9	37	1
019482-00 21 14W 21 ABCC	1295.00	192.00	3	G A73	-98.8662	38.2148	-48198.	149633.	9.23	36.44	10	37	1
019378-00 21 17W 36 CCC	500.00	27.92	4	G A73	-99.1487	38.1752	-72824.	145399.	1.83	22.78	2	23	1
019115-00 22 15W 3 DCDB	935.00	166.00	3	G A73	-98.9551	38.1614	-55975.	143725.	9.12	30.37	10	31	1
019427-00 22 15W 10 BACC	1140.00	206.00	3	G A73	-98.9620	38.1569	-56582.	143223.	9.13	29.88	10	30	1
019271-00 22 15W 18 ADBB	1120.00	228.00	3	G A73	-99.0078	38.1415	-60584.	141535.	8.42	27.27	9	28	1
019906-00 22 15W 28 BDBB	920.00	195.00	3	G A73	-98.9804	38.1125	-58217.	138278.	10.92	27.17	11	28	1
019443-00 22 15W 34 ADDD	715.00	175.00	3	G A73	-98.9496	38.0952	-55547.	136327.	12.90	27.73	13	28	0
019695-00 22 16W 20 CCAA	700.00	198.00	3	G A73	-99.1094	38.1193	-69461.	139135.	6.18	22.01	7	23	1
019570-00 22 16W 34 CBCD	505.00	166.00	3	G A73	-99.0751	38.0913	-66492.	135979.	8.86	22.24	9	23	1
019103-00 22 17W 3 DCCC	1530.00	122.00	3	G A73	-99.1763	38.1603	-75243.	143764.	1.69	20.97	2	21	0
019377-00 23 16W 2 BAAB	645.00	170.00	3	G A73	-99.0509	38.0868	-64390.	135466.	9.92	23.07	10	24	1
019168-00 23 16W 31 CBBB	975.00	184.00	3	G A73	-99.1313	38.0066	-71483.	126575.	11.53	16.19	12	17	1
019351-00 23 17W 25 DABB	965.00	185.00	3	G A73	-99.1358	38.0212	-71857.	128206.	10.59	16.63	11	17	1
019436-00 25 17W 5 CBDD	555.00	152.00	3	G A73	-99.2195	37.9021	-79297.	114986.	14.18	7.91	15	8	0
019680-00 25 17W 5 DDBB	850.00	221.00	3	G A73	-99.2093	37.9012	-78403.	114869.	14.58	8.30	15	9	0
019724-00 25 17W 7 ADBB	935.00	221.00	3	G A73	-99.2273	37.8940	-79986.	114087.	14.36	7.22	15	8	0
019014-00 25 19W 4 ACAA	815.00	90.00	3	G A73	-99.4099	37.9094	-95927.	115977.	7.30	0.16	8	1	0
021158-00 19 13W 17 CABB	1000.00	231.00	3	G A74	-98.7877	38.3976	-41258.	169992.	1.96	47.67	2	48	0
020481-00 19 14W 27 ACAB	700.00	57.00	3	G A74	-98.8542	38.3721	-47051.	167186.	1.10	43.76	2	44	1
020533-00 19 14W 29 DDBC	1305.00	195.00	3	G A74	-98.8888	38.3640	-50062.	166295.	0.38	41.94	1	2	0
020534-00 19 14W 31 ADCC	675.00	120.00	3	G A74	-98.9072	38.3549	-51659.	165293.	0.26	40.78	1	41	0
020182-00 20 12W 18 CCAA	800.00	234.00	3	G A74	-98.6963	38.3076	-33363.	159912.	9.92	47.65	10	48	0
021256-00 20 13W 20 ADBB	610.00	32.00	3	G A74	-98.7781	38.3003	-40481.	159128.	7.56	43.87	8	44	1
020189-00 20 14W 5 ACCB	680.00	119.00	3	G A74	-98.8932	38.3413	-50455.	163761.	1.47	40.78	2	41	1
020333-00 20 14W 6 CDDA	1200.00	120.00	3	G A74	-98.9127	38.3339	-52158.	162954.	1.20	39.63	2	40	1
020213-00 20 14W 7 BCAA	830.00	107.00	3	G A74	-98.9173	38.3285	-52561.	162350.	1.34	39.21	2	40	1
020550-00 20 14W 17 BACB	800.00	60.00	3	G A74	-98.8978	38.3158	-50873.	160920.	2.69	39.48	3	40	1
020323-00 20 14W 19 BDBB	710.00	169.00	3	G A74	-98.9161	38.2995	-52480.	159109.	2.96	38.00	3	38	1
021153-00 20 14W 23 DDBB	1000.00	240.00	3	G A74	-98.8333	38.2932	-45283.	158369.	6.09	41.23	7	42	1
021118-00 20 14W 27 ACAA	1200.00	270.00	3	G A74	-98.8529	38.2861	-46989.	157578.	5.82	40.09	6	41	1
021119-00 20 14W 33 BDBB	880.00	216.00	3	G A74	-98.8795	38.2716	-49319.	155973.	5.70	38.33	6	39	1
021120-00 20 14W 33 CDBB	845.00	216.00	3	G A74	-98.8795	38.2643	-49323.	155165.	6.10	38.02	7	39	1
021157-00 20 15W 25 BCAA	412.00	34.00	3	G A74	-98.9357	38.2860	-54189.	157617.	3.03	36.59	4	37	1
020366-00 20 15W 35 CBDD	405.00	88.00	3	G A74	-98.9542	38.2653	-55816.	155322.	3.52	34.91	4	35	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
021098-00	20	15W	36	BDBB	880.00	207.00	3	G A74	-98.9346	38.2716	-54106.	156012.	3.84	36.01	4	37	1
021139-00	21	13W	6	BDBB	835.00	184.50	3	G A74	-98.7974	38.2570	-42185.	154312.	9.26	41.18	10	42	1
021140-00	21	13W	6	CDBB	665.00	167.00	3	G A74	-98.7975	38.2500	-42193.	153524.	9.64	40.87	10	41	1
020656-00	21	14W	7	DDBB	1000.00	195.00	3	G A74	-98.8983	38.2357	-50979.	151978.	7.02	35.98	8	36	1
021156-00	21	14W	20	ADBB	1000.00	240.00	3	G A74	-98.8801	38.2139	-49408.	149535.	8.81	35.81	9	36	1
019938-00	21	14W	25	ADBB	785.00	195.00	3	G A74	-98.8064	38.1992	-43005.	147861.	12.09	38.30	13	39	0
019939-00	21	14W	25	DDBB	1000.00	240.00	3	G A74	-98.8064	38.1919	-43009.	147049.	12.49	37.98	13	38	0
020324-00	21	15W	9	AACC	790.00	198.00	3	G A74	-98.9716	38.2443	-57347.	152988.	4.07	33.26	5	34	1
021221-00	21	15W	10	BBCC	1175.00	129.00	3	G A74	-98.9670	38.2444	-56946.	152988.	4.23	33.46	5	34	1
021032-00	21	15W	11	CDDC	785.00	196.00	3	G A74	-98.9414	38.2332	-54730.	151723.	5.70	34.05	6	35	1
020583-00	21	15W	14	DCAA	610.00	198.00	3	G A74	-98.9357	38.2213	-54245.	150391.	6.53	33.78	7	34	1
020978-00	21	15W	16	CCBB	505.00	121.00	3	G A74	-98.9853	38.2215	-58555.	150452.	4.85	31.70	5	32	1
020582-00	21	15W	24	BACC	530.00	164.00	3	G A74	-98.9254	38.2148	-53354.	149667.	7.23	33.93	8	34	1
020652-00	21	15W	31	BADA	695.00	165.00	3	G A74	-99.0134	38.1870	-61036.	146613.	5.77	29.01	6	30	1
021314-00	21	15W	32	BADC	750.00	176.00	3	G A74	-98.9966	38.1861	-59574.	146504.	6.38	29.68	7	30	1
021313-00	21	15W	32	CADD	705.00	195.00	3	G A74	-98.9954	38.1788	-59469.	145689.	6.82	29.41	7	30	1
021579-00	21	15W	33	CACC	795.00	195.00	3	G A74	-98.9805	38.1788	-58172.	145677.	7.33	30.04	8	31	1
020841-00	21	15W	36	DCAA	805.00	195.00	3	G A74	-98.9171	38.1777	-52659.	145518.	9.52	32.68	10	33	1
020078-00	21	16W	14	BBDD	930.00	165.00	3	G A74	-99.0547	38.2293	-64591.	151363.	2.08	29.10	3	30	1
021159-00	22	14W	1	CDBB	1000.00	240.00	3	G A74	-98.8156	38.1628	-43826.	143802.	13.76	36.33	14	37	0
021303-00	22	14W	5	BDA	3000.00	474.00	3	G A74	-98.8863	38.1699	-49979.	144628.	10.99	33.64	11	34	1
019930-00	22	14W	30	BDBB	1000.00	240.00	3	G A74	-98.9073	38.1124	-51850.	138221.	13.40	30.26	14	31	0
020839-00	22	15W	1	ACAA	740.00	195.00	3	G A74	-98.9172	38.1704	-52668.	144708.	9.92	32.36	10	33	1
020840-00	22	15W	1	DCAA	795.00	195.00	3	G A74	-98.9173	38.1631	-52681.	143893.	10.31	32.04	11	33	1
020816-00	22	15W	24	CCAA	605.00	195.00	3	G A74	-98.9265	38.1196	-53521.	139045.	12.35	29.76	13	30	0
021651-00	22	15W	35	AACC	550.00	138.00	3	G A74	-98.9347	38.0988	-54245.	136723.	13.21	28.52	14	29	0
019942-00	22	15W	36	CDBB	660.00	177.00	3	G A74	-98.9256	38.0906	-53463.	135805.	13.95	28.54	14	29	0
020107-00	22	16W	3	CBCD	1600.00	232.00	3	G A74	-99.0751	38.1639	-66425.	144084.	4.93	25.40	5	26	1
020085-00	22	16W	8	DDBB	490.00	161.00	3	G A74	-99.0992	38.1486	-68540.	142388.	4.94	23.71	5	24	1
020713-00	22	16W	10	ABB	800.00	240.00	3	G A74	-99.0665	38.1590	-65681.	143533.	5.48	25.55	6	26	1
021241-00	22	16W	11	DAAA	815.00	195.00	3	G A74	-99.0406	38.1523	-63430.	142765.	6.72	26.35	7	27	1
020826-00	22	16W	22	AADD	780.00	195.00	3	G A74	-99.0589	38.1277	-65051.	140032.	7.44	24.51	8	25	1
020221-00	22	16W	26	DCDC	705.00	116.00	3	G A74	-99.0462	38.1023	-63968.	137185.	9.24	23.94	10	24	1
020837-00	22	16W	27	ACAA	765.00	195.00	3	G A74	-99.0635	38.1122	-65461.	138306.	8.12	23.64	9	24	1
020838-00	22	17W	36	BACC	775.00	195.00	3	G A74	-99.1447	38.0984	-72559.	136828.	6.11	19.61	7	20	1

Appendix 1. Well data (cont)

(a)					(b)	(c)	(d)		(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section					Rate (gpm)	Approp (ac-ft)	Use code		Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
020836-00	22	17W	36	CACC	800.00	195.00	3	G	A74	-99.1447	38.0912	-72566.	136021.	6.50	19.29	7	20	1
020980-00	23	15W	2	BCAA	710.00	182.00	3	G	A74	-98.9452	38.0834	-55173.	135010.	13.68	27.40	14	28	0
020571-00	23	15W	2	CDBB	1040.00	158.00	3	G	A74	-98.9441	38.0761	-55082.	134197.	14.12	27.13	15	28	0
020979-00	23	15W	10	CCAA	695.00	160.00	3	G	A74	-98.9636	38.0615	-56797.	132580.	14.25	25.67	15	26	0
021310-00	23	16W	4	DDBB	550.00	147.00	3	G	A74	-99.0808	38.0759	-67006.	134260.	9.50	21.33	10	22	1
020568-00	23	16W	17	ADC	550.00	53.00	3	G	A74	-99.0987	38.0517	-68594.	131580.	10.20	19.52	11	20	1
021355-00	23	17W	12	BBCB	500.00	144.00	3	G	A74	-99.1494	38.0704	-72991.	133702.	7.47	18.19	8	19	1
020845-00	24	16W	3	BBDD	600.00	145.00	3	G	A74	-99.0728	37.9969	-66381.	125443.	14.04	18.24	15	19	0
019997-00	24	17W	9	BDBB	905.00	221.00	3	G	A74	-99.1998	37.9810	-77490.	123767.	10.59	12.17	11	13	1
019998-00	24	18W	13	ADBB	740.00	213.00	3	G	A74	-99.2445	37.9668	-81406.	122221.	9.84	9.66	10	10	1
020000-00	24	18W	13	CDBB	655.00	187.00	3	G	A74	-99.2535	37.9596	-82205.	121425.	9.92	8.96	10	9	1
020129-00	24	18W	14	ACDD	1000.00	209.00	3	G	A74	-99.2638	37.9642	-83093.	121954.	9.32	8.73	10	9	1
019999-00	24	18W	14	DDBB	900.00	221.00	3	G	A74	-99.2626	37.9597	-82999.	121444.	9.61	8.58	10	9	1
020684-00	24	18W	16	BDBB	780.00	192.00	3	G	A74	-99.3085	37.9673	-86997.	122340.	7.63	6.97	8	7	1
021317-00	24	18W	16	DBDD	490.00	111.00	3	G	A74	-99.3004	37.9609	-86300.	121622.	8.25	7.04	9	8	1
020518-00	24	18W	17	ADBB	935.00	195.00	3	G	A74	-99.3177	37.9674	-87796.	122355.	7.32	6.59	8	7	1
021357-00	24	18W	21	BCAD	555.00	183.00	3	G	A74	-99.3096	37.9519	-87109.	120621.	8.43	6.26	9	7	1
021356-00	24	18W	21	CDBB	1000.00	96.00	3	G	A74	-99.3085	37.9454	-87023.	119895.	8.81	6.02	9	7	1
020088-00	24	18W	23	BBCC	620.00	195.00	3	G	A74	-99.2765	37.9534	-84215.	120759.	9.47	7.73	10	8	1
021677-00	24	18W	31	DDBB	720.00	192.00	3	G	A74	-99.3360	37.9163	-89462.	116673.	9.45	3.59	10	4	1
020332-00	24	18W	35	ACAA	735.00	180.00	3	G	A74	-99.2641	37.9232	-83174.	117376.	11.52	6.93	12	7	1
020207-00	25	17W	6	CBDD	705.00	158.00	3	G	A74	-99.2370	37.9022	-80821.	115009.	13.58	7.17	14	8	0
020114-00	25	17W	8	ACAA	900.00	195.00	3	G	A74	-99.2104	37.8939	-78511.	114062.	14.93	7.93	15	8	0
020917-00	25	18W	5	ACAA	1005.00	185.00	3	G	A74	-99.3189	37.9089	-87973.	115832.	10.43	3.99	11	4	1
020920-00	25	18W	8	BDBB	955.00	195.00	3	G	A74	-99.3267	37.8941	-88675.	114193.	10.96	3.02	11	4	1
021300-00	25	18W	11	BCAA	965.00	195.00	3	G	A74	-99.2733	37.8941	-84009.	114134.	12.79	5.28	13	6	1
021699-00	25	18W	12	ACAA	870.00	198.00	3	G	A74	-99.2459	37.8940	-81611.	114106.	13.72	6.44	14	7	0
020442-00	25	18W	13	CDBB	830.00	198.00	3	G	A74	-99.2538	37.8723	-82332.	111686.	14.62	5.15	15	6	0
020668-00	25	18W	14	DCAA	835.00	195.00	3	G	A74	-99.2640	37.8723	-83220.	111693.	14.28	4.72	15	5	0
020918-00	25	18W	17	AACC	1010.00	195.00	3	G	A74	-99.3175	37.8804	-87888.	112654.	12.02	2.81	13	3	1
020423-00	25	18W	23	CCAA	910.00	195.00	3	G	A74	-99.2732	37.8576	-84039.	110067.	14.76	3.69	15	4	0
022124-00	19	13W	33	DDBC	565.00	96.00	3	G	A75	-98.7595	38.3496	-38833.	164628.	5.51	46.79	6	47	-1
022481-00	19	14W	21	DBDD	935.00	104.00	3	G	A75	-98.8716	38.3803	-48552.	168107.	0.08	43.38	1	44	0
022960-00	20	14W	24	AAD	900.00	118.00	6	G	A75	-98.8120	38.3018	-43426.	159315.	6.34	42.50	7	43	1
022228-00	20	14W	26	ADBB	755.00	114.00	3	G	A75	-98.8333	38.2860	-45289.	157560.	6.48	40.91	7	41	1

[redacted]

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
021779-00 20 14W 27 DDBB	780.00	137.00	3	G A75	-98.8518	38.2788	-46900.	156769.	6.25	39.82	7	40	1
022597-00 20 15W 25 CCAB	850.00	147.00	3	G A75	-98.9368	38.2789	-54296.	156820.	3.38	36.23	4	37	1
022094-00 20 15W 36 CDBB	735.00	168.00	3	G A75	-98.9346	38.2644	-54116.	155205.	4.23	35.69	5	36	1
021775-00 21 14W 31 ADBB	3000.00	480.00	3	G A75	-98.8982	38.1849	-51004.	146308.	9.77	33.79	10	34	1
022304-00 21 14W 34 CDBB	1600.00	465.00	3	G A75	-98.8524	38.1775	-47018.	145463.	11.72	35.41	12	36	1
022804-00 21 15W 17 CDCD	1240.00	31.08	3	G A75	-98.9978	38.2187	-59651.	150143.	4.58	31.04	5	32	1
022495-00 21 15W 20 BACC	720.00	182.00	3	G A75	-98.9989	38.2150	-59751.	149738.	4.74	30.84	5	31	1
022837-00 21 16W 13 ACAA	755.00	108.00	3	G A75	-99.0271	38.2284	-62189.	151249.	3.06	30.23	4	31	1
022295-00 21 16W 24 BCAA	575.00	151.00	3	G A75	-99.0361	38.2139	-62987.	149635.	3.54	29.22	4	30	1
022230-00 21 16W 34 CDCB	1200.00	197.00	3	G A75	-99.0717	38.1757	-66120.	145401.	4.40	26.05	5	27	1
021777-00 22 14W 7 CDBB	785.00	195.00	3	G A75	-98.9072	38.1486	-51810.	142267.	11.44	31.84	12	32	0
022367-00 22 14W 8 DDBB	1300.00	240.00	3	G A75	-98.8800	38.1485	-49442.	142236.	12.36	32.99	13	33	0
021778-00 22 14W 18 AACC	725.00	195.00	3	G A75	-98.8982	38.1422	-51038.	141547.	12.08	31.94	13	32	0
021884-00 22 14W 22 CACC	900.00	195.00	3	G A75	-98.8522	38.1202	-47042.	139072.	14.83	32.94	15	33	0
022240-00 22 15W 7 ADAA	875.00	120.00	3	G A75	-99.0044	38.1560	-60278.	143154.	7.75	28.04	8	29	1
022097-00 22 15W 10 CBDD	850.00	197.00	3	G A75	-98.9632	38.1496	-56693.	142414.	9.49	29.51	10	30	1
022031-00 22 15W 22 DDBB	275.00	72.00	3	G A75	-98.9528	38.1197	-55811.	139066.	11.46	28.65	12	29	0
022284-00 22 16W 29 ACAB	765.00	195.00	3	G A75	-99.1014	38.1120	-68772.	138315.	6.84	22.03	7	23	1
022261-00 22 17W 14 ABDD	500.00	62.00	3	G A75	-99.1549	38.1422	-73397.	141718.	3.40	21.08	4	22	1
021999-00 22 17W 24 AACC	715.00	195.00	3	G A75	-99.1355	38.1275	-71725.	140066.	4.85	21.26	5	22	1
022000-00 22 17W 25 CDBB	695.00	195.00	3	G A75	-99.1447	38.1048	-72551.	137536.	5.77	19.88	6	20	1
022489-00 23 16W 13 CDBB	670.00	195.00	3	G A75	-99.0348	38.0469	-63021.	131000.	12.62	22.02	13	23	0
021898-00 23 16W 22 ADBB	810.00	192.00	3	G A75	-99.0625	38.0396	-65440.	130200.	12.08	20.53	13	21	0
022390-00 23 16W 27 DDBB	800.00	192.00	3	G A75	-99.0625	38.0178	-65462.	127772.	13.26	19.59	14	20	0
023341-00 23 17W 12 ADBB	700.00	220.00	3	G A75	-99.1356	38.0685	-71793.	133487.	8.04	18.70	9	19	1
023201-00 23 17W 16 DDBB	675.00	120.00	3	G A75	-99.1906	38.0466	-76611.	131081.	7.36	15.41	8	16	1
023251-00 24 17W 14 CCAA	820.00	195.00	3	G A75	-99.1646	37.9592	-74433.	121307.	12.97	12.72	13	13	1
023013-00 24 17W 31 ABDC	775.00	192.00	3	G A75	-99.2293	37.9239	-80130.	117424.	12.67	8.44	13	9	1
021738-00 24 17W 34 ACAA	975.00	195.00	3	G A75	-99.1739	37.9230	-75286.	117279.	14.60	10.75	15	11	0
021737-00 24 17W 35 BDBB	905.00	195.00	3	G A75	-99.1636	37.9230	-74385.	117269.	14.96	11.18	15	12	0
021854-00 24 18W 16 CCAA	590.00	184.00	3	G A75	-99.3096	37.9601	-87098.	121540.	7.98	6.62	8	7	1
023184-00 24 18W 17 DCBB	1000.00	195.00	3	G A75	-99.3221	37.9602	-88197.	121559.	7.55	6.09	8	7	1
022435-00 24 18W 34 ACAA	1070.00	180.00	3	G A75	-99.2824	37.9233	-84769.	117404.	10.90	6.16	11	7	1
022436-00 24 18W 34 BDBB	880.00	189.00	3	G A75	-99.2904	37.9234	-85468.	117420.	10.62	5.83	11	6	1
022437-00 24 18W 35 DBDD	765.00	195.00	3	G A75	-99.2642	37.9169	-83186.	116670.	11.86	6.65	12	7	1

[redacted]

Appendix 1. Well data (cont)

(a)	(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section	Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
022438-00 24 18W 36 CCAA	760.00	195.00	3	G A75	-99.2551	37.9159	-82387.	116556.	12.23	7.00	13	8	1
023268-00 25 18W 2 BDBB	1000.00	168.00	3	G A75	-99.2722	37.9087	-83898.	115765.	12.03	5.96	13	6	1
021741-00 25 18W 3 BDBB	3000.00	720.00	3	G A75	-99.2905	37.9088	-85491.	115792.	11.41	5.19	12	6	1
023269-00 25 18W 5 DACC	795.00	195.00	3	G A75	-99.3177	37.9024	-87876.	115105.	10.82	3.76	11	4	1
021909-00 25 18W 16 CDBB	1000.00	195.00	3	G A75	-99.3083	37.8722	-87095.	111725.	12.77	2.84	13	3	1
021786-00 25 18W 21 DDBB	750.00	240.00	3	G A75	-99.2993	37.8577	-86324.	110097.	13.87	2.59	14	3	0
022878-00 25 18W 30 CDBB	1000.00	166.00	3	G A75	-99.3455	37.8433	-90381.	108543.	13.06	0.01	14	1	0
021744-00 25 19W 4 DAB	1000.00	89.00	3	G A75	-99.4082	37.9053	-95784.	115516.	7.58	0.05	8	1	0
023952-00 20 13W 36 BACC	880.00	195.00	3	G A76	-98.7136	38.2723	-34884.	155975.	11.25	45.39	12	46	1
025361-00 20 15W 13 AADD	0.00	38.00	3	G A76	-98.9219	38.3149	-52968.	160839.	1.93	38.42	2	39	0
024044-00 20 15W 35 DDBB	720.00	180.00	3	G A76	-98.9439	38.2644	-54920.	155216.	3.92	35.31	4	36	1
024910-00 21 13W 31 BDBB	865.00	195.00	3	G A76	-98.7974	38.1846	-42229.	146231.	13.19	38.05	14	39	0
024860-00 21 14W 24 DDBB	795.00	195.00	3	G A76	-98.8064	38.2065	-43000.	148673.	11.70	38.61	12	39	1
025105-00 21 14W 32 DCBC	1620.00	240.00	3	G A76	-98.8846	38.1767	-49825.	145387.	10.68	34.01	11	35	1
024995-00 21 14W 33 CDBB	1820.00	240.00	3	G A76	-98.8708	38.1775	-48623.	145475.	11.10	34.63	12	35	1
025223-00 21 15W 3 ABCC	350.00	95.00	3	G A76	-98.9578	38.2582	-56138.	154531.	3.79	34.45	4	35	1
025222-00 21 15W 3 CABC	700.00	125.00	3	G A76	-98.9624	38.2531	-56540.	153957.	3.91	34.03	4	35	1
023867-00 21 15W 30 BABC	800.00	197.00	3	G A76	-99.0168	38.2023	-61315.	148323.	4.82	29.53	5	30	1
024212-00 21 15W 30 BCCC	1115.00	240.00	3	G A76	-99.0212	38.1968	-61705.	147720.	4.97	29.10	5	30	1
023953-00 21 15W 35 BDBB	685.00	180.00	3	G A76	-98.9437	38.1850	-54962.	146346.	8.23	31.87	9	32	1
024839-00 21 16W 14 ADCC	955.00	203.00	3	G A76	-99.0443	38.2256	-63687.	150950.	2.63	29.38	3	30	1
023868-00 21 16W 24 DCCB	350.00	60.00	3	G A76	-99.0304	38.2049	-62496.	148623.	4.22	29.07	5	30	1
024211-00 21 16W 25 CDBB	1600.00	480.00	3	G A76	-99.0349	38.1921	-62904.	147206.	4.76	28.32	5	29	1
024210-00 21 16W 36 BBDB	1000.00	203.00	3	G A76	-99.0372	38.1867	-63107.	146599.	4.98	27.99	5	28	1
024927-00 22 14W 1 ACBB	925.00	198.00	3	G A76	-98.8110	38.1701	-43423.	144614.	13.52	36.84	14	37	0
024877-00 22 14W 4 DBC	1200.00	228.00	3	G A76	-98.8656	38.1643	-48179.	143997.	11.99	34.28	12	35	1
023612-00 22 14W 9 CCCB	1000.00	216.00	3	G A76	-98.8754	38.1466	-49043.	142030.	12.62	33.10	13	34	0
025079-00 22 14W 20 DDBB	1200.00	240.00	3	G A76	-98.8799	38.1195	-49459.	139001.	13.93	31.73	14	32	0
025292-00 22 14W 21 ADBB	800.00	240.00	3	G A76	-98.8615	38.1266	-47848.	139787.	14.17	32.82	15	33	0
025078-00 22 14W 21 CDBB	1200.00	240.00	3	G A76	-98.8707	38.1194	-48654.	138991.	14.25	32.12	15	33	0
025142-00 22 15W 19 BDBB	870.00	174.00	3	G A76	-99.0167	38.1270	-61369.	139919.	8.91	26.27	9	27	1
025002-00 22 15W 33 DDDC	630.00	192.00	3	G A76	-98.9691	38.0879	-57256.	135526.	12.63	26.58	13	27	0
024308-00 22 16W 1 CCAA	680.00	195.00	3	G A76	-99.0360	38.1633	-63020.	143983.	6.29	27.02	7	28	1
024553-00 22 16W 12 BACC	875.00	191.00	3	G A76	-99.0348	38.1569	-62926.	143272.	6.67	26.80	7	27	1
023907-00 22 16W 21 BCBB	484.00	134.00	3	G A76	-99.0946	38.1266	-68160.	139936.	6.29	22.95	7	23	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
024999-00 22 16W 22 BBBB	475.00	142.00	3	G A76	-99.0762	38.1303	-66555.	140334.	6.71	23.89	7	24	1
025000-00 22 16W 22 CBDB	440.00	164.00	3	G A76	-99.0738	38.1212	-66357.	139320.	7.28	23.60	8	24	1
023849-00 22 16W 24 BBDD	765.00	192.00	3	G A76	-99.0359	38.1278	-63048.	140027.	8.21	25.49	9	26	1
025001-00 22 16W 27 CBCC	470.00	147.00	3	G A76	-99.0761	38.1058	-66572.	137597.	8.04	22.83	9	23	1
024309-00 22 16W 32 CDAC	540.00	195.00	3	G A76	-99.1062	38.0894	-69205.	135787.	7.91	20.85	8	21	1
024998-00 22 16W 36 DCAA	665.00	173.00	3	G A76	-99.0268	38.0905	-62284.	135858.	10.54	24.25	11	25	1
024348-00 22 17W 26 CDAA	745.00	195.00	3	G A76	-99.1595	38.1048	-73838.	137552.	5.27	19.26	6	20	1
023734-00 23 15W 4 CCAA	625.00	181.00	3	G A76	-98.9816	38.0760	-58353.	134212.	12.85	25.54	13	26	0
024213-00 23 16W 7 BBBB	660.00	188.00	3	G A76	-99.1310	38.0722	-71389.	133888.	8.00	19.05	8	20	1
024705-00 23 16W 9 CBDC	480.00	180.00	3	G A76	-99.0924	38.0621	-68033.	132739.	9.85	20.24	10	21	1
025342-00 23 16W 17 DACC	640.00	192.00	3	G A76	-99.0993	38.0476	-68645.	131126.	10.40	19.32	11	20	1
024214-00 23 17W 1 ACAA	730.00	192.00	3	G A76	-99.1367	38.0831	-71874.	135107.	7.21	19.28	8	20	1
024586-00 23 17W 23 ADAA	620.00	195.00	3	G A76	-99.1506	38.0395	-73133.	130254.	9.10	16.80	10	17	1
024934-00 23 17W 32 ADBB	700.00	210.00	3	G A76	-99.2088	38.0103	-78239.	127049.	8.70	13.07	9	14	1
023617-00 24 16W 3 BBDD	120.00	31.00	3	G A76	-99.0728	37.9969	-66381.	125443.	14.04	18.24	15	19	0
023811-00 24 16W 4 CACC	735.00	173.00	3	G A76	-99.0901	37.9895	-67898.	124635.	13.86	17.19	14	18	0
024268-00 24 17W 6 ACAA	285.00	53.00	3	G A76	-99.2281	37.9957	-79944.	125438.	8.83	11.61	9	12	1
024875-00 24 17W 6 DCAA	665.00	195.00	3	G A76	-99.2282	37.9884	-79955.	124624.	9.22	11.29	10	12	1
023389-00 24 17W 29 BDAA	795.00	195.00	3	G A76	-99.2148	37.9375	-78843.	118924.	12.43	9.64	13	10	1
023556-00 24 17W 30 BDBA	900.00	143.00	3	G A76	-99.2347	37.9375	-80584.	118950.	11.75	8.80	12	9	1
023870-00 24 18W 4 BCAA	1000.00	237.00	3	G A76	-99.3096	37.9964	-87056.	125586.	6.02	8.20	7	9	1
024788-00 24 18W 10 CDDD	370.00	131.00	3	G A76	-99.2867	37.9717	-85091.	122808.	8.14	8.09	9	9	1
023573-00 24 18W 21 ADBB	1200.00	240.00	3	G A76	-99.2993	37.9527	-86212.	120704.	8.73	6.73	9	7	1
024254-00 24 18W 27 CADD	685.00	195.00	3	G A76	-99.2869	37.9315	-85154.	118327.	10.30	6.33	11	7	1
024777-00 25 18W 9 BCAA	1000.00	195.00	3	G A76	-99.3096	37.8941	-87185.	114174.	11.54	3.74	12	4	1
024778-00 25 18W 9 CDBB	885.00	195.00	3	G A76	-99.3084	37.8868	-87087.	113359.	11.98	3.47	12	4	1
024480-00 25 18W 10 ADBB	800.00	240.00	3	G A76	-99.2813	37.8941	-84706.	114144.	12.51	4.94	13	5	1
024481-00 25 18W 16 ADBB	800.00	195.00	3	G A76	-99.2992	37.8796	-86293.	112539.	12.69	3.54	13	4	1
027074-00 19 13W 19 DBDB	1000.00	83.00	3	G A77	-98.7990	38.3813	-42245.	168180.	2.47	46.49	3	47	-1
025881-00 19 14W 23 ACDC	575.00	50.00	3	G A77	-98.8360	38.3839	-45459.	168489.	1.08	45.04	2	46	1
027495-00 19 14W 32 CABC	0.00	31.00	3	G A77	-98.8979	38.3531	-50859.	165088.	0.66	41.09	1	42	0
026162-00 20 12W 30 CDBB	585.00	160.00	3	G A77	-98.6951	38.2786	-33276.	156675.	11.53	46.44	12	47	-1
027517-00 20 13W 3 DCBB	1800.00	240.00	3	G A77	-98.7457	38.3364	-37647.	163144.	6.69	46.80	7	47	-1
026931-00 20 13W 4 BBDA	750.00	107.50	2	G A77	-98.7700	38.3452	-39746.	164142.	5.40	46.16	6	47	-1
025914-00 20 13W 10 DABB	885.00	195.00	3	G A77	-98.7412	38.3256	-37255.	161943.	7.43	46.53	8	47	-1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
026159-00	20	13W	20	CBBA	570.00	158.00	3	G A77	-98.7908	38.2967	-41589.	158737.	7.33	43.18	8	44	1
026160-00	20	13W	20	DDBB	715.00	192.00	3	G A77	-98.7781	38.2931	-40487.	158324.	7.95	43.55	8	44	1
026163-00	20	13W	22	DCAA	875.00	180.00	3	G A77	-98.7425	38.2931	-37390.	158318.	9.15	45.07	10	46	1
028067-00	20	13W	23	ADBB	960.00	198.00	3	G A77	-98.7229	38.3004	-35682.	159118.	9.41	46.21	10	47	-1
026161-00	20	13W	23	CDBB	700.00	192.00	3	G A77	-98.7322	38.2932	-36490.	158314.	9.50	45.50	10	46	1
027931-00	20	13W	26	BACC	710.00	149.00	3	G A77	-98.7322	38.2868	-36494.	157605.	9.84	45.23	10	46	1
026256-00	20	13W	31	BACC	530.00	138.00	3	G A77	-98.8057	38.2724	-42899.	156024.	8.15	41.49	9	42	1
025873-00	20	13W	34	BBDC	915.00	143.00	3	G A77	-98.7528	38.2722	-38294.	155987.	9.94	43.73	10	44	1
026321-00	20	13W	36	CACC	725.00	195.00	3	G A77	-98.7135	38.2649	-34883.	155159.	11.65	45.07	12	46	1
025768-00	20	14W	5	CCBC	575.00	132.00	3	G A77	-98.9024	38.3348	-51258.	163049.	1.50	40.11	2	41	1
026802-00	20	14W	5	DBCB	625.00	75.00	3	G A77	-98.8931	38.3376	-50455.	163350.	1.67	40.62	2	41	1
026255-00	20	14W	13	ACDB	345.00	36.00	3	G A77	-98.8171	38.3130	-43862.	160568.	5.56	42.77	6	43	1
026806-00	20	14W	24	BCAA	800.00	230.00	3	G A77	-98.8252	38.3004	-44578.	159168.	5.97	41.88	6	42	1
026807-00	20	14W	25	DDBB	725.00	192.00	3	G A77	-98.8149	38.2787	-43691.	156737.	7.50	41.38	8	42	1
025538-00	20	14W	28	CDBB	840.00	189.00	3	G A77	-98.8795	38.2788	-49313.	156779.	5.31	38.65	6	39	1
025666-00	20	14W	34	ADD	58.00	94.00	2	G A77	-98.8489	38.2693	-46656.	155705.	6.86	39.53	7	40	1
026803-00	20	15W	14	CCDC	200.00	12.00	3	G A77	-98.9551	38.3052	-55865.	159776.	1.33	36.60	2	37	0
027711-00	20	15W	34	DACB	410.00	91.00	3	G A77	-98.9622	38.2663	-56513.	155430.	3.20	34.61	4	35	1
025641-00	20	15W	35	ACBB	0.00	178.71	3	G A77	-98.9484	38.2717	-55306.	156025.	3.38	35.43	4	36	1
026717-00	21	12W	8	BBDD	810.00	195.00	3	G A77	-98.6703	38.2431	-31130.	152700.	14.30	45.96	15	46	0
027075-00	21	13W	5	AACC	715.00	131.00	3	G A77	-98.7700	38.2578	-39803.	154381.	10.14	42.37	11	43	1
025645-00	21	13W	7	BDBB	880.00	185.00	3	G A77	-98.7975	38.2428	-42196.	152722.	10.03	40.56	11	41	1
027509-00	21	13W	27	BDBB	605.00	106.00	3	G A77	-98.7427	38.1986	-37452.	147766.	14.27	40.97	15	41	0
025603-00	21	13W	28	CDBB	720.00	189.00	3	G A77	-98.7610	38.1916	-39056.	146987.	14.04	39.89	15	40	0
027281-00	21	14W	3	BDBB	900.00	228.00	3	G A77	-98.8525	38.2572	-46976.	154353.	7.40	38.85	8	39	1
026134-00	21	14W	6	ADBB	810.00	183.00	3	G A77	-98.8984	38.2571	-50965.	154373.	5.85	36.91	6	37	1
026135-00	21	14W	6	BDBB	1000.00	183.00	3	G A77	-98.9072	38.2571	-51735.	154379.	5.55	36.54	6	37	1
026319-00	21	14W	7	CAC	1000.00	225.00	3	G A77	-98.9067	38.2370	-51704.	152131.	6.66	35.69	7	36	1
027457-00	21	14W	8	DCAA	685.00	182.00	3	G A77	-98.8813	38.2356	-49495.	151966.	7.59	36.71	8	37	1
027018-00	21	14W	9	BCAA	725.00	199.00	3	G A77	-98.8721	38.2429	-48691.	152772.	7.51	37.41	8	38	1
026320-00	21	14W	11	ACA	1000.00	240.00	3	G A77	-98.8267	38.2423	-44738.	152685.	9.07	39.31	10	40	1
026516-00	21	14W	12	BDBB	900.00	240.00	3	G A77	-98.8158	38.2428	-43788.	152732.	9.41	39.79	10	40	1
026258-00	21	14W	13	BDBB	800.00	240.00	3	G A77	-98.8157	38.2283	-43794.	151111.	10.20	39.16	11	40	1
026259-00	21	14W	14	ADBB	800.00	231.00	3	G A77	-98.8250	38.2283	-44598.	151115.	9.89	38.77	10	39	1
026362-00	21	14W	17	CDBB	1000.00	219.00	3	G A77	-98.8893	38.2211	-50203.	150352.	8.11	35.74	9	36	1

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Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
026317-00	21	14W	18	DBA	1800.00	228.00	3	G A77	-98.9000	38.2243	-51134.	150712.	7.57	35.42	8	36	1
026318-00	21	14W	23	ACAA	820.00	195.00	3	G A77	-98.8261	38.2137	-44703.	149494.	10.64	38.09	11	39	1
025758-00	21	14W	24	ADBB	775.00	188.00	3	G A77	-98.8064	38.2138	-42994.	149487.	11.30	38.93	12	39	1
025656-00	21	14W	36	ADBB	1000.00	240.00	3	G A77	-98.8064	38.1847	-43013.	146238.	12.88	37.67	13	38	0
027209-00	21	15W	10	CBDC	740.00	150.00	3	G A77	-98.9646	38.2371	-56745.	152173.	4.70	33.24	5	34	1
026158-00	21	15W	23	CDBB	695.00	162.00	3	G A77	-98.9438	38.2067	-54956.	148777.	7.05	32.81	8	33	1
026322-00	21	15W	26	CACC	715.00	154.00	3	G A77	-98.9437	38.1931	-54961.	147256.	7.79	32.22	8	33	1
026376-00	21	15W	27	ABDD	775.00	137.00	3	G A77	-98.9541	38.2004	-55859.	148080.	7.04	32.10	8	33	1
026493-00	21	16W	13	BCAA	560.00	98.00	3	G A77	-99.0363	38.2284	-62987.	151249.	2.75	29.84	3	30	1
028111-00	21	16W	14	CBDD	745.00	190.00	3	G A77	-99.0547	38.2220	-64595.	150556.	2.47	28.78	3	29	1
026686-00	21	16W	25	ACAA	275.00	63.00	3	G A77	-99.0269	38.1995	-62201.	148019.	4.63	28.98	5	29	1
025677-00	21	16W	26	CDBC	700.00	45.00	3	G A77	-99.0535	38.1912	-64517.	147113.	4.18	27.50	5	28	1
026461-00	21	16W	32	DCA	4800.00	1367.80	4	G A77	-99.1010	38.1771	-68675.	145570.	3.34	24.87	4	25	1
026415-00	21	16W	36	DBCA	420.00	103.00	3	G A77	-99.0291	38.1796	-62409.	145801.	5.64	28.02	6	29	1
027616-00	22	14W	14	ADBB	1000.00	240.00	3	G A77	-98.8248	38.1409	-44638.	141368.	14.63	35.00	15	35	0
027588-00	22	14W	15	BDBB	900.00	240.00	3	G A77	-98.8523	38.1410	-47040.	141393.	13.70	33.83	14	34	0
026104-00	22	14W	20	ADBB	750.00	188.00	3	G A77	-98.8800	38.1267	-49455.	139808.	13.54	32.04	14	33	0
026151-00	22	14W	21	BCAA	870.00	189.00	3	G A77	-98.8719	38.1267	-48753.	139799.	13.82	32.38	14	33	0
027824-00	22	14W	28	ADBB	1000.00	240.00	3	G A77	-98.8614	38.1121	-47847.	138171.	14.96	32.20	15	33	0
027825-00	22	14W	28	BDBB	1000.00	240.00	3	G A77	-98.8707	38.1122	-48658.	138182.	14.64	31.81	15	32	0
026528-00	22	15W	2	CCBB	1800.00	237.00	3	G A77	-98.9482	38.1632	-55373.	143923.	9.26	30.74	10	31	1
026529-00	22	15W	2	DCBB	1800.00	237.00	3	G A77	-98.9391	38.1632	-54578.	143911.	9.57	31.12	10	32	1
025690-00	22	15W	6	CDBB	740.00	188.00	3	G A77	-99.0166	38.1633	-61336.	143973.	6.94	27.84	7	28	1
027957-00	22	15W	9	DDBB	805.00	179.00	3	G A77	-98.9713	38.1487	-57395.	142317.	9.26	29.13	10	30	1
025979-00	22	15W	13	BACC	855.00	195.00	3	G A77	-98.9254	38.1423	-53407.	141575.	11.16	30.79	12	31	0
027844-00	22	15W	20	ADCD	875.00	144.00	3	G A77	-98.9885	38.1243	-58914.	139599.	10.01	27.34	11	28	1
026291-00	22	15W	25	BCAA	800.00	147.00	3	G A77	-98.9266	38.1124	-53527.	138235.	12.74	29.45	13	30	0
026682-00	22	15W	33	ADBB	165.00	55.00	3	G A77	-98.9713	38.0979	-57440.	136642.	12.02	26.92	13	27	0
026126-00	22	16W	6	ACCB	410.00	143.00	3	G A77	-99.1220	38.1685	-70505.	144625.	3.10	23.61	4	24	1
026114-00	22	16W	20	ABAB	285.00	88.00	3	G A77	-99.1014	38.1302	-68753.	140346.	5.86	22.82	6	23	1
027826-00	22	16W	31	BBCD	715.00	194.00	3	G A77	-99.1299	38.0984	-71266.	136816.	6.61	20.23	7	21	1
026683-00	22	17W	10	CDBA	765.00	193.00	3	G A77	-99.1796	38.1485	-75546.	142447.	2.22	20.31	3	21	1
026072-00	22	17W	27	ABDC	695.00	205.00	3	G A77	-99.1742	38.1130	-75115.	138484.	4.32	19.00	5	19	1
026340-00	22	17W	28	DDBB	800.00	330.00	3	G A77	-99.1903	38.1048	-76525.	137580.	4.22	17.96	5	18	1
026144-00	22	17W	35	DDBA	840.00	204.00	3	G A77	-99.1528	38.0903	-73268.	135926.	6.28	18.91	7	19	1

Appendix 1. Well data (cont)

(a)	(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section	Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
027456-00 23 15W 1 CBBB	690.00	195.00	3	G A77	-98.9303	38.0797	-53876.	134588.	14.39	27.87	15	28	0
026147-00 23 15W 4 DCAA	825.00	182.00	3	G A77	-98.9726	38.0760	-57568.	134204.	13.16	25.92	14	26	0
025453-00 23 15W 18 CDBB	920.00	180.00	3	G A77	-99.0166	38.0469	-61432.	130988.	13.24	22.80	14	23	0
026260-00 23 16W 5 ADBB	675.00	158.00	3	G A77	-99.0992	38.0830	-68608.	135073.	8.49	20.86	9	21	1
026598-00 23 16W 12 ABDD	570.00	162.00	3	G A77	-99.0268	38.0696	-62304.	133522.	11.67	23.35	12	24	1
025866-00 23 16W 20 BCDB	1095.00	227.00	3	G A77	-99.1106	38.0376	-69647.	130018.	10.56	18.41	11	19	1
026043-00 23 17W 2 CCAA	850.00	184.00	3	G A77	-99.1643	38.0758	-74286.	134317.	6.67	17.80	7	18	1
026042-00 23 17W 2 DCAA	755.00	195.00	3	G A77	-99.1551	38.0758	-73486.	134312.	6.98	18.19	7	19	1
025689-00 23 17W 8 ADBD	135.00	47.00	3	G A77	-99.2077	38.0675	-78079.	133427.	5.65	15.60	6	16	1
025691-00 23 17W 8 DACC	125.00	41.00	3	G A77	-99.2088	38.0620	-78181.	132818.	5.91	15.32	6	16	1
025647-00 23 17W 12 DDBB	500.00	150.00	3	G A77	-99.1356	38.0613	-71801.	132676.	8.43	18.38	9	19	1
026202-00 23 17W 16 CDBC	690.00	122.00	3	G A77	-99.1997	38.0457	-77405.	130985.	7.10	14.99	8	15	1
027481-00 23 17W 19 DDDD	740.00	174.00	3	G A77	-99.2236	38.0295	-79511.	129198.	7.16	13.27	8	14	1
026019-00 23 17W 21 ADBB	615.00	173.00	3	G A77	-99.1906	38.0393	-76619.	130273.	7.75	15.10	8	16	1
026020-00 23 17W 21 CDBB	685.00	107.00	3	G A77	-99.1997	38.0321	-77421.	129472.	7.83	14.40	8	15	1
026018-00 23 17W 26 ADDD	785.00	177.00	3	G A77	-99.1507	38.0222	-73154.	128323.	10.03	16.04	11	17	1
025747-00 23 17W 29 BDBB	800.00	177.00	3	G A77	-99.2179	38.0249	-79020.	128684.	7.60	13.31	8	14	1
027482-00 23 17W 30 ADDB	855.00	146.00	3	G A77	-99.2247	38.0231	-79612.	128490.	7.47	12.95	8	13	1
028046-00 23 17W 36 ADBB	690.00	152.00	3	G A77	-99.1359	38.0103	-71877.	126985.	11.18	16.15	12	17	1
028047-00 23 17W 36 CCAA	640.00	106.00	3	G A77	-99.1463	38.0030	-72792.	126175.	11.22	15.39	12	16	1
025552-00 23 18W 36 CDBB	1100.00	240.00	3	G A77	-99.2535	38.0032	-82153.	126298.	7.56	10.87	8	11	1
027396-00 24 16W 4 BDBB	1000.00	195.00	3	G A77	-99.0901	37.9959	-67898.	125346.	13.51	17.46	14	18	0
027397-00 24 16W 5 ACAA	1000.00	195.00	3	G A77	-99.1005	37.9959	-68800.	125349.	13.16	17.02	14	18	0
025910-00 24 16W 5 CACC	795.00	195.00	3	G A77	-99.1084	37.9894	-69495.	124638.	13.24	16.41	14	17	0
027398-00 24 16W 8 CACC	980.00	195.00	3	G A77	-99.1083	37.9749	-69506.	123015.	14.03	15.78	15	16	0
027756-00 24 17W 9 DCAA	920.00	195.00	3	G A77	-99.1919	37.9737	-76808.	122949.	11.25	12.19	12	13	1
027758-00 24 17W 13 CACC	975.00	195.00	3	G A77	-99.1452	37.9602	-72740.	121398.	13.57	13.58	14	14	0
028258-00 24 17W 13 DACC	825.00	154.00	3	G A77	-99.1360	37.9602	-71940.	121397.	13.88	13.97	14	14	0
027757-00 24 17W 14 BDBB	1000.00	240.00	3	G A77	-99.1634	37.9664	-74324.	122114.	12.61	13.08	13	14	1
027646-00 24 17W 16 ADBB	1000.00	240.00	3	G A77	-99.1908	37.9665	-76719.	122141.	11.68	11.92	12	12	1
027651-00 24 17W 16 DDBB	1000.00	234.00	3	G A77	-99.1908	37.9592	-76729.	121334.	12.07	11.60	13	12	1
025710-00 24 17W 18 CACC	720.00	150.00	3	G A77	-99.2357	37.9603	-80645.	121494.	10.49	9.75	11	10	1
027645-00 24 17W 20 BBDD	1000.00	218.00	3	G A77	-99.2192	37.9530	-79217.	120660.	11.44	10.13	12	11	1
027650-00 24 17W 21 ACAA	720.00	195.00	3	G A77	-99.1920	37.9520	-76836.	120524.	12.42	11.24	13	12	1
027648-00 24 17W 22 BDBB	1000.00	210.00	3	G A77	-99.1817	37.9520	-75940.	120515.	12.77	11.67	13	12	1

[redacted]

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
026427-00 24 17W 22 CCDB	105.00	15.00	6	G A77	-99.1840	37.9428	-76146.	119499.	13.19	11.18	14	12	0
026955-00 24 17W 23 ADBB	760.00	191.00	3	G A77	-99.1543	37.9520	-73547.	120495.	13.70	12.84	14	13	0
027647-00 24 17W 29 ADAA	955.00	150.00	3	G A77	-99.2057	37.9374	-78049.	118910.	12.75	10.03	13	11	1
027649-00 24 17W 34 BACC	745.00	178.00	3	G A77	-99.1819	37.9239	-75985.	117387.	14.28	10.45	15	11	0
025553-00 24 18W 3 ACAA	3200.00	780.00	3	G A77	-99.2820	37.9962	-84650.	125535.	6.97	9.35	7	10	1
026253-00 24 18W 10 BDBB	610.00	163.00	3	G A77	-99.2901	37.9817	-85375.	123925.	7.48	8.38	8	9	1
025658-00 24 18W 11 ADBB	700.00	160.00	3	G A77	-99.2626	37.9815	-82968.	123878.	8.43	9.54	9	10	1
025775-00 24 18W 11 BDBB	570.00	188.00	3	G A77	-99.2717	37.9815	-83768.	123888.	8.12	9.15	9	10	1
027144-00 24 18W 12 DDBB	665.00	195.00	3	G A77	-99.2445	37.9741	-81395.	123033.	9.45	9.98	10	10	1
025709-00 24 18W 13 DCAA	650.00	144.00	3	G A77	-99.2456	37.9595	-81515.	121409.	10.19	9.29	11	10	1
027605-00 24 18W 15 BCAA	395.00	110.00	3	G A77	-99.2913	37.9672	-85495.	122309.	8.22	7.70	9	8	1
025450-00 24 18W 15 CBDD	670.00	195.00	3	G A77	-99.2913	37.9609	-85502.	121604.	8.56	7.42	9	8	1
025972-00 24 18W 17 BDDA	975.00	195.00	3	G A77	-99.3233	37.9656	-88294.	122162.	7.22	6.27	8	7	1
027305-00 24 18W 20 CBDD	725.00	195.00	3	G A77	-99.3279	37.9464	-88716.	120028.	8.10	5.24	9	6	1
027257-00 24 18W 27 CCDC	240.00	60.00	3	G A77	-99.2927	37.9279	-85660.	117932.	10.30	5.93	11	6	1
027774-00 24 18W 29 ABB	800.00	195.00	3	G A77	-99.3216	37.9413	-88176.	119453.	8.59	5.29	9	6	1
026267-00 24 18W 31 BDBB	730.00	183.00	3	G A77	-99.3450	37.9236	-90238.	117500.	8.75	3.53	9	4	1
026235-00 24 18W 31 CDBB	825.00	195.00	3	G A77	-99.3450	37.9163	-90249.	116683.	9.14	3.21	10	4	1
027443-00 24 18W 36 DBDD	785.00	188.00	3	G A77	-99.2458	37.9168	-81582.	116643.	12.49	7.43	13	8	1
026581-00 25 17W 4 BDBB	955.00	117.00	3	G A77	-99.2002	37.9084	-77597.	115674.	14.50	9.00	15	10	0
025589-00 25 18W 2 ADBB	670.00	160.70	3	G A77	-99.2631	37.9087	-83099.	115755.	12.34	6.34	13	7	1
026053-00 25 18W 2 DACC	1060.00	225.00	3	G A77	-99.2631	37.9023	-83107.	115040.	12.69	6.06	13	7	1
025798-00 25 18W 5 CACC	925.00	195.00	3	G A77	-99.3268	37.9024	-88672.	115116.	10.51	3.38	11	4	1
025522-00 25 18W 6 CACC	1000.00	195.00	3	G A77	-99.3450	37.9025	-90265.	115147.	9.88	2.61	10	3	1
026210-00 25 18W 7 DDBB	900.00	198.00	3	G A77	-99.3358	37.8869	-89483.	113395.	11.04	2.32	12	3	1
025624-00 25 18W 8 ADBB	835.00	185.00	3	G A77	-99.3176	37.8941	-87880.	114181.	11.27	3.40	12	4	1
026356-00 25 18W 9 ADBB	985.00	195.00	3	G A77	-99.2994	37.8941	-86294.	114167.	11.89	4.17	12	5	1
026355-00 25 18W 9 DCAA	865.00	195.00	3	G A77	-99.3005	37.8869	-86393.	113355.	12.25	3.81	13	4	1
026692-00 25 18W 12 DCAA	935.00	192.00	3	G A77	-99.2458	37.8868	-81615.	113296.	14.11	6.12	15	7	0
025931-00 25 18W 13 DBDD	845.00	198.00	3	G A77	-99.2459	37.8732	-81637.	111781.	14.85	5.53	15	6	0
026026-00 25 18W 14 ADBB	760.00	181.00	3	G A77	-99.2628	37.8795	-83111.	112502.	13.93	5.09	14	6	0
025724-00 25 18W 14 BCAA	970.00	195.00	3	G A77	-99.2730	37.8795	-84001.	112508.	13.58	4.65	14	5	0
025725-00 25 18W 14 CBDD	770.00	191.00	3	G A77	-99.2730	37.8732	-84004.	111801.	13.93	4.38	14	5	0
026795-00 25 18W 17 DDBB	850.00	240.00	3	G A77	-99.3175	37.8722	-87895.	111732.	12.46	2.45	13	3	1
027596-00 25 18W 20 AABB	1000.00	117.00	3	G A77	-99.3174	37.8685	-87899.	111325.	12.66	2.29	13	3	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
025625-00	25	18W	21	CDBB	995.00	195.00	3	G	A77	-99.3084	37.8577	-87125.	110113.	13.55	2.20	14	3	0
026794-00	25	18W	27	BDBB	850.00	240.00	3	G	A77	-99.2903	37.8503	-85546.	109269.	14.57	2.65	15	3	0
027828-00	25	18W	28	BBDD	830.00	195.00	3	G	A77	-99.3097	37.8514	-87244.	109407.	13.85	1.87	14	2	0
027829-00	25	18W	28	DCAA	455.00	121.00	3	G	A77	-99.3007	37.8431	-86469.	108470.	14.60	1.89	15	2	0
026793-00	25	19W	24	ADBB	850.00	240.00	3	G	A77	-99.3543	37.8653	-91124.	110998.	11.58	0.59	12	1	0
030775-00	19	14W	12	DAAA	710.00	72.00	3	G	A78	-98.8116	38.4121	-43326.	171619.	0.37	47.29	1	48	0
028773-00	19	14W	25	BBBC	1735.00	354.00	3	G	A78	-98.8291	38.3748	-44869.	167471.	1.80	44.93	2	45	1
028434-00	19	14W	36	BBCC	1275.00	168.00	3	G	A78	-98.8288	38.3586	-44848.	165656.	2.70	44.25	3	45	1
030961-00	20	13W	9	DDBB	820.00	178.00	3	G	A78	-98.7597	38.3221	-38870.	161553.	7.00	45.59	7	46	1
030603-00	20	13W	16	BDCC	980.00	116.00	3	G	A78	-98.7689	38.3121	-39673.	160442.	7.23	44.77	8	45	1
030605-00	20	13W	21	ACAD	785.00	192.00	3	G	A78	-98.7609	38.2995	-38981.	159031.	8.19	44.56	9	45	1
030962-00	20	13W	24	ACAA	845.00	195.00	3	G	A78	-98.7055	38.3004	-34171.	159109.	10.00	46.94	10	47	-1
028359-00	20	13W	25	ACAD	895.00	201.00	3	G	A78	-98.7055	38.2850	-34178.	157391.	10.83	46.28	11	47	-1
028779-00	20	13W	31	CDBB	710.00	207.00	3	G	A78	-98.8057	38.2642	-42905.	155116.	8.59	41.14	9	42	1
028778-00	20	13W	31	DDBB	845.00	207.00	3	G	A78	-98.7966	38.2642	-42109.	155109.	8.90	41.52	9	42	1
028864-00	20	14W	6	DABB	700.00	144.00	3	G	A78	-98.9070	38.3394	-51657.	163565.	1.10	40.11	2	41	1
029004-00	20	14W	7	AAB	1000.00	267.00	3	G	A78	-98.9064	38.3317	-51609.	162695.	1.54	39.80	2	40	1
029005-00	20	14W	7	CDAA	1000.00	236.00	3	G	A78	-98.9127	38.3213	-52167.	161538.	1.89	39.09	2	40	1
031134-00	20	14W	10	DDCC	1300.00	144.00	3	G	A78	-98.8517	38.3186	-46862.	161211.	4.09	41.55	5	42	1
030432-00	20	14W	13	BDBD	500.00	41.00	3	G	A78	-98.8228	38.3138	-44360.	160659.	5.32	42.56	6	43	1
030433-00	20	14W	26	DDBB	655.00	195.00	3	G	A78	-98.8334	38.2787	-45297.	156749.	6.87	40.60	7	41	1
031135-00	20	14W	30	BCAD	800.00	110.00	3	G	A78	-98.9173	38.2844	-52595.	157430.	3.73	37.29	4	38	1
031136-00	20	15W	23	CDB	1200.00	233.00	3	G	A78	-98.9523	38.2930	-55628.	158408.	2.09	36.19	3	37	1
028611-00	20	15W	26	DDDD	575.00	100.00	3	G	A78	-98.9403	38.2762	-54598.	156524.	3.41	35.97	4	36	1
030355-00	21	12W	5	AACC	1000.00	97.50	3	G	A78	-98.6597	38.2577	-30204.	154332.	13.86	47.04	14	48	0
030697-00	21	14W	13	ADBB	1000.00	240.00	3	G	A78	-98.8064	38.2283	-42987.	151106.	10.52	39.55	11	40	1
028798-00	21	14W	19	AACC	800.00	195.00	3	G	A78	-98.8984	38.2148	-50996.	149648.	8.15	35.08	9	36	1
029947-00	21	14W	22	DACC	765.00	195.00	3	G	A78	-98.8432	38.2074	-46202.	148795.	10.41	37.09	11	38	1
030458-00	21	14W	23	DDBB	1200.00	240.00	3	G	A78	-98.8249	38.2065	-44607.	148681.	11.08	37.83	12	38	1
029269-00	21	14W	28	ADBB	900.00	227.00	3	G	A78	-98.8616	38.1993	-47804.	147904.	10.23	35.97	11	36	1
029270-00	21	14W	33	BCBB	1200.00	120.00	3	G	A78	-98.8754	38.1848	-49019.	146288.	10.55	34.75	11	35	1
028431-00	21	15W	21	ADBB	530.00	135.00	3	G	A78	-98.9714	38.2142	-57352.	149625.	5.71	31.96	6	32	1
028401-00	21	15W	34	DACC	1000.00	195.00	3	G	A78	-98.9528	38.1787	-55765.	145650.	8.26	31.21	9	32	1
029649-00	21	16W	26	ACDB	640.00	120.00	3	G	A78	-99.0465	38.1975	-63904.	147816.	4.08	28.07	5	29	1
030867-00	21	16W	26	BCAC	715.00	131.00	3	G	A78	-99.0558	38.1985	-64715.	147926.	3.71	27.71	4	28	1

Appendix 1. Well data (cont)

(a)					(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section					Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
030794-00	21	16W	34	CBCB	580.00	110.00	3	G A78	-99.0763	38.1794	-66514.	145807.	4.05	26.02	5	27	1
030652-00	22	14W	7	BDBB	1000.00	225.00	3	G A78	-98.9071	38.1558	-51802.	143075.	11.04	32.16	12	33	0
028592-00	22	14W	8	ACBB	1600.00	240.00	3	G A78	-98.8846	38.1558	-49837.	143052.	11.81	33.11	12	34	0
029811-00	22	14W	11	BCAA	775.00	180.00	3	G A78	-98.8351	38.1555	-45531.	143002.	13.49	35.19	14	36	0
029455-00	22	15W	14	ACDA	700.00	117.00	3	G A78	-98.9358	38.1396	-54309.	141279.	10.96	30.24	11	31	1
029271-00	22	15W	16	CDBB	620.00	103.00	3	G A78	-98.9805	38.1342	-58213.	140705.	9.74	28.11	10	29	1
030086-00	22	15W	28	CBC	800.00	198.00	3	G A78	-98.9844	38.1065	-58575.	137618.	11.10	26.74	12	27	0
029467-00	22	16W	3	ABD	150.00	84.60	3	G A78	-99.0642	38.1717	-65474.	144944.	4.87	26.19	5	27	1
029201-00	22	16W	17	AAA	450.00	9.00	3	G A78	-99.0963	38.1445	-68292.	141930.	5.26	23.66	6	24	1
029706-00	22	16W	28	DCAB	760.00	190.00	3	G A78	-99.0831	38.1049	-67176.	137498.	7.85	22.50	8	23	1
030491-00	22	17W	16	CDAD	480.00	125.00	3	G A78	-99.1960	38.1330	-76996.	140727.	2.50	18.94	3	19	1
030351-00	22	18W	13	DBAA	1000.00	237.00	3	G A78	-99.2456	38.1374	-81311.	141265.	0.58	17.04	1	18	0
029631-00	23	15W	3	CCAA	775.00	195.00	3	G A78	-98.9635	38.0760	-56778.	134201.	13.46	26.31	14	27	0
028625-00	23	15W	8	ADBB	710.00	178.00	3	G A78	-98.9896	38.0687	-59059.	133404.	12.97	24.89	13	25	0
029633-00	23	15W	9	BDBB	1200.00	240.00	3	G A78	-98.9805	38.0687	-58269.	133399.	13.28	25.27	14	26	0
029632-00	23	16W	24	ADBB	1200.00	240.00	3	G A78	-99.0256	38.0397	-62224.	130184.	13.33	22.10	14	23	0
030172-00	23	16W	30	CCBC	770.00	239.00	3	G A78	-99.1313	38.0167	-71467.	127694.	10.99	16.62	11	17	1
030407-00	23	16W	34	CCAA	735.00	183.00	3	G A78	-99.0728	38.0032	-66375.	126152.	13.70	18.52	14	19	0
030327-00	23	17W	7	ADC	800.00	147.00	3	G A78	-99.2262	38.0662	-79697.	133298.	5.09	14.76	6	15	1
029245-00	23	17W	14	BDBB	850.00	120.00	3	G A78	-99.1631	38.0540	-74207.	131880.	7.89	16.90	8	17	1
030008-00	23	17W	29	ADBB	760.00	164.00	3	G A78	-99.2088	38.0249	-78222.	128672.	7.91	13.70	8	14	1
030007-00	23	17W	30	CADA	835.00	150.00	3	G A78	-99.2322	38.0195	-80272.	128094.	7.41	12.48	8	13	1
029660-00	23	17W	35	ACAA	590.00	182.00	3	G A78	-99.1553	38.0103	-73572.	126998.	10.52	15.33	11	16	1
030893-00	23	18W	28	CDBA	600.00	126.00	3	G A78	-99.3074	38.0181	-86837.	128010.	4.92	9.24	5	10	1
030894-00	23	18W	32	ADCA	635.00	126.00	3	G A78	-99.3165	38.0091	-87646.	127014.	5.10	8.46	6	9	1
030439-00	23	18W	33	DCAA	660.00	141.00	3	G A78	-99.3005	38.0036	-86250.	126387.	5.94	8.90	6	9	1
029103-00	23	18W	35	CDBB	840.00	182.00	3	G A78	-99.2718	38.0034	-83746.	126333.	6.93	10.10	7	11	1
029937-00	24	16W	4	DDBB	850.00	126.00	3	G A78	-99.0809	37.9887	-67095.	124532.	14.21	17.54	15	18	0
030171-00	24	16W	5	BDBB	915.00	195.00	3	G A78	-99.1084	37.9958	-69493.	125351.	12.89	16.69	13	17	1
029776-00	24	16W	19	CACC	780.00	188.00	3	G A78	-99.1268	37.9458	-71150.	119780.	14.97	13.73	15	14	0
030018-00	24	17W	3	CCAA	720.00	197.00	3	G A78	-99.1828	37.9882	-75992.	124563.	10.78	13.21	11	14	1
028739-00	24	17W	4	CCAA	700.00	143.00	3	G A78	-99.2009	37.9883	-77579.	124584.	10.16	12.44	11	13	1
028738-00	24	17W	4	DACC	700.00	97.00	3	G A78	-99.1907	37.9892	-76687.	124675.	10.46	12.91	11	13	1
030507-00	24	17W	7	BDBB	545.00	159.00	3	G A78	-99.2357	37.9812	-80618.	123824.	9.36	10.66	10	11	1
030773-00	24	18W	5	CABB	1300.00	285.00	3	G A78	-99.3267	37.9930	-88551.	125219.	5.63	7.32	6	8	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
029056-00	24	18W	8	BDDA	650.00	141.00	3	G A78	-99.3233	37.9801	-88272.	123786.	6.43	6.91	7	7	1
029055-00	24	18W	18	BACC	655.00	99.00	3	G A78	-99.3448	37.9683	-90167.	122489.	6.34	5.48	7	6	1
029927-00	24	18W	22	ADDC	695.00	166.00	3	G A78	-99.2788	37.9498	-84422.	120353.	9.59	7.47	10	8	1
029925-00	24	18W	22	CDBB	900.00	237.00	3	G A78	-99.2903	37.9453	-85430.	119862.	9.44	6.79	10	7	1
029926-00	24	18W	28	BDBB	900.00	150.00	3	G A78	-99.3085	37.9381	-87036.	119076.	9.21	5.70	10	6	1
029092-00	24	18W	32	BCAA	805.00	98.00	3	G A78	-99.3280	37.9236	-88756.	117478.	9.33	4.24	10	5	1
030317-00	24	19W	13	DACD	535.00	71.00	3	G A78	-99.3528	37.9611	-90873.	121685.	6.46	4.83	7	5	1
030336-00	24	19W	22	BDBB	600.00	240.00	3	G A78	-99.3997	37.9529	-94985.	120827.	5.30	2.49	6	3	1
030647-00	24	19W	23	ADA	1200.00	400.00	3	G A78	-99.3692	37.9526	-92318.	120761.	6.36	3.77	7	4	1
028799-00	25	17W	6	DBAD	1200.00	360.00	3	G A78	-99.2283	37.9040	-80066.	115202.	13.78	7.61	14	8	0
029304-00	25	18W	7	BCAA	1000.00	195.00	3	G A78	-99.3461	37.8943	-90376.	114230.	10.29	2.20	11	3	1
029193-00	25	18W	22	CDBB	1035.00	160.00	3	G A78	-99.2902	37.8576	-85526.	110085.	14.18	2.98	15	3	0
031444-00	19	13W	27	CCAD	705.00	114.00	3	G A79	-98.7513	38.3640	-38116.	166227.	5.01	47.76	6	48	0
032035-00	19	14W	22	ACB	500.00	8.50	3	G A79	-98.8561	38.3862	-47203.	168753.	0.28	44.29	1	45	0
032527-00	19	14W	26	CBDB	0.00	38.00	3	G A79	-98.8450	38.3667	-46249.	166573.	1.71	43.92	2	44	1
032528-00	19	14W	26	CCA	1250.00	130.00	3	G A79	-98.8443	38.3644	-46197.	166321.	1.85	43.84	2	44	1
032451-00	19	14W	28	DBCB	600.00	82.50	3	G A79	-98.8749	38.3667	-48852.	166591.	0.70	42.65	1	43	0
031418-00	20	12W	31	BDBB	700.00	178.00	3	G A79	-98.6951	38.2713	-33279.	155863.	11.93	46.13	12	47	-1
032445-00	20	13W	29	ADBB	835.00	195.00	3	G A79	-98.7782	38.2858	-40494.	157517.	8.34	43.24	9	44	1
031377-00	20	14W	2	ACBC	875.00	68.00	3	G A79	-98.8377	38.3422	-45634.	163836.	3.28	43.16	4	44	1
031378-00	20	14W	2	ACBC	0.00	68.00	3	G A79	-98.8377	38.3422	-45634.	163836.	3.28	43.16	4	44	1
032520-00	20	14W	5	BDCC	675.00	120.00	3	G A79	-98.8978	38.3404	-50856.	163662.	1.36	40.54	2	41	1
031380-00	20	14W	8	CDBB	600.00	59.00	3	G A79	-98.8978	38.3212	-50868.	161529.	2.40	39.72	3	40	1
031376-00	20	14W	11	ADBB	1200.00	240.00	3	G A79	-98.8330	38.3286	-45232.	162318.	4.18	42.77	5	43	1
031379-00	20	14W	17	CCCC	1200.00	117.00	3	G A79	-98.9024	38.3039	-51284.	159601.	3.18	38.77	4	39	1
031453-00	20	14W	18	DACC	975.00	120.00	3	G A79	-98.9070	38.3076	-51679.	160013.	2.82	38.74	3	39	1
031452-00	20	14W	20	ABAA	820.00	146.00	3	G A79	-98.8897	38.3029	-50182.	159476.	3.66	39.26	4	40	1
032213-00	20	14W	20	CDBB	785.00	134.00	3	G A79	-98.8979	38.2923	-50896.	158300.	3.96	38.46	4	39	1
032444-00	20	14W	21	DCAA	780.00	198.00	3	G A79	-98.8713	38.2932	-48588.	158384.	4.81	39.62	5	40	1
031197-00	21	14W	1	BDBB	1110.00	195.00	3	G A79	-98.8157	38.2571	-43775.	154324.	8.64	40.41	9	41	1
031196-00	21	14W	1	DDB	2200.00	480.00	3	G A79	-98.8060	38.2496	-42934.	153483.	9.38	40.50	10	41	1
032179-00	21	14W	12	DDBB	1000.00	240.00	3	G A79	-98.8065	38.2355	-42986.	151916.	10.12	39.87	11	40	1
032463-00	21	14W	15	ACAA	720.00	169.00	3	G A79	-98.8444	38.2283	-46293.	151131.	9.23	37.95	10	38	1
031303-00	21	14W	22	CDBB	1000.00	240.00	3	G A79	-98.8524	38.2066	-46999.	148707.	10.14	36.67	11	37	1
031577-00	21	15W	5	CDB	800.00	120.00	3	G A79	-98.9987	38.2499	-59698.	153626.	2.86	32.36	3	33	1

Appendix 1. Well data (cont)

(a)					(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section					Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
031578-00	21	15W	5	DDCC	1000.00	150.00	3	G A79	-98.9900	38.2478	-58949.	153384.	3.26	32.63	4	33	1
032003-00	21	15W	7	ABDA	750.00	62.00	3	G A79	-99.0094	38.2449	-60633.	153076.	2.77	31.69	3	32	1
031575-00	21	15W	8	ABC	1200.00	240.00	3	G A79	-98.9940	38.2446	-59300.	153031.	3.30	32.32	4	33	1
031576-00	21	15W	8	BBBB	800.00	84.00	3	G A79	-99.0038	38.2468	-60151.	153282.	2.85	32.00	3	33	1
031591-00	21	15W	8	CBCC	955.00	180.00	3	G A79	-99.0038	38.2368	-60154.	152167.	3.40	31.57	4	32	1
031566-00	21	15W	8	CDCC	520.00	60.00	3	G A79	-98.9992	38.2332	-59754.	151764.	3.75	31.61	4	32	1
031563-00	21	15W	8	DCBB	400.00	106.00	3	G A79	-98.9946	38.2360	-59353.	152070.	3.75	31.93	4	32	1
031214-00	21	15W	18	AAAA	620.00	120.00	3	G A79	-99.0049	38.2322	-60253.	151660.	3.60	31.33	4	32	1
031417-00	21	15W	26	BCAA	675.00	125.00	3	G A79	-98.9449	38.1995	-55058.	147966.	7.41	32.45	8	33	1
031715-00	21	15W	33	DDBB	730.00	184.00	3	G A79	-98.9712	38.1778	-57366.	145567.	7.69	30.40	8	31	1
031403-00	21	15W	35	DDBB	695.00	108.00	3	G A79	-98.9344	38.1777	-54161.	145530.	8.94	31.95	9	32	1
031545-00	21	16W	34	BCBC	600.00	117.00	3	G A79	-99.0762	38.1839	-66508.	146314.	3.81	26.22	4	27	1
032365-00	22	14W	16	DDBB	1100.00	240.00	3	G A79	-98.8616	38.1338	-47847.	140594.	13.78	33.13	14	34	0
031600-00	22	15W	7	CACC	760.00	165.00	3	G A79	-99.0166	38.1497	-61347.	142453.	7.68	27.25	8	28	1
031946-00	22	15W	15	CBCB	535.00	120.00	3	G A79	-98.9667	38.1360	-57011.	140898.	10.10	28.77	11	29	1
031216-00	22	15W	16	DDBB	1200.00	120.00	3	G A79	-98.9713	38.1342	-57414.	140699.	10.05	28.50	11	29	1
031217-00	22	15W	16	DDBB	0.00	120.00	3	G A79	-98.9713	38.1342	-57414.	140699.	10.05	28.50	11	29	1
032016-00	22	15W	34	CCAA	710.00	138.00	3	G A79	-98.9634	38.0906	-56754.	135828.	12.68	26.94	13	27	0
032015-00	22	15W	35	CCAA	850.00	171.00	3	G A79	-98.9451	38.0906	-55159.	135820.	13.30	27.72	14	28	0
031830-00	22	15W	35	DACC	0.00	63.00	3	G A79	-98.9348	38.0915	-54259.	135913.	13.60	28.20	14	29	0
031622-00	22	15W	35	DACC	720.00	65.00	3	G A79	-98.9348	38.0915	-54259.	135913.	13.60	28.20	14	29	0
031941-00	22	16W	21	ADBB	370.00	102.00	3	G A79	-99.0808	38.1267	-66957.	139930.	6.75	23.54	7	24	1
031940-00	22	16W	21	DDAA	350.00	193.22	6	G A79	-99.0773	38.1194	-66659.	139116.	7.26	23.37	8	24	1
031431-00	23	16W	5	CDAA	510.00	195.00	3	G A79	-99.1050	38.0757	-69117.	134264.	8.69	20.30	9	21	1
031427-00	23	16W	5	DACC	640.00	198.00	3	G A79	-99.0992	38.0766	-68614.	134362.	8.83	20.59	9	21	1
031425-00	23	16W	8	ADAA	655.00	167.00	3	G A79	-99.0958	38.0685	-68325.	133449.	9.39	20.38	10	21	1
031426-00	23	16W	8	BAAA	365.00	147.00	3	G A79	-99.1050	38.0721	-69120.	133859.	8.88	20.14	9	21	1
031623-00	23	16W	11	BCAB	1000.00	240.00	3	G A79	-99.0555	38.0686	-64804.	133438.	10.75	22.09	11	23	1
031430-00	23	16W	23	BDBB	725.00	198.00	3	G A79	-99.0533	38.0396	-64637.	130199.	12.39	20.93	13	21	0
031428-00	23	16W	23	CCAA	725.00	198.00	3	G A79	-99.0544	38.0324	-64743.	129389.	12.75	20.56	13	21	0
031429-00	23	16W	23	DACC	645.00	198.00	3	G A79	-99.0440	38.0333	-63837.	129483.	13.05	21.04	14	22	0
032393-00	23	17W	23	DDAA	410.00	121.00	3	G A79	-99.1506	38.0322	-73142.	129444.	9.49	16.48	10	17	1
031667-00	23	17W	35	CDBB	700.00	195.00	3	G A79	-99.1634	38.0029	-74285.	126186.	10.64	14.67	11	15	1
032430-00	24	17W	9	ADBB	1200.00	240.00	3	G A79	-99.1908	37.9810	-76698.	123758.	10.90	12.55	11	13	1
031335-00	24	17W	14	DBDD	920.00	195.00	3	G A79	-99.1555	37.9601	-73637.	121403.	13.23	13.14	14	14	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
032322-00	24	17W	15	ADBB	1200.00	240.00	3	G A79	-99.1725	37.9664	-75121.	122121.	12.30	12.69	13	13	1
032323-00	24	17W	15	BDBB	1200.00	240.00	3	G A79	-99.1817	37.9665	-75921.	122132.	11.99	12.31	12	13	1
031506-00	24	17W	20	ADCC	0.00	135.00	3	G A79	-99.2090	37.9493	-78330.	120235.	11.99	10.40	12	11	1
032321-00	24	17W	26	CDBB	1055.00	195.00	3	G A79	-99.1635	37.9303	-74374.	118077.	14.57	11.50	15	12	0
032521-00	24	17W	27	CACC	965.00	195.00	3	G A79	-99.1818	37.9311	-75972.	118191.	13.90	10.76	14	11	0
031628-00	24	17W	33	BDBB	825.00	182.00	3	G A79	-99.2001	37.9230	-77575.	117295.	13.72	9.64	14	10	0
031966-00	24	18W	11	CACC	590.00	130.00	3	G A79	-99.2718	37.9752	-83780.	123186.	8.45	8.87	9	9	1
032363-00	24	18W	12	AACC	750.00	195.00	3	G A79	-99.2444	37.9822	-81382.	123942.	9.01	10.33	10	11	1
032362-00	24	18W	12	BACC	675.00	187.00	3	G A79	-99.2535	37.9823	-82172.	123964.	8.69	9.96	9	10	1
031965-00	24	18W	21	DCBB	1000.00	231.00	3	G A79	-99.3039	37.9454	-86625.	119888.	8.97	6.21	9	7	1
031917-00	24	18W	23	CDBB	1000.00	189.00	3	G A79	-99.2720	37.9451	-83833.	119829.	10.07	7.55	11	8	1
032324-00	24	18W	36	ABDD	765.00	195.00	3	G A79	-99.2458	37.9240	-81573.	117447.	12.10	7.74	13	8	1
032524-00	25	17W	4	CDBB	725.00	160.00	3	G A79	-99.2002	37.9012	-77605.	114860.	14.89	8.68	15	9	0
032310-00	25	18W	1	DBDD	1020.00	315.00	3	G A79	-99.2459	37.9022	-81602.	115019.	13.28	6.79	14	7	0
032358-00	25	18W	5	BDBB	730.00	142.00	3	G A79	-99.3269	37.9089	-88672.	115840.	10.16	3.65	11	4	1
031630-00	25	18W	10	DDBB	900.00	217.00	3	G A79	-99.2811	37.8868	-84699.	113329.	12.91	4.63	13	5	1
032523-00	25	18W	11	DBDD	720.00	166.00	3	G A79	-99.2641	37.8877	-83207.	113415.	13.44	5.39	14	6	0
031993-00	25	19W	13	CDBB	900.00	198.00	3	G A79	-99.3633	37.8726	-91908.	111830.	10.87	0.53	11	1	0
031994-00	25	19W	13	DBAC	200.00	302.59	6	G A79	-99.3565	37.8753	-91302.	112118.	10.96	0.94	11	1	0
033500-00	19	13W	28	CAC	60.00	16.60	2	G A80	-98.7681	38.3663	-39570.	166494.	4.32	47.15	5	48	0
032737-00	19	13W	28	CDA	210.00	55.00	2	G A80	-98.7657	38.3645	-39368.	166289.	4.50	47.17	5	48	0
032977-00	19	13W	34	DCDD	600.00	135.00	3	G A80	-98.7422	38.3478	-37334.	164413.	6.19	47.44	7	48	0
032979-00	19	14W	28	CDBD	1400.00	177.00	3	G A80	-98.8784	38.3640	-49155.	166289.	0.73	42.39	1	43	0
033276-00	19	14W	31	DAD	825.00	165.00	3	G A80	-98.9042	38.3518	-51407.	164940.	0.52	40.77	1	41	0
032788-00	20	13W	8	BDBA	645.00	162.00	3	G A80	-98.7860	38.3294	-41149.	162384.	5.72	44.79	6	45	1
033313-00	20	14W	31	BBDB	1000.00	69.00	3	G A80	-98.9187	38.2733	-52725.	156195.	4.29	36.76	5	37	1
033508-00	20	15W	36	AAC	530.00	80.00	3	G A80	-98.9248	38.2729	-53255.	156151.	4.10	36.48	5	37	1
033725-00	21	12W	5	AACC	0.00	97.50	3	G A80	-98.6597	38.2577	-30204.	154332.	13.86	47.04	14	48	0
033520-00	21	13W	4	BBB	1000.00	240.00	3	G A80	-98.7648	38.2600	-39348.	154626.	10.20	42.69	11	43	1
033375-00	21	13W	32	BDBB	980.00	198.00	3	G A80	-98.7795	38.1845	-40667.	146212.	13.80	38.80	14	39	0
033195-00	21	14W	26	DDBB	765.00	195.00	3	G A80	-98.8249	38.1920	-44612.	147061.	11.86	37.20	12	38	1
033347-00	21	14W	30	BDBB	1200.00	219.00	3	G A80	-98.9071	38.1994	-51770.	147933.	8.69	34.04	9	35	1
033348-00	21	14W	30	CDBB	1200.00	222.00	3	G A80	-98.9070	38.1921	-51768.	147122.	9.08	33.73	10	34	1
033025-00	21	15W	8	ACC	700.00	60.00	3	G A80	-98.9940	38.2410	-59301.	152627.	3.50	32.17	4	33	1
033027-00	21	15W	8	BCBC	1045.00	156.00	3	G A80	-99.0038	38.2422	-60153.	152775.	3.10	31.81	4	32	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
032911-00 21 15W 9 CCDD	370.00	78.00	3	G A80	-98.9819	38.2334	-58251.	151770.	4.32	32.35	5	33	1
033161-00 21 15W 17 BBAA	90.00	42.60	6	G A80	-99.0003	38.2323	-59854.	151662.	3.76	31.53	4	32	1
032904-00 21 15W 17 DDBB	1000.00	134.00	3	G A80	-98.9898	38.2215	-58953.	150451.	4.69	31.50	5	32	1
033314-00 21 15W 20 ACBD	675.00	17.00	3	G A80	-98.9932	38.2133	-59254.	149538.	5.02	31.00	6	32	1
033346-00 21 15W 25 AACC	835.00	198.00	3	G A80	-98.9161	38.2003	-52554.	148039.	8.33	33.70	9	34	1
033044-00 22 14W 6 CDBB	1000.00	240.00	3	G A80	-98.9071	38.1631	-51794.	143885.	10.65	32.47	11	33	1
032732-00 22 14W 8 CDBB	1200.00	240.00	3	G A80	-98.8892	38.1485	-50242.	142246.	12.05	32.60	13	33	0
032827-00 22 15W 7 ACBB	800.00	240.00	3	G A80	-99.0122	38.1560	-60955.	143159.	7.48	27.71	8	28	1
033350-00 22 15W 34 DCAA	840.00	194.00	3	G A80	-98.9542	38.0906	-55957.	135824.	12.99	27.33	13	28	0
033144-00 22 16W 16 ADDD	255.00	74.00	3	G A80	-99.0773	38.1385	-66645.	141250.	6.23	24.20	7	25	1
033041-00 22 16W 20 BDBB	815.00	192.00	3	G A80	-99.1083	38.1266	-69353.	139943.	5.82	22.37	6	23	1
033708-00 22 17W 2 ABDC	150.00	28.84	2	G A80	-99.1561	38.1711	-73471.	144948.	1.80	22.29	2	23	1
032957-00 22 17W 22 ACDA	800.00	68.00	3	G A80	-99.1732	38.1249	-75012.	139805.	3.71	19.55	4	20	1
032669-00 22 17W 35 CDAA	755.00	195.00	3	G A80	-99.1596	38.0903	-73867.	135932.	6.05	18.62	7	19	1
033645-00 23 17W 11 DDBB	685.00	195.00	3	G A80	-99.1539	38.0613	-73400.	132688.	7.81	17.60	8	18	1
033300-00 24 17W 1 DDBB	1300.00	236.00	3	G A80	-99.1359	37.9884	-71904.	124544.	12.36	15.20	13	16	1
032986-00 24 17W 12 CCBB	2000.00	240.00	3	G A80	-99.1498	37.9737	-73125.	122918.	12.68	13.98	13	14	1
033682-00 24 17W 24 ABDD	900.00	165.00	3	G A80	-99.1372	37.9530	-72047.	120589.	14.23	13.61	15	14	0
033636-00 24 17W 26 ABDD	915.00	195.00	3	G A80	-99.1555	37.9384	-73663.	118984.	14.40	12.20	15	13	0
032584-00 24 17W 27 ADBB	1200.00	240.00	3	G A80	-99.1727	37.9374	-75164.	118886.	13.87	11.43	14	12	0
032587-00 24 17W 29 CBDD	700.00	175.00	3	G A80	-99.2193	37.9311	-79249.	118222.	12.62	9.18	13	10	1
032585-00 24 17W 32 ACAA	780.00	192.00	3	G A80	-99.2103	37.9230	-78468.	117302.	13.37	9.20	14	10	0
032586-00 24 17W 32 DDBB	1200.00	240.00	3	G A80	-99.2092	37.9157	-78383.	116491.	13.80	8.93	14	9	0
032596-00 24 18W 25 BCB	1050.00	177.99	4	G A80	-99.2578	37.9373	-82602.	118940.	10.98	7.81	11	8	1
033177-00 24 19W 26 CBD	500.00	68.00	3	G A80	-99.3830	37.9325	-93545.	118533.	6.97	2.31	7	3	1
032958-00 25 18W 32 BCA	1000.00	120.00	3	G A80	-99.3289	37.8355	-88944.	107653.	14.05	0.37	15	1	0
033703-00 25 18W 33 BCAA	980.00	195.00	3	G A80	-99.3101	37.8359	-87294.	107675.	14.67	1.18	15	2	0
033757-00 19 13W 21 DCBB	585.00	30.00	3	G A81	-98.7642	38.3795	-39226.	167962.	3.73	47.88	4	48	0
033857-00 20 12W 31 ADBB	1000.00	240.00	3	G A81	-98.6860	38.2713	-32481.	155858.	12.24	46.52	13	47	-1
034440-00 20 13W 7 DDBB	1200.00	240.00	3	G A81	-98.7964	38.3221	-42059.	161573.	5.76	44.04	6	45	1
034747-00 20 13W 23 DCAA	345.00	99.00	3	G A81	-98.7241	38.2932	-35788.	158312.	9.77	45.85	10	46	1
033776-00 20 13W 29 BDBB	840.00	198.00	3	G A81	-98.7874	38.2858	-41299.	157522.	8.03	42.85	9	43	1
034128-00 20 13W 35 BDBB	1000.00	240.00	3	G A81	-98.7320	38.2713	-36490.	155877.	10.69	44.57	11	45	1
034192-00 20 13W 36 DACC	920.00	209.00	3	G A81	-98.7043	38.2649	-34078.	155156.	11.96	45.47	12	46	1
034473-00 20 14W 22 CBAA	910.00	198.00	3	G A81	-98.8620	38.2969	-47779.	158797.	4.92	40.17	5	41	1

Appendix 1. Well data (cont)

(a)	(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section	Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
034720-00 20 14W 29 ACAA	1060.00	186.00	3	G A81	-98.8899	38.2857	-50206.	157558.	4.59	38.51	5	39	1
034719-00 20 14W 29 CCAA	650.00	120.00	3	G A81	-98.8990	38.2785	-51006.	156764.	4.67	37.81	5	38	1
034721-00 20 14W 29 DDBB	1010.00	183.00	3	G A81	-98.8887	38.2787	-50112.	156775.	5.01	38.26	6	39	1
034529-00 20 15W 35 AADD	800.00	70.00	3	G A81	-98.9403	38.2726	-54604.	156120.	3.60	35.81	4	36	1
033839-00 21 14W 4 DDBB	1000.00	240.00	3	G A81	-98.8617	38.2501	-47785.	153572.	7.47	38.16	8	39	1
033849-00 21 14W 14 DDBB	900.00	240.00	3	G A81	-98.8249	38.2210	-44600.	150305.	10.29	38.46	11	39	1
034743-00 21 15W 6 ACCC	715.00	138.00	3	G A81	-99.0127	38.2546	-60911.	154161.	2.13	31.97	3	32	1
033827-00 21 15W 12 CCAA	830.00	180.00	3	G A81	-98.9264	38.2357	-53423.	151994.	6.07	34.80	7	35	1
033826-00 21 15W 12 DCAA	790.00	157.00	3	G A81	-98.9173	38.2356	-52633.	151985.	6.38	35.18	7	36	1
033895-00 22 14W 19 CDBB	1000.00	240.00	3	G A81	-98.9073	38.1196	-51844.	139030.	13.00	30.58	14	31	0
034607-00 22 14W 21 DDBC	1000.00	240.00	3	G A81	-98.8614	38.1185	-47844.	138880.	14.61	32.47	15	33	0
034038-00 22 15W 5 CDBB	800.00	154.00	3	G A81	-98.9987	38.1633	-59774.	143963.	7.55	28.60	8	29	1
034028-00 22 15W 30 CDBB	605.00	169.00	3	G A81	-99.0166	38.1051	-61382.	137478.	10.09	25.32	11	26	1
034147-00 22 16W 5 CBAD	60.00	4.60	2	G A81	-99.1096	38.1657	-69431.	144313.	3.66	24.02	4	25	1
034730-00 22 16W 10 BAA	0.00	17.89	6	G A81	-99.0688	38.1590	-65879.	143532.	5.41	25.45	6	26	1
034732-00 22 16W 10 BACC	35.00	17.86	6	G A81	-99.0716	38.1567	-66131.	143276.	5.44	25.23	6	26	1
034633-00 22 16W 10 BBBA	40.00	17.86	6	G A81	-99.0751	38.1594	-66427.	143578.	5.18	25.20	6	26	1
034733-00 22 16W 10 BCCD	60.00	27.00	6	G A81	-99.0750	38.1530	-66432.	142870.	5.52	24.93	6	25	1
034728-00 22 16W 10 BCD	40.00	17.89	6	G A81	-99.0733	38.1535	-66282.	142921.	5.55	25.02	6	26	1
034731-00 22 16W 10 BDA	40.00	17.89	6	G A81	-99.0688	38.1554	-65883.	143126.	5.61	25.29	6	26	1
034729-00 22 16W 10 BDD	40.00	17.89	6	G A81	-99.0687	38.1535	-65884.	142922.	5.70	25.22	6	26	1
034026-00 22 16W 12 ADBB	740.00	195.00	3	G A81	-99.0257	38.1560	-62128.	143167.	7.03	27.14	8	28	1
034039-00 22 16W 13 DDBB	775.00	166.00	3	G A81	-99.0256	38.1342	-62145.	140736.	8.21	26.20	9	27	1
034002-00 22 16W 14 AAAB	0.00	114.00	3	G A81	-99.0417	38.1450	-63536.	141951.	7.08	25.99	8	26	1
034592-00 22 16W 20 DAA	175.00	32.00	2	G A81	-99.0963	38.1225	-68313.	139477.	6.45	22.70	7	23	1
034029-00 22 16W 36 CDBB	620.00	164.00	3	G A81	-99.0348	38.0905	-62984.	135864.	10.26	23.91	11	24	1
034023-00 22 17W 11 CCAA	1000.00	180.00	3	G A81	-99.1636	38.1486	-74154.	142443.	2.76	20.99	3	21	1
034024-00 22 17W 11 CCAA	0.00	180.00	3	G A81	-99.1636	38.1486	-74154.	142443.	2.76	20.99	3	21	1
034025-00 22 17W 14 BCAA	1000.00	180.00	3	G A81	-99.1637	38.1413	-74173.	141630.	3.15	20.67	4	21	1
034752-00 23 15W 30 ADBB	910.00	175.00	3	G A81	-99.0082	38.0251	-60715.	128550.	14.71	22.21	15	23	0
034678-00 23 16W 4 CDBB	635.00	109.00	3	G A81	-99.0900	38.0758	-67811.	134259.	9.19	20.94	10	21	1
034065-00 23 16W 11 BDB	0.00	48.00	3	G A81	-99.0526	38.0682	-64554.	133385.	10.87	22.19	11	23	1
034281-00 23 16W 31 BDBB	740.00	195.00	3	G A81	-99.1267	38.0103	-71076.	126981.	11.49	16.54	12	17	1
034417-00 23 16W 31 DBBB	625.00	159.00	3	G A81	-99.1221	38.0067	-70680.	126574.	11.84	16.58	12	17	1
033899-00 23 16W 34 ADBB	1000.00	240.00	3	G A81	-99.0625	38.0106	-65470.	126962.	13.65	19.27	14	20	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
034170-00	23	17W	2	ADBB	805.00	114.00	3	G A81	-99.1539	38.0830	-73377.	135120.	6.63	18.55	7	19	1
034171-00	23	17W	2	BDBB	680.00	86.00	3	G A81	-99.1631	38.0830	-74179.	135126.	6.32	18.16	7	19	1
034556-00	23	17W	26	DDBB	640.00	189.00	3	G A81	-99.1541	38.0176	-73458.	127814.	10.17	15.70	11	16	1
033750-00	23	19W	29	DDBB	1000.00	231.00	3	G A81	-99.4274	38.0184	-97313.	128162.	0.82	4.18	1	5	0
034280-00	24	17W	12	DDBB	915.00	210.00	3	G A81	-99.1360	37.9738	-71925.	122919.	13.14	14.56	14	15	0
034270-00	24	19W	28	DBC	200.00	19.00	3	G A81	-99.4127	37.9325	-96145.	118559.	5.96	1.05	6	2	-1
034271-00	24	19W	28	DBC	200.00	19.00	3	G A81	-99.4127	37.9325	-96145.	118559.	5.96	1.05	6	2	-1
035141-00	19	14W	35	DDBB	1400.00	143.00	3	G A82	-98.8332	38.3504	-45241.	164747.	2.99	43.70	3	44	1
035033-00	20	12W	19	CDBB	1200.00	238.00	3	G A82	-98.6951	38.2931	-33268.	158293.	10.74	47.07	11	48	0
035283-00	20	13W	22	CACB	1000.00	230.00	3	G A82	-98.7505	38.2950	-38085.	158525.	8.78	44.81	9	45	1
035191-00	20	13W	25	BDBB	1000.00	240.00	3	G A82	-98.7137	38.2859	-34884.	157498.	10.51	45.97	11	46	1
035193-00	20	13W	25	CDBB	1000.00	240.00	3	G A82	-98.7136	38.2786	-34884.	156688.	10.91	45.66	11	46	1
035196-00	20	13W	26	CDCB	805.00	201.00	3	G A82	-98.7321	38.2768	-36491.	156487.	10.39	44.80	11	45	1
035199-00	20	13W	26	DDDD	815.00	203.00	3	G A82	-98.7194	38.2759	-35387.	156387.	10.86	45.30	11	46	1
035192-00	20	13W	27	ADBB	1000.00	240.00	3	G A82	-98.7414	38.2859	-37295.	157505.	9.58	44.80	10	45	1
035222-00	20	14W	4	CAAA	1200.00	225.00	3	G A82	-98.8758	38.3395	-48944.	163553.	2.15	41.44	3	42	1
035307-00	20	14W	16	BAB	900.00	60.00	3	G A82	-98.8788	38.3172	-49219.	161065.	3.26	40.34	4	41	1
035296-00	21	14W	17	ADBB	1000.00	231.00	3	G A82	-98.8801	38.2284	-49399.	151154.	8.03	36.44	9	37	1
035295-00	21	14W	17	BDBB	1000.00	231.00	3	G A82	-98.8893	38.2284	-50196.	151163.	7.71	36.05	8	37	1
035624-00	21	14W	27	ADBB	1000.00	180.00	3	G A82	-98.8432	38.1992	-46207.	147883.	10.85	36.74	11	37	1
034895-00	21	15W	28	BDBB	1000.00	240.00	3	G A82	-98.9806	38.1997	-58167.	148012.	6.19	30.95	7	31	1
035634-00	21	15W	29	BDCB	20.00	25.01	6	G A82	-98.9989	38.1979	-59760.	147820.	5.67	30.09	6	31	1
035181-00	21	16W	34	DCBB	1200.00	90.00	3	G A82	-99.0671	38.1776	-65721.	145602.	4.46	26.33	5	27	1
034975-00	22	13W	5	ADBB	870.00	189.00	3	G A82	-98.7702	38.1698	-39868.	144567.	14.91	38.56	15	39	0
035139-00	22	15W	6	ADD	1100.00	240.00	3	G A82	-99.0050	38.1683	-60315.	144526.	7.06	28.55	8	29	1
035111-00	22	15W	11	CDDD	1000.00	240.00	3	G A82	-98.9403	38.1460	-54699.	141992.	10.46	30.32	11	31	1
035368-00	22	15W	18	DDBB	1030.00	152.00	3	G A82	-99.0078	38.1342	-60593.	140725.	8.81	26.95	9	27	1
034920-00	22	15W	28	ABAB	500.00	120.00	3	G A82	-98.9734	38.1161	-57610.	138682.	10.96	27.63	11	28	1
034921-00	22	15W	28	ABCB	500.00	120.00	3	G A82	-98.9757	38.1143	-57813.	138479.	10.98	27.45	11	28	1
035168-00	22	15W	31	DDBB	1200.00	198.00	3	G A82	-99.0078	38.0905	-60630.	135848.	11.18	25.06	12	26	1
034918-00	22	16W	34	DABB	755.00	195.00	3	G A82	-99.0624	38.0941	-65383.	136279.	9.14	22.90	10	23	1
035112-00	22	16W	36	ADBB	1100.00	240.00	3	G A82	-99.0256	38.0978	-62172.	136669.	10.18	24.62	11	25	1
035369-00	22	17W	36	ADBB	885.00	194.00	3	G A82	-99.1356	38.0975	-71762.	136720.	6.47	19.96	7	20	1
035376-00	22	18W	13	DBAA	550.00	160.00	3	G A82	-99.2456	38.1374	-81311.	141265.	0.58	17.04	1	18	0
035375-00	22	18W	13	DBBA	350.00	80.00	3	G A82	-99.2479	38.1374	-81511.	141270.	0.50	16.94	1	17	0

Appendix 1. Well data (cont)

(a)	(b)	(c)	(d)	(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section	Rate (gpm)	Approp (ac-ft)	Use code	Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
035806-00 23 15W 29 BBBB	845.00	195.00	3	G A82	-99.0039	38.0288	-60336.	128951.	14.66	22.55	15	23	0
035226-00 23 16W 1 AADA	1000.00	240.00	3	G A82	-99.0222	38.0850	-61890.	135245.	10.99	24.21	11	25	1
035767-00 23 17W 8 DAAD	360.00	79.00	3	G A82	-99.2054	38.0638	-77883.	133016.	5.92	15.54	6	16	1
035766-00 23 17W 8 DDAA	170.00	64.00	3	G A82	-99.2054	38.0611	-77886.	132710.	6.07	15.42	7	16	1
035304-00 23 17W 15 CDBB	600.00	139.00	3	G A82	-99.1814	38.0466	-75814.	131076.	7.67	15.80	8	16	1
035635-00 24 17W 1 BDBB	1200.00	240.00	3	G A82	-99.1452	37.9956	-72701.	125358.	11.65	15.12	12	16	1
034879-00 24 17W 24 BDBB	1200.00	228.00	3	G A82	-99.1452	37.9520	-72748.	120491.	14.01	13.23	15	14	0
035204-00 25 18W 8 DCAA	955.00	195.00	3	G A82	-99.3187	37.8868	-87983.	113369.	11.63	3.04	12	4	1
035914-00 19 14W 31 DDDD	900.00	195.00	3	G A83	-98.9036	38.3477	-51356.	164485.	0.77	40.62	1	41	0
036379-00 19 14W 34 AACB	10.00	0.01	2	G A83	-98.8517	38.3595	-46842.	165769.	1.88	43.32	2	44	1
036205-00 19 14W 34 DDCB	250.00	189.96	2	G A83	-98.8516	38.3486	-46838.	164557.	2.47	42.85	3	43	1
036403-00 20 14W 31 ADBB	1000.00	195.00	3	G A83	-98.9090	38.2715	-51883.	155986.	4.71	37.09	5	38	1
036404-00 20 14W 31 DDBB	970.00	195.00	3	G A83	-98.9126	38.2643	-52198.	155181.	4.98	36.62	5	37	1
035908-00 21 12W 6 ADBB	1000.00	240.00	3	G A83	-98.6781	38.2568	-31801.	154231.	13.29	46.22	14	47	0
036169-00 21 13W 13 ADBC	0.00	100.00	3	G A83	-98.6964	38.2265	-33413.	150866.	14.31	44.14	15	45	0
036382-00 21 14W 22 ADBB	1200.00	230.00	3	G A83	-98.8432	38.2138	-46198.	149504.	10.06	37.37	11	38	1
036266-00 21 14W 29 ACAD	1000.00	246.00	3	G A83	-98.8812	38.1984	-49513.	147814.	9.61	35.10	10	36	1
035873-00 21 16W 27 DCBA	700.00	135.00	3	G A83	-99.0660	38.1921	-65612.	147223.	3.71	27.00	4	28	1
035953-00 22 14W 3 CDBB	1000.00	240.00	3	G A83	-98.8523	38.1629	-47025.	143833.	12.51	34.78	13	35	0
036010-00 22 14W 17 ADBB	1000.00	240.00	3	G A83	-98.8800	38.1412	-49447.	141427.	12.76	32.67	13	33	0
035903-00 22 14W 32 BDCB	1000.00	240.00	3	G A83	-98.8892	38.0959	-50284.	136380.	14.90	30.32	15	31	0
036178-00 22 17W 27 BCDB	250.00	83.00	3	G A83	-99.1834	38.1103	-75920.	138183.	4.16	18.49	5	19	1
035939-00 22 18W 13 CBBB	500.00	120.00	3	G A83	-99.2583	38.1375	-82413.	141289.	0.14	16.51	1	17	0
036202-00 23 15W 6 ADBB	800.00	240.00	3	G A83	-99.0078	38.0832	-60634.	135034.	11.57	24.74	12	25	1
036201-00 23 15W 6 BDBB	0.00	82.00	3	G A83	-99.0167	38.0832	-61408.	135039.	11.27	24.37	12	25	1
036036-00 23 15W 10 BDBB	1100.00	240.00	3	G A83	-98.9624	38.0688	-56688.	133389.	13.89	26.04	14	27	0
036275-00 23 16W 6 CCAA	800.00	240.00	3	G A83	-99.1276	38.0758	-71091.	134289.	7.92	19.35	8	20	1
035896-00 23 16W 32 BBCC	1000.00	237.00	3	G A83	-99.1129	38.0113	-69871.	127079.	11.90	17.17	12	18	1
036242-00 23 17W 12 DDBB	300.00	90.00	3	G A83	-99.1356	38.0613	-71801.	132676.	8.43	18.38	9	19	1
036286-00 23 17W 33 ADBB	800.00	240.00	3	G A83	-99.1906	38.0103	-76650.	127029.	9.32	13.84	10	14	1
036103-00 24 17W 14 ADBB	1200.00	240.00	3	G A83	-99.1543	37.9665	-73531.	122110.	12.92	13.47	13	14	1
036146-00 24 18W 32 ADBB	1100.00	240.00	3	G A83	-99.3177	37.9235	-87855.	117463.	9.68	4.68	10	5	1
036423-00 19 13W 31 ACAA	500.00	184.13	4	G A84	-98.7976	38.3578	-42139.	165554.	3.79	45.53	4	46	1
036606-00 19 14W 34 AACB	1500.00	1.66	2	G A84	-98.8517	38.3595	-46842.	165769.	1.88	43.32	2	44	1
036605-00 19 14W 34 AACB	1500.00	1.66	2	G A84	-98.8517	38.3595	-46842.	165769.	1.88	43.32	2	44	1

Appendix 1. Well data (cont)

(a)					(b)	(c)	(d)		(e)	(f, g)		(h, i)		(j, k)		(l, m)		(n)
Well id, township, range, section, quarter-section					Rate (gpm)	Approp (ac-ft)	Use code		Year	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers y (m)	Grid row/col. (mi)		Grid index row/col		cell activ.
036604-00	19	14W	34	AACB	1500.00	1.66	2	G	A84	-98.8517	38.3595	-46842.	165769.	1.88	43.32	2	44	1
036926-00	20	12W	29	CDBB	710.00	189.00	3	G	A84	-98.6767	38.2785	-31676.	156664.	12.15	47.22	13	48	0
036789-00	20	13W	3	BDCC	900.00	210.00	3	G	A84	-98.7503	38.3408	-38043.	163636.	6.30	46.79	7	47	-1
036573-00	20	13W	16	BACC	600.00	81.00	3	G	A84	-98.7689	38.3157	-39670.	160848.	7.04	44.93	8	45	1
036463-00	20	14W	3	AAAB	20.00	20.00	2	G	A84	-98.8493	38.3468	-46638.	164352.	2.65	42.87	3	43	1
036467-00	20	14W	22	DDBB	865.00	195.00	3	G	A84	-98.8517	38.2933	-46880.	158387.	5.46	40.46	6	41	1
036865-00	21	13W	28	ADBB	1000.00	240.00	3	G	A84	-98.7519	38.1987	-38254.	147783.	13.96	40.59	14	41	0
036505-00	22	14W	15	ADBB	1000.00	240.00	3	G	A84	-98.8432	38.1410	-46241.	141384.	14.01	34.22	15	35	0
036521-00	22	15W	22	DDAA	350.00	92.00	3	G	A84	-98.9494	38.1197	-55510.	139062.	11.58	28.80	12	29	0
036557-00	22	15W	23	ADBB	800.00	240.00	3	G	A84	-98.9346	38.1269	-54219.	139861.	11.68	29.74	12	30	0
036722-00	22	17W	33	ADBB	1000.00	240.00	3	G	A84	-99.1904	38.0975	-76540.	136767.	4.61	17.64	5	18	1
036452-00	23	15W	7	DDBB	1000.00	240.00	3	G	A84	-99.0077	38.0615	-60643.	132604.	12.76	23.80	13	24	0
036456-00	23	16W	7	CBBC	250.00	75.00	3	G	A84	-99.1310	38.0640	-71399.	132976.	8.44	18.69	9	19	1
036940-00	23	16W	13	ADBB	900.00	240.00	3	G	A84	-99.0256	38.0541	-62215.	131800.	12.54	22.73	13	23	0
036939-00	23	16W	13	DDBB	900.00	240.00	3	G	A84	-99.0256	38.0469	-62219.	130994.	12.94	22.41	13	23	0
036455-00	23	17W	18	CDBC	600.00	141.00	3	G	A84	-99.2353	38.0458	-80518.	131030.	5.88	13.49	6	14	1
036515-00	24	17W	7	AADD	1000.00	240.00	3	G	A84	-99.2239	37.9820	-79590.	123906.	9.71	11.20	10	12	1
036794-00	24	17W	24	DDBB	875.00	169.00	3	G	A84	-99.1360	37.9448	-71956.	119683.	14.71	13.30	15	14	0
036549-00	24	17W	26	BDBB	1100.00	240.00	3	G	A84	-99.1635	37.9375	-74365.	118883.	14.18	11.82	15	12	0
036850-00	24	18W	32	BCAA	0.00	98.00	3	G	A84	-99.3280	37.9236	-88756.	117478.	9.33	4.24	10	5	1
036745-00	25	18W	16	BCAA	1200.00	214.00	3	G	A84	-99.3095	37.8795	-87189.	112543.	12.34	3.11	13	4	1
037210-00	19	14W	22	CDBB	1000.00	235.00	3	G	A85	-98.8612	38.3794	-47652.	168000.	0.47	43.78	1	44	0
037324-00	19	14W	32	ADBB	800.00	136.00	3	G	A85	-98.8888	38.3577	-50061.	165587.	0.73	41.67	1	42	0
037047-00	20	13W	4	BBDA	200.00	202.54	2	G	A85	-98.7700	38.3452	-39746.	164142.	5.40	46.16	6	47	-1
037048-00	20	13W	4	BBDB	400.00	613.77	2	G	A85	-98.7711	38.3452	-39847.	164143.	5.36	46.11	6	47	-1
037439-00	20	13W	17	CDBB	1000.00	381.00	3	G	A85	-98.7873	38.3076	-41276.	159947.	6.86	43.79	7	44	1
037056-00	20	14W	13	CDBB	1200.00	180.00	3	G	A85	-98.8240	38.3076	-44469.	159967.	5.62	42.24	6	43	1
037057-00	20	14W	13	DDBB	1200.00	240.00	3	G	A85	-98.8148	38.3077	-43669.	159971.	5.93	42.63	6	43	1
037367-00	20	14W	28	BDBB	1000.00	240.00	3	G	A85	-98.8795	38.2860	-49304.	157582.	4.92	38.96	5	39	1
037507-00	21	12W	8	ADBB	1000.00	240.00	3	G	A85	-98.6599	38.2422	-30227.	152602.	14.69	46.37	15	47	0
037069-00	21	13W	3	ADBB	1100.00	240.00	3	G	A85	-98.7331	38.2568	-36586.	154254.	11.44	43.89	12	44	1
037113-00	21	14W	23	BACC	1200.00	240.00	3	G	A85	-98.8341	38.2146	-45401.	149597.	10.32	37.79	11	38	1
036980-00	21	15W	11	BDDD	1000.00	240.00	3	G	A85	-98.9403	38.2403	-54627.	152523.	5.35	34.41	6	35	1
037238-00	21	15W	25	DDBB	1200.00	240.00	3	G	A85	-98.9160	38.1921	-52552.	147129.	8.78	33.35	9	34	1
037417-00	21	15W	31	DDBB	1200.00	195.00	3	G	A85	-99.0078	38.1779	-60553.	145595.	6.45	28.85	7	29	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
037029-00	21	15W	36	ADBB	1200.00	240.00	3	G A85	-98.9160	38.1849	-52554.	146322.	9.17	33.04	10	34	1
037190-00	21	16W	12	DDDD	1000.00	123.00	3	G A85	-99.0225	38.2330	-61788.	151753.	2.97	30.62	3	31	1
037156-00	22	15W	12	DDBB	970.00	195.00	3	G A85	-98.9162	38.1486	-52598.	142276.	11.13	31.46	12	32	0
036972-00	23	16W	33	ADBB	1000.00	240.00	3	G A85	-99.0809	38.0105	-67073.	126963.	13.04	18.49	14	19	0
037102-00	23	17W	25	ACAA	895.00	176.00	3	G A85	-99.1369	38.0249	-71950.	128614.	10.35	16.74	11	17	1
037504-00	23	18W	18	ADDD	750.00	224.00	3	G A85	-99.3327	38.0518	-89002.	131794.	2.24	9.63	3	10	0
037474-00	24	16W	7	DDBB	1000.00	240.00	3	G A85	-99.1175	37.9739	-70311.	122915.	13.77	15.35	14	16	0
037035-00	24	18W	20	ADBB	1000.00	240.00	3	G A85	-99.3176	37.9529	-87806.	120738.	8.10	5.96	9	6	1
037036-00	24	18W	20	BDBB	1000.00	240.00	3	G A85	-99.3267	37.9529	-88606.	120749.	7.79	5.58	8	6	1
036989-00	25	18W	28	ADBB	1000.00	240.00	3	G A85	-99.2994	37.8504	-86345.	109284.	14.25	2.27	15	3	0
037609-00	21	12W	7	ACDA	1000.00	120.00	3	G A86	-98.6794	38.2403	-31925.	152394.	14.14	45.46	15	46	0
037613-00	21	12W	7	BDAA	1200.00	115.50	3	G A86	-98.6839	38.2421	-32316.	152598.	13.89	45.34	14	46	0
037847-00	21	14W	4	BDBB	1200.00	110.00	3	G A86	-98.8709	38.2572	-48580.	154362.	6.77	38.07	7	39	1
037598-00	23	17W	22	CDBB	1100.00	233.00	3	G A86	-99.1815	38.0321	-75833.	129462.	8.45	15.17	9	16	1
038144-00	23	17W	31	BBAB	1000.00	165.00	3	G A87	-99.2375	38.0141	-80746.	127493.	7.52	12.01	8	13	1
038702-00	20	13W	7	CBDD	1000.00	240.00	3	G A88	-98.8067	38.3229	-42954.	161662.	5.38	43.63	6	44	1
038713-00	20	14W	29	BDBC	1010.00	186.00	3	G A88	-98.8979	38.2845	-50903.	157429.	4.38	38.12	5	39	1
038692-00	21	16W	13	DBCD	1000.00	150.00	3	G A88	-99.0293	38.2221	-62388.	150545.	3.33	29.86	4	30	1
038646-00	22	14W	12	DABB	1100.00	240.00	3	G A88	-98.8064	38.1519	-43026.	142579.	14.66	36.25	15	37	0
038623-00	22	16W	16	ADBD	325.00	96.00	3	G A88	-99.0796	38.1403	-66843.	141455.	6.05	24.18	7	25	1
038544-00	23	17W	18	CDCD	200.00	71.00	3	G A88	-99.2343	38.0440	-80425.	130827.	6.02	13.45	7	14	1
038482-00	23	18W	27	DDBB	11.67	18.82	2	G A88	-99.2810	38.0181	-84537.	127979.	5.82	10.35	6	11	1
039109-00	20	15W	27	CCCC	150.00	78.25	4	G A89	-98.9760	38.2762	-57704.	156550.	2.20	34.46	3	35	1
039056-00	21	13W	1	CDBB	1200.00	240.00	3	G A89	-98.7055	38.2494	-34191.	153420.	12.77	44.74	13	45	1
038743-00	21	13W	10	DABB	800.00	120.00	3	G A89	-98.7332	38.2386	-36610.	152226.	12.42	43.10	13	44	1
038833-00	21	13W	10	DDBB	800.00	120.00	3	G A89	-98.7333	38.2349	-36615.	151816.	12.62	42.94	13	43	0
039066-00	21	13W	11	DDBB	1200.00	240.00	3	G A89	-98.7148	38.2348	-35012.	151797.	13.24	43.72	14	44	0
039070-00	21	13W	12	BDBB	1200.00	240.00	3	G A89	-98.7056	38.2421	-34201.	152604.	13.16	44.42	14	45	0
039080-00	21	13W	12	CDBB	1200.00	240.00	3	G A89	-98.7056	38.2348	-34210.	151790.	13.56	44.11	14	45	0
038740-00	21	13W	15	ACCC	800.00	120.00	3	G A89	-98.7379	38.2249	-37028.	150705.	13.00	42.31	14	43	0
038840-00	21	13W	15	ADBB	800.00	120.00	3	G A89	-98.7333	38.2276	-36623.	151002.	13.01	42.62	14	43	0
038834-00	21	13W	15	BDBB	800.00	120.00	3	G A89	-98.7426	38.2277	-37427.	151017.	12.70	42.24	13	43	0
038742-00	21	13W	15	BDCC	800.00	120.00	3	G A89	-98.7426	38.2250	-37430.	150712.	12.84	42.12	13	43	0
038831-00	21	13W	16	BDBB	800.00	120.00	3	G A89	-98.7610	38.2279	-39031.	151047.	12.07	41.46	13	42	0
039054-00	21	14W	3	ABDD	1200.00	195.00	3	G A89	-98.8444	38.2580	-46274.	154443.	7.62	39.23	8	40	1

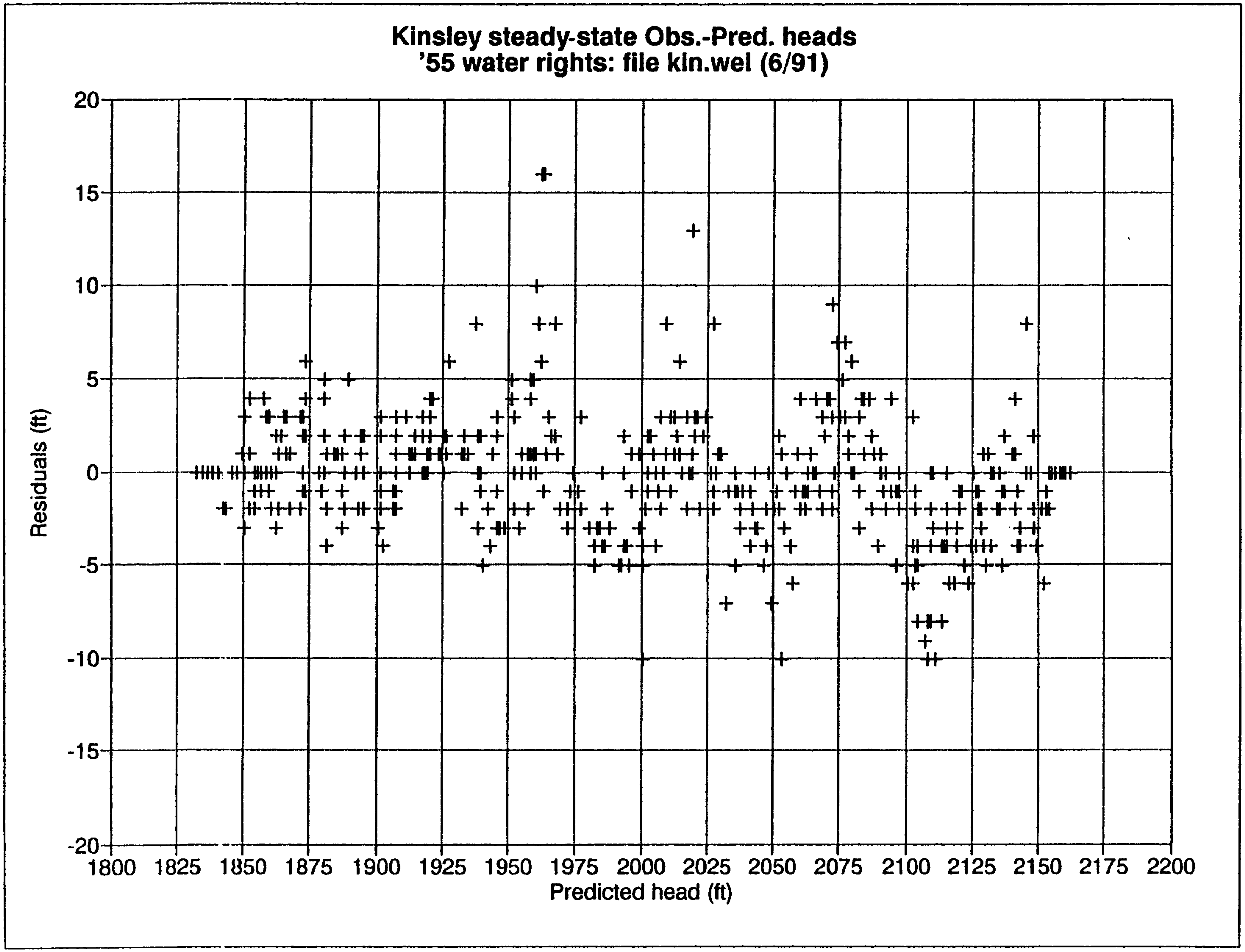
Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
039068-00	21	14W	4	BDBB	1200.00	85.00	3	G A89	-98.8709	38.2572	-48580.	154362.	6.77	38.07	7	39	1
039052-00	25	19W	12	DBCC	1200.00	209.00	3	G A89	-99.3586	37.8880	-91476.	113544.	10.20	1.40	11	2	-1
039292-00	20	13W	15	AADA	800.00	201.00	3	G A90	-98.7377	38.3166	-36959.	160933.	8.04	46.28	9	47	-1
039513-00	20	14W	12	ADAB	465.00	35.00	3	G A90	-98.8124	38.3288	-43441.	162322.	4.87	43.65	5	44	1
039446-00	21	12W	4	AACC	1000.00	179.00	3	G A90	-98.6413	38.2578	-28599.	154332.	14.47	47.83	15	48	0
039426-00	21	13W	10	BDAB	600.00	120.00	3	G A90	-98.7401	38.2423	-37210.	152643.	11.99	42.97	12	43	1
039586-00	21	13W	26	BDBB	1200.00	216.00	3	G A90	-98.7242	38.1984	-35843.	147733.	14.91	41.75	15	42	0
039435-00	21	13W	31	ACBB	1600.00	222.00	3	G A90	-98.7930	38.1846	-41843.	146228.	13.34	38.24	14	39	0
039434-00	21	13W	31	DDBB	1000.00	120.00	3	G A90	-98.7885	38.1773	-41456.	145409.	13.88	38.11	14	39	0
039793-00	23	16W	20	CDBB	1000.00	98.00	3	G A90	-99.1084	38.0322	-69454.	129411.	10.93	18.27	11	19	1
039790-00	23	16W	33	CDBB	1000.00	195.00	3	G A90	-99.0902	38.0032	-67892.	126158.	13.11	17.78	14	18	0
039758-00	23	17W	8	DDAA	150.00	41.00	3	G A90	-99.2054	38.0611	-77886.	132710.	6.07	15.42	7	16	1
039353-00	23	17W	25	BACC	1000.00	240.00	3	G A90	-99.1449	38.0258	-72649.	128726.	10.03	16.44	11	17	1
039495-00	24	16W	17	ADBB	900.00	198.00	3	G A90	-99.0992	37.9668	-68713.	122101.	14.78	15.82	15	16	0
039298-00	24	17W	18	BDAA	1000.00	150.00	3	G A90	-99.2324	37.9667	-80354.	122199.	10.25	10.17	11	11	1
899080-00	19	13W	34	CBCB	700.00	15.00	2	G A91	-98.7548	38.3523	-38427.	164924.	5.52	47.10	6	48	0
899079-00	19	13W	34	DBDC	700.00	15.00	2	G A91	-98.7433	38.3513	-37431.	164814.	5.96	47.55	6	48	0
900130-00	20	14W	13	DDCC	100.00	0.30	2	G A91	-98.8149	38.3050	-43673.	159671.	6.07	42.52	7	43	1
899104-00	20	14W	36	AABD	40.00	32.30	2	G A91	-98.8137	38.2742	-43594.	156232.	7.78	41.23	8	42	1
899103-00	20	14W	36	ABDD	40.00	16.10	2	G A91	-98.8161	38.2724	-43796.	156031.	7.80	41.05	8	42	1
899105-00	20	14W	36	ACAC	40.00	16.10	2	G A91	-98.8172	38.2706	-43898.	155830.	7.86	40.93	8	41	1
909034-00	20	15W	27	CCC	20.00	25.00	4	G A91	-98.9754	38.2767	-57653.	156600.	2.19	34.50	3	35	1
900006-00	21	13W	6	ADCB	100.00	0.30	2	G A91	-98.7884	38.2552	-41402.	154104.	9.66	41.48	10	42	1
039912-00	21	13W	15	AADA	800.00	120.00	3	G A91	-98.7298	38.2294	-36318.	151199.	13.03	42.85	14	43	0
039913-00	21	13W	15	BAAD	800.00	120.00	3	G A91	-98.7391	38.2304	-37122.	151316.	12.67	42.50	13	43	0
039892-00	21	13W	23	CCAA	1000.00	195.00	3	G A91	-98.7253	38.2057	-35938.	148547.	14.47	42.01	15	43	0
039893-00	21	13W	23	DDBB	1000.00	195.00	3	G A91	-98.7150	38.2055	-35037.	148529.	14.83	42.45	15	43	0
900027-00	21	16W	2	ACAD	100.00	0.30	2	G A91	-99.0457	38.2563	-63783.	154373.	0.92	30.65	1	31	0
889122-00	22	16W	4	DBAC	1500.00	328.00	2	G A91	-99.0832	38.1657	-67128.	144292.	4.56	25.13	5	26	1
889033-00	22	16W	8	BBCA	5000.00	1042.00	2	G A91	-99.1118	38.1576	-69633.	143404.	4.03	23.57	5	24	1
900010-00	22	17W	21	DDDA	50.00	0.76	2	G A91	-99.1869	38.1175	-76214.	138995.	3.65	18.66	4	19	1
899028-00	23	15W	30	CAAA	300.00	17.31	2	G A91	-99.0135	38.0215	-61184.	128152.	14.72	21.83	15	22	0
900155-00	23	17W	22	DBCC	60.00	1.07	2	G A91	-99.1769	38.0331	-75433.	129560.	8.55	15.40	9	16	1
039862-00	23	18W	11	ACDD	500.00	150.00	3	G A91	-99.2638	38.0659	-82979.	133295.	3.83	13.16	4	14	1
900156-00	24	17W	6	DDBD	60.00	1.07	2	G A91	-99.2260	37.9875	-79771.	124518.	9.35	11.34	10	12	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
900154-00	24	17W	8	ABAC	60.00	1.07	2	G	A91	-99.2113	37.9838	-78485.	124088.	10.05	11.81	11	12	1
900183-00	24	17W	11	ABBD	60.00	1.07	2	G	A91	-99.1577	37.9837	-73804.	124032.	11.88	14.07	12	15	1
900167-00	24	17W	11	CABD	60.00	1.07	2	G	A91	-99.1622	37.9764	-74212.	123225.	12.12	13.56	13	14	1
899001-00	24	19W	35	ABDC	465.00	86.00	2	G	A91	-99.3745	37.9247	-92817.	117648.	7.68	2.32	8	3	1
039877-00	25	18W	6	CACC	1075.00	195.00	3	G	A91	-99.3450	37.9025	-90265.	115147.	9.88	2.61	10	3	1

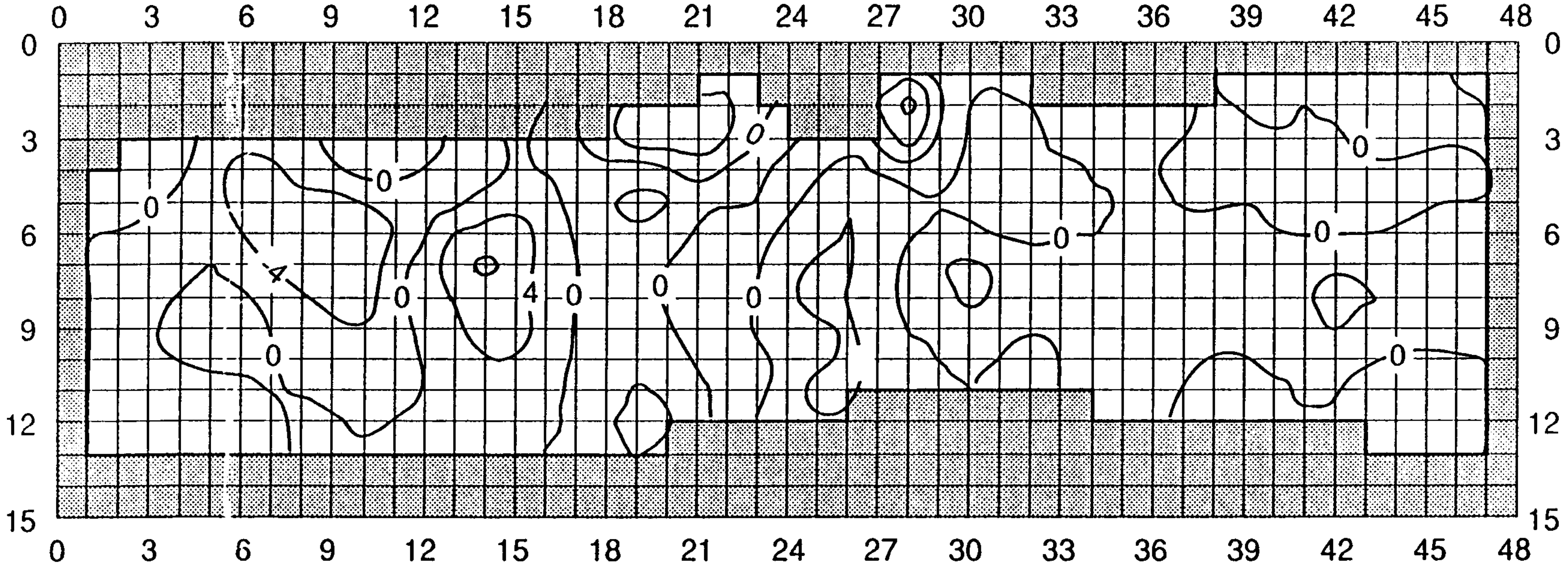
Appendix 2. Residual Analysis Plots



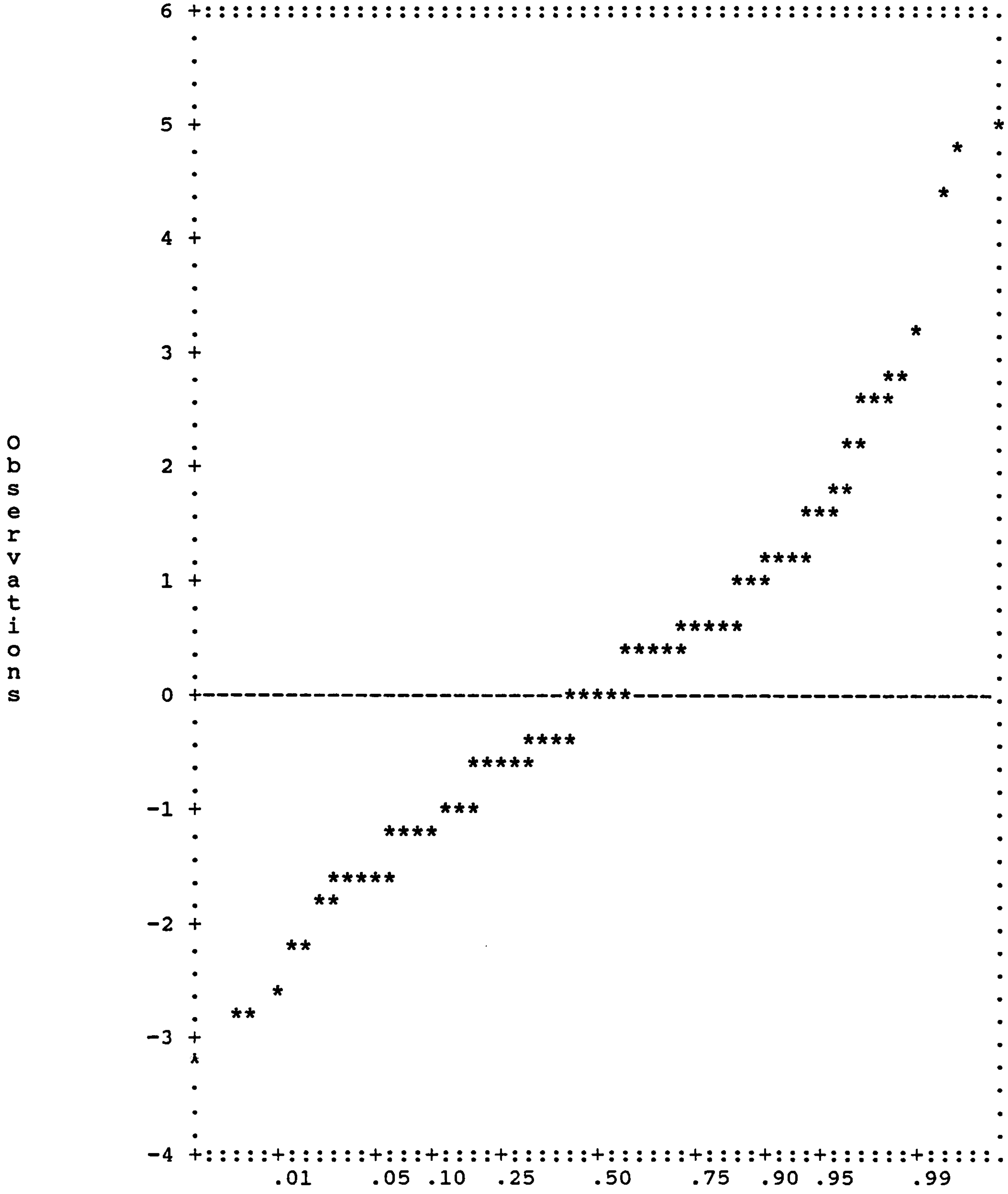
Kinsley steady-state Obs.-Pred. heads
'55 water rights: file kin.wel (6/91)

[redacted]

Kinsley to Great Bend steady-state residual (observed - simulated water level) contours

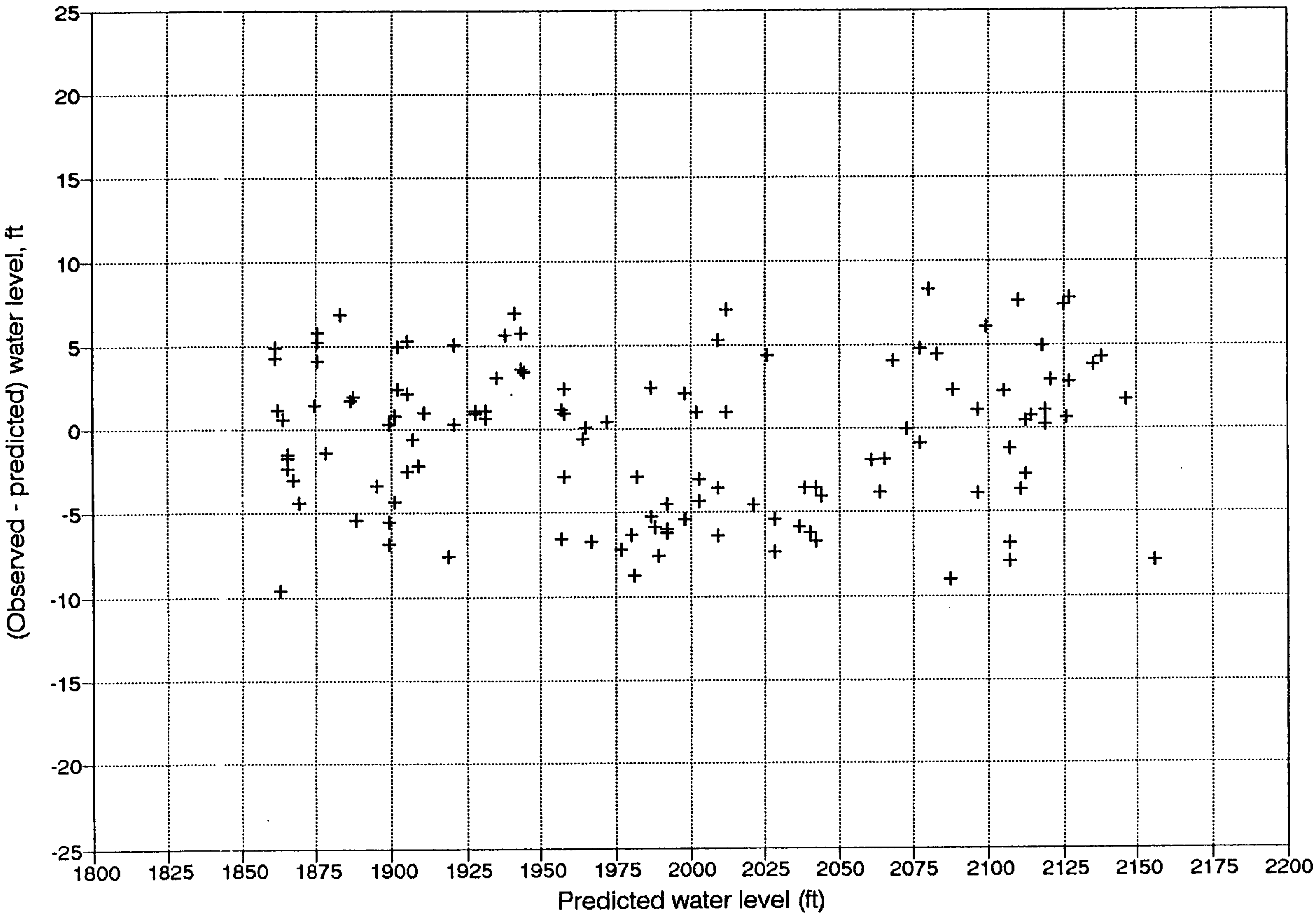


1 Probability plot for normal distribution



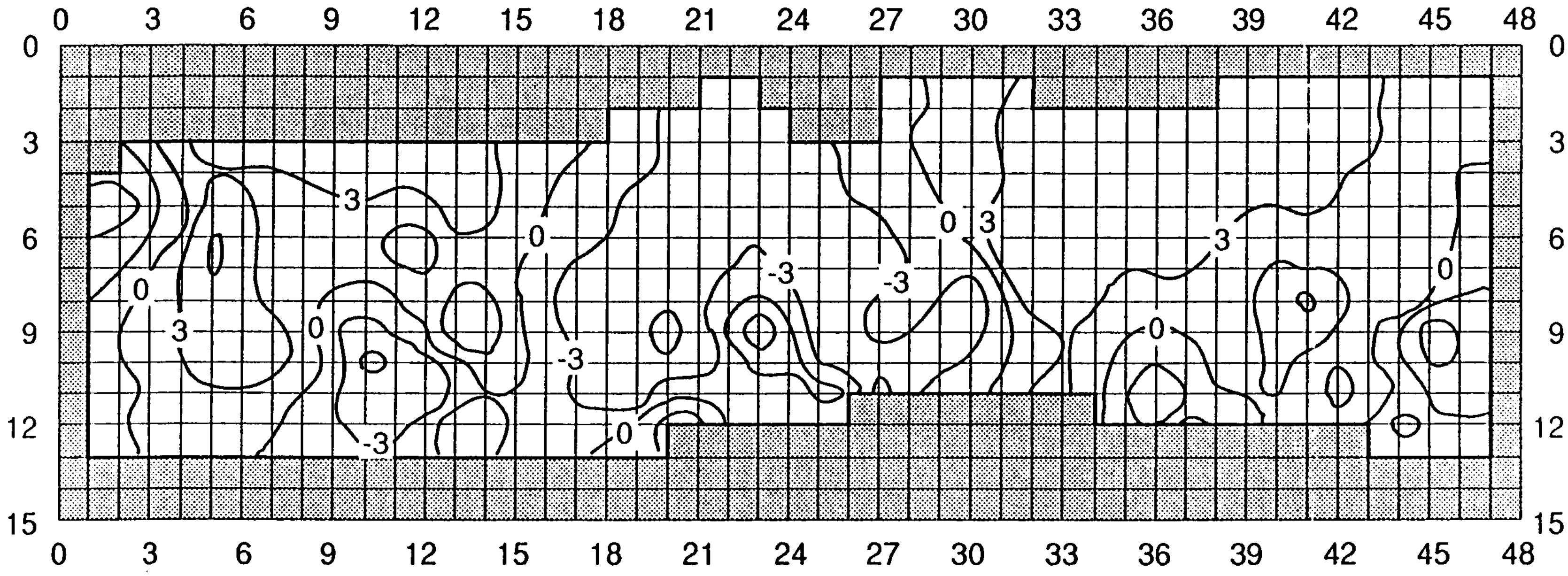
Cumulative Probability, steady-state (1955)

ks85: Kinsley Transient Model
1985 residuals vs predicted water level

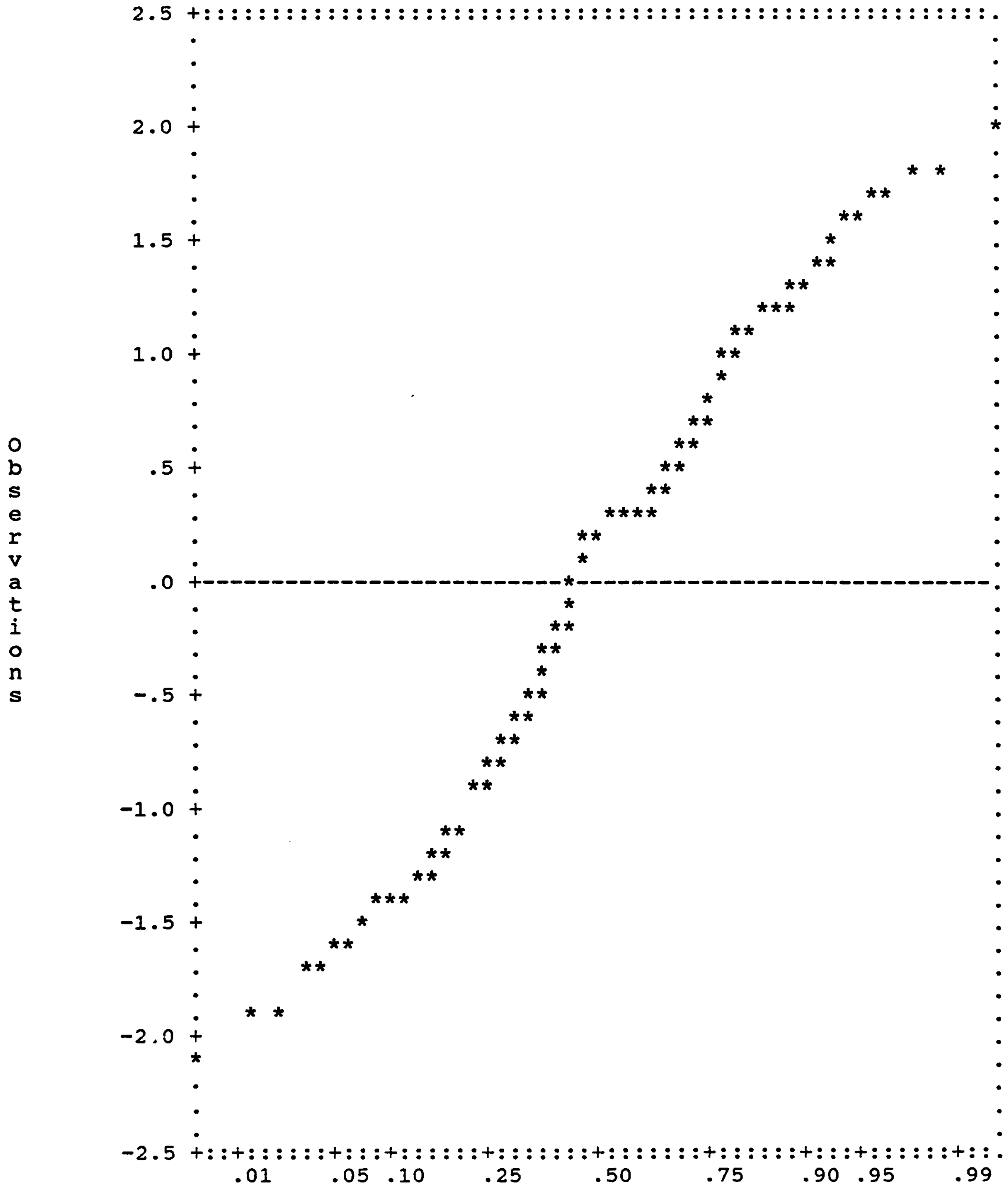


[redacted] [redacted]

Kinsley to Great Bend 1985 residuals (observed - simulated water levels), ft.

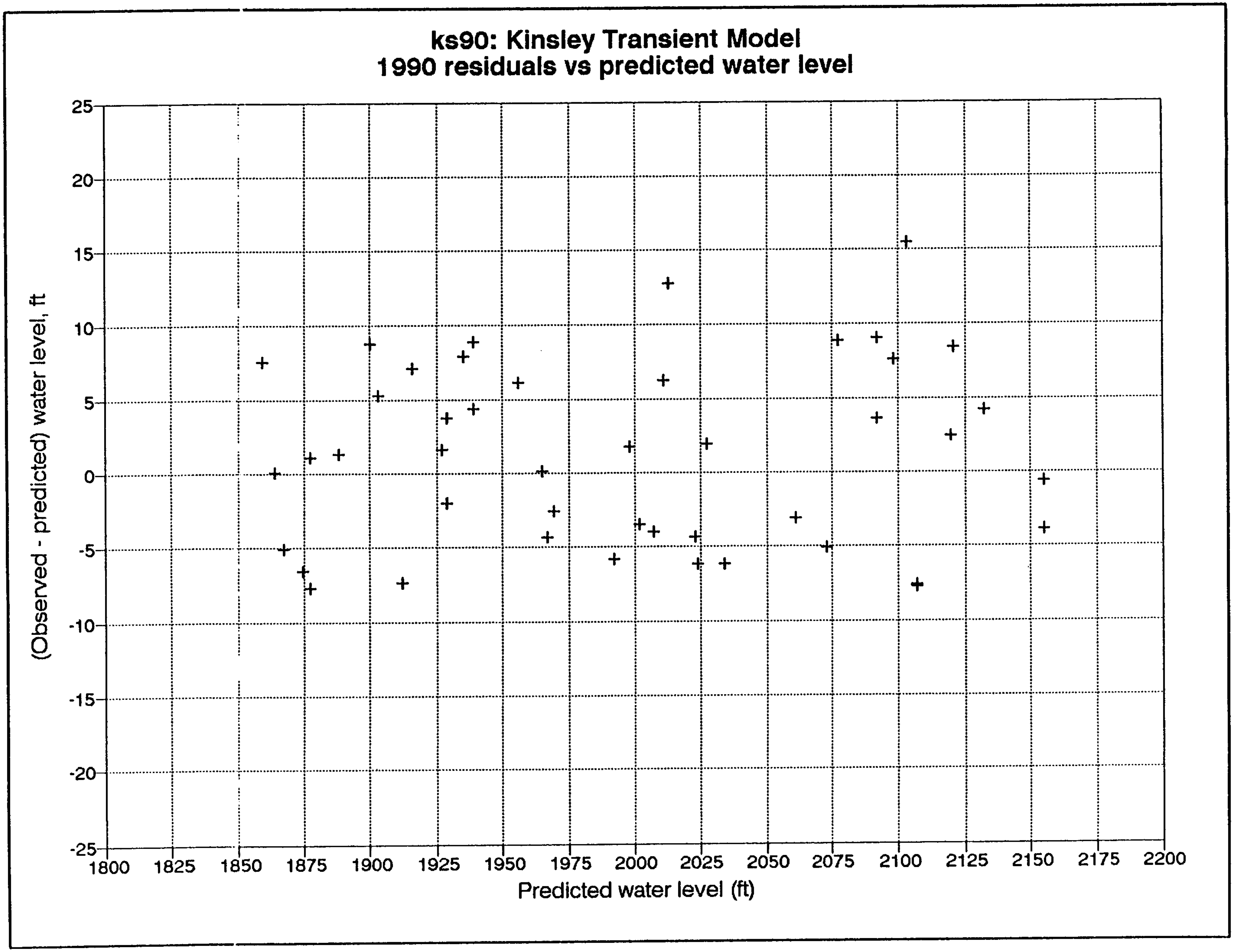


1 Probability plot for normal distribution



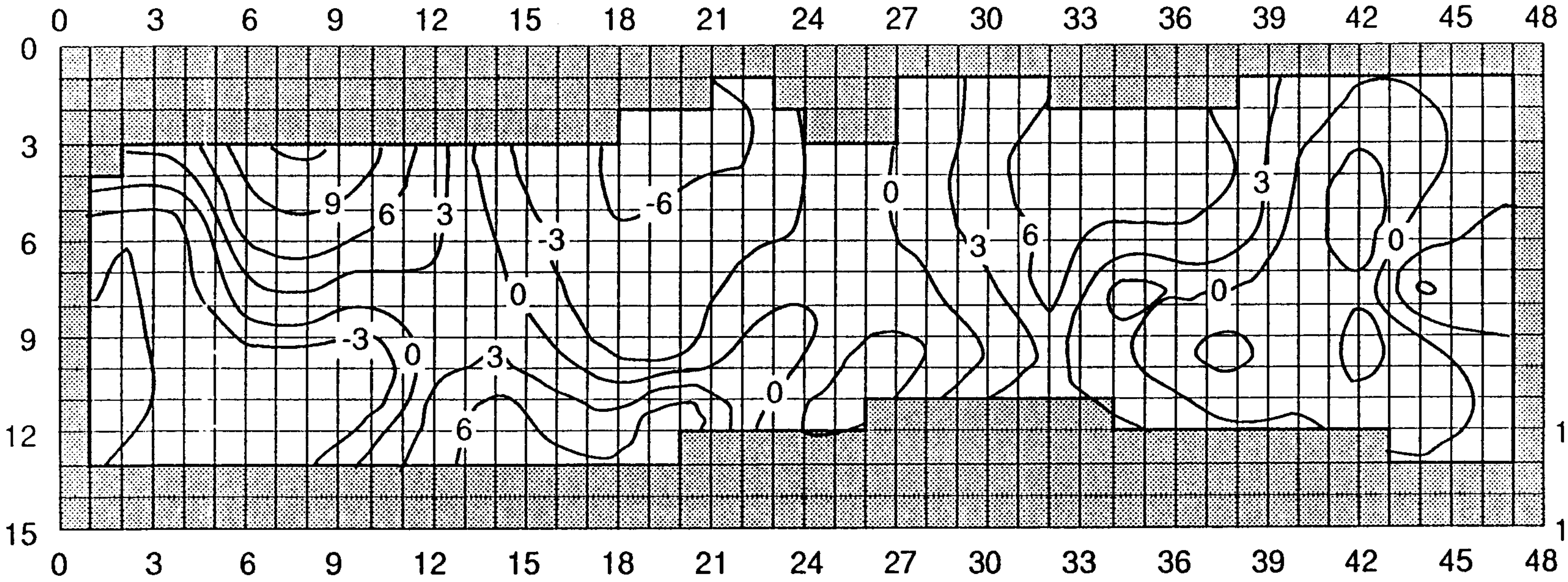
Cumulative Probability, 1985

3/2/92



ks90: Kinsley Transient Model
1990 residuals vs predicted water level

Kinsley to Great Bend 1990 residuals (observed-simulated water levels), ft



Kinsley transient model, 1990 residuals (observed - predicted)

Probability plot for normal distribution