GROUND-WATER LEVELS AND USE OF WATER FOR IRRIGATION IN THE SARATOGA VALLEY, SOUTH-CENTRAL WYOMING, 1980-81

By L. W. Lenfest, Jr.

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DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
2120 Capitol Avenue
P.O. Box 1125
Cheyenne, Wyoming 82003

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CONVERSION FACTORS

For those readers interested in using the metric system, the following table may be used to convert the inch-pound units of measurement used in this report to the International System (SI) of metric units:

Multiply	By	To obtain
acre	0.4047	hectacre
acre-foot (acre-ft)	0.001233	cubic hectometer
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06308	liter per second
kilowatt hour (kWh)	3.600	megajoule
mile (mi)	1.609	kilometer
foot squared per day (ft^2/d)	0.09290	meter squared per day

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ABSTRACT

Although surface water is the principal source of irrigation water in the Saratoga Valley, development of ground water for irrigation increased during the 1960's and 1970's and may continue to increase. Most of the 30 irrigation wells in the valley are capable of producing more than 200 gallons per minute. Approximately 2,700 acre-feet of ground water for irrigation were pumped from the shallow aquifer during 1980 and 4,200 acre-feet during 1981. The shallow aquifer, the subject of this study, consists of the North Park Formation and a lower sandstone unit of late Tertiary (Miocene) age and deposits of Quaternary age along the North Platte River.

During 1980 water levels were measured in about 140 wells, 41 of which had been measured prior to 1969. In most of the 41 wells, the 1980 water levels were within 5 feet of the pre-1969 water levels. During 1980-81, 21 of the wells were used as observation wells; 12 were measured manually each month, and 9 were equipped with water-level recorders.

A water-level contour map of the study area was prepared by the Kriging statistical procedure using water-surface altitudes for 235 ground-water and stream locations. The map indicates that the direction of ground-water flow is from the borders of the study area toward the North Platte River and northwesterly (downstream) parallel to the river, except in the northern one-third of the valley, where flow is westerly.

INTRODUCTION

The Saratoga Valley is in Carbon County, south-central Wyoming, along the North Platte River about 25 mi south and east of Rawlins, Wyo. The study area (fig. 1) is bounded approximately by the Medicine Bow Mountains on the east, the Sierra Madre on the west, the Wyoming-Colorado State line on the south, and Interstate 80 on the north.

The development of ground water, primarily for irrigation, has increased in the Saratoga Valley since 1960. Ground-water development and use for irrigation is primarily concentrated in three small areas in the Saratoga Valley; the remaining irrigation, stock, and domestic use wells are scattered throughout the valley. The effects of ground-water pumpage on the shallow aquifer have not comprehensively been monitored in the past, and long term effect of pumpage on the shallow aquifer is not known.

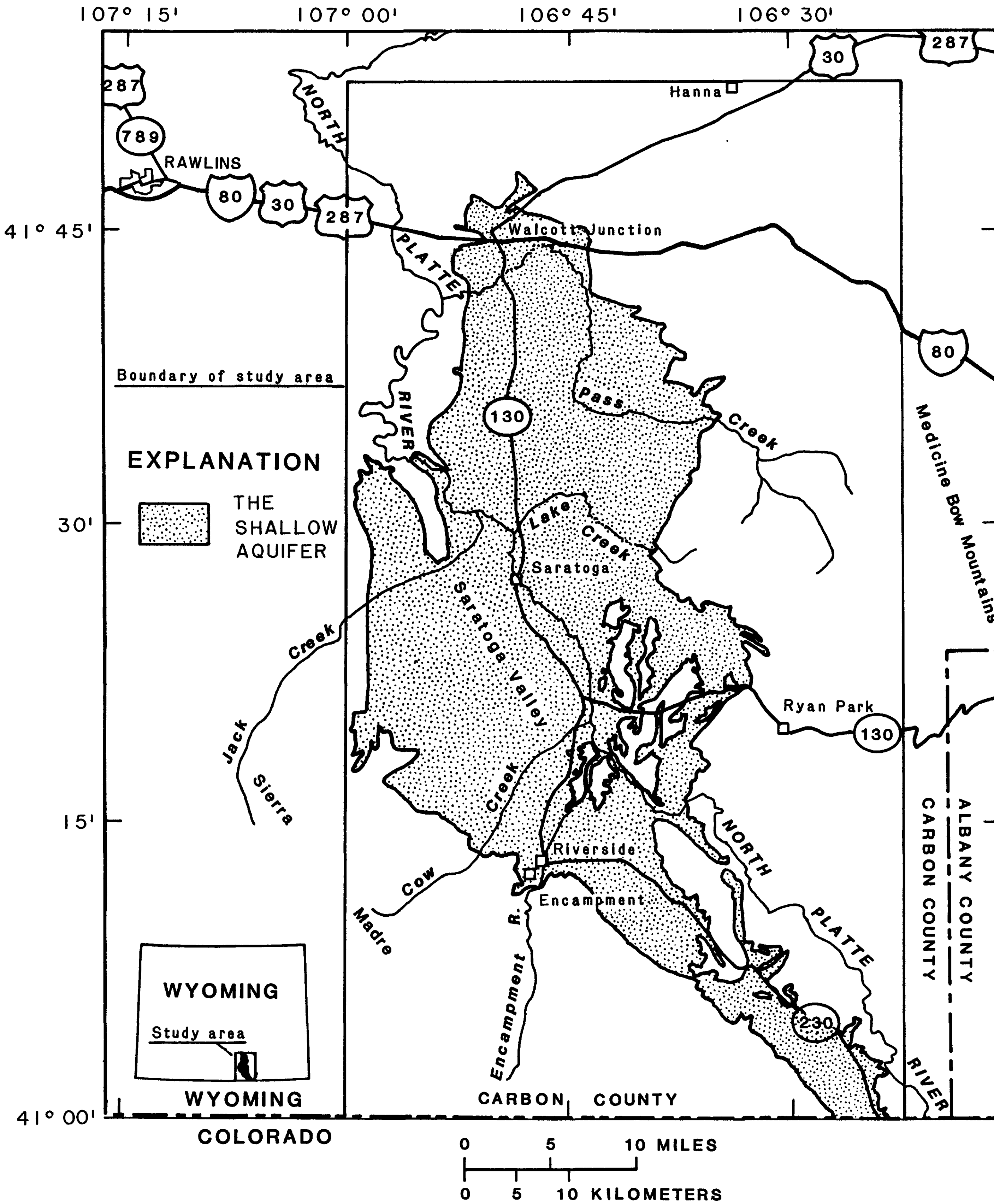

Figure 1.--Location of the shallow aquifer within the study area.

The principal objectives of the study are to provide information about current development of ground-water resources, the amount of water used for irrigation in the Saratoga Valley, and the extent of water-level decline in the valley due to irrigation use. The data presented in this report will serve as a basis for future studies of the area. The study is limited to the collection and analysis of data from the shallow aquifer system within the Saratoga Valley.

Methods of Investigation

Data collection, which began during May 1980, consisted of field-locating wells and measuring water levels. Twenty-one wells were selected for periodic water-level measurements; continuous water-level recorders were installed on 9 of these wells. Water levels were measured in about 140 wells during the summer and fall of 1980; a water-level-contour map was constructed from the measured ground-water levels and from stream altitudes using the Kriging statistical procedure and computerized contouring techniques.

Irrigation pumpage was estimated from electric-power records using relations developed between measured well yield and power used. Location and extent of surface- and ground-water irrigation data were obtained from the Wyoming State Engineer's records and from field observations.

Previous Investigations

Several hydrologic investigations and geologic maps that include all or parts of the Saratoga Valley have been completed. The geology of part of the Saratoga Valley was described in a report by Houston and others (1968); Weitz and Love (1952) prepared a geologic map of Carbon County. A hydrologic atlas prepared by Lowry and others (1973, sheet 3) includes several references and provides hydraulic properties of the aquifers at three places in the valley, historical well data, and geologic data.

Acknowledgments

The author thanks the many residents in the valley who allowed U.S. Geological Survey personnel to make periodic measurements of water levels in their wells. The author also acknowledges the cooperation from Dan Wallis, J. Burton Tuttle, Dick Butterfield, Ed Sholine, Eugene Walck, Jim Berger, Frank Carroll, John Rouse, and Robert Helmer, who permitted continuous water-level recorders to be installed on their wells. Discharges were measured at wells owned by J. Burton Tuttle, Dick Butterfield, Frank Carrol, Robert Helmer, John Crow, and Buck Hoem. Personnel from the Wyoming State Engineer's Office provided well data and maps of irrigated acreage.

This study was conducted in cooperation with the Wyoming State Engineer and the Wyoming Economic Development and Stabilization Board.

Well-Numbering System

The numbering system used to identify wells in this report is based on the Federal system of land subdivision (fig. 2). The first number indicates the township, the second the range, and the third the section in which the well is located. The lowercase letters following the section number locate the well in the section. The first letter denotes the quarter section, the second letter the quarter-quarter section, and the third letter the quarter-quarter-quarter section. The subdivisions of a section are lettered a, b, c, d in a counterclockwise direction starting in the northeast quarter. When more than one well occupies a 10-acre tract (quarter-quarter-quarter section), consecutive 2-digit numbers starting with 01 follow the last lowercase letter of the well number.

GEOHYDROLOGY OF THE SARATOGA VALLEY

Although rocks in the Saratoga Valley range from Precambrian to Quaternary in age, the primary focus of this study was on those which comprise the shallow aquifer in the valley. The shallow aquifer (fig. 1) consists of the North Park Formation and a lower sandstone unit, both of late Tertiary (Miocene) age, and alluvial deposits of Quaternary age. All the wells in which ground-water levels were measured monthly and the wells with digital water-level recorders are completed in the shallow aquifer.

Precambrian rocks border the shallow aquifer within the study area on the south and to a limited extent on the east. Baggot Rocks and Beaver Creek Hills, which are of Precambrian age, are dominant features in the south-central part of the valley. The Precambrian rocks yield water to wells only where secondary permeability exists as the result of fracturing or weathering. Well yields of 5 gal/min are possible (Lowry and others, 1973, sheet 2).

Rocks that range in age from the Mississippian to early Teritiary border the shallow aquifer on the north and west. These rocks primarily include the Steele Shale, Mesaverde Formation, and Medicine Bow Formations of Late Cretaceous age. Minor outcrops of the Ferris Formation of Late Cretaceous and Paleocene age and of the Hanna Formation of Paleocene age occur within the rocks bordering the northeastern edge of the shallow aquifer. Specific information about yields of wells completed in these rocks is not available.

Most of the shallow aquifer consists of the North Park Formation and a lower sandstone unit of Miocene age. The North Park Formation, which is exposed throughout most of the valley, consists of medium- to coarse-grained sandstone and conglomerate with siltstone, claystone, and limestone. It is as much as 1,500 ft thick (de la Montagne, 1953, p. 13). The lower sandstone unit is exposed in the northwestern part of the valley, extending west of Saratoga beyond the edge of the study area. The unit consists of fine- to medium-grained sandstone with sandy conglomerate at its base and is as much as 1,400 ft thick (de la Montagne, 1953, p. 13). The lower sandstone unit was shown as the Arikaree Formation of early Miocene age by Lowry and others (1973). Some investigators, including de la Montagne (1953), call this unit the Browns Park Formation.

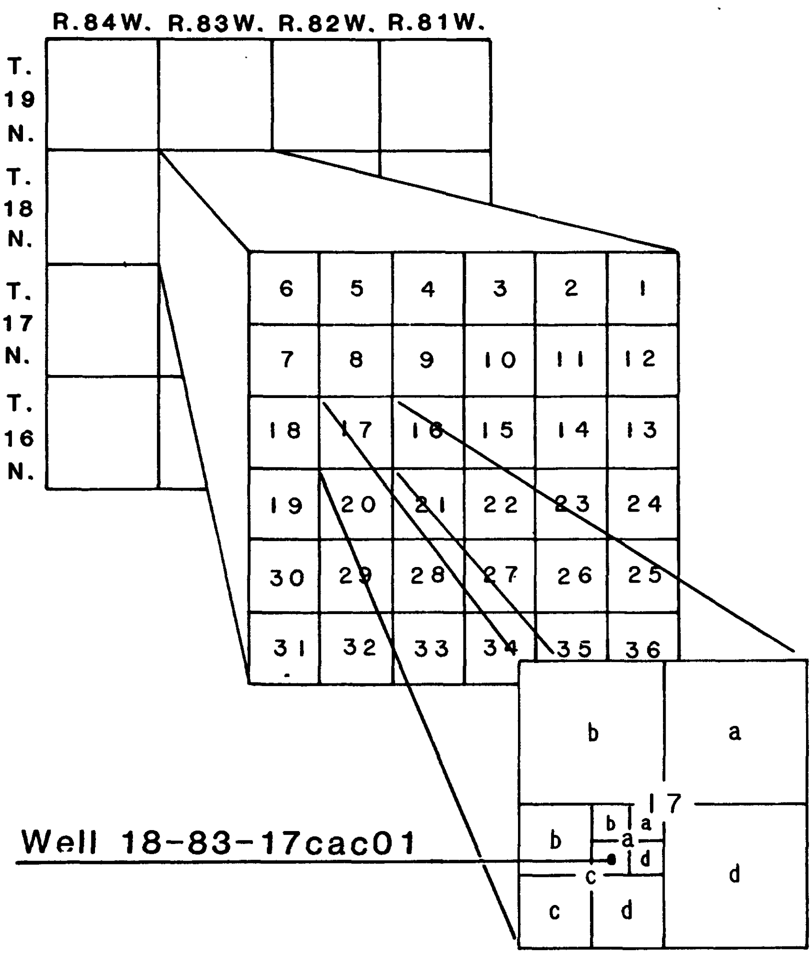

Figure 2.--Well-numbering system.

Well yields for Tertiary rocks, including the North Park Formation and the lower sandstone unit, range from 500 to 1,000 gal/min (Lowry and others, 1973, sheet 3). Because the North Park Formation and lower sandstone unit have similar lithologic and hydrologic properties, they are shown as one geologic unit on plate 1. Aquifer tests conducted by the Geological Survey in 1967 and 1968 indicate transmissivities are about 5,000 ft^2/d in the shallow aquifer (Lowry and others, 1973, sheet 3).

The remainder of the shallow aquifer consists of alluvial deposits of Quaternary age located along the North Platte River and some of its tributaries. Alluvial deposits underlying flood plains and terraces are considered as one geologic unit in this report and are shown as undifferentiated deposits of Quaternary age on the geologic map (pl. 1). Alluvial deposits consist primarily of sand, gravel, and cobbles in the flood plains of streams that head in the mountains or in other areas where resistant rocks are abundant. Elsewhere, alluvial deposits in flood plains are composed primarily of fine-grained material. Similar material underlies most terraces (Lowry and others, 1973, sheet 3).

GROUND-WATER LEVELS

Observation Wells

Water-level measurements were made in about 140 wells in the Saratoga Valley during the summer and fall of 1980 (pl. 2). To determine ground-water-level trends in the study area, water levels were measured monthly in 12 wells and hourly records of water levels in 9 wells were obtained with digital recorders (table 1). All wells were remeasured during late October or early November 1980. Measurements made during the fall of 1980 were used to construct a water-level-contour map that is described in a subsequent section of this report.

Historical ground-water levels consist primarily of measurements made during a well inventory conducted during the fall of 1967 and several measurements made between 1949 and 1968. Water levels in 41 of the wells with pre-1969 water-level measurements were measured again as a part of the 1980 well inventory and compared with the older measurements. Most of the water levels were within 5 ft of each other; 20 of the water levels measured during 1980 were higher than those measured prior to 1969, 20 were lower, and 1 was the same. The greatest apparent decline of water level was 12 ft in a domestic well southeast of Saratoga.

Five continuous-water-level recorders were placed on wells in areas of ground-water withdrawal for irrigation. Wells 15-84-10adb and 18-83-17cac are within 500 ft of one or more irrigation wells. Hydrographs of the daily maximum water level for those wells show the effects of sustained pumpage for irrigation (figs. 3 and 4). There are 6 irrigation wells within a 0.5-mi radius of well 14-83-03cab, although none is closer than 1,000 ft. The hydrograph of this well shows effects of pumpage for irrigation from early June through September (fig. 4). Wells 15-83-34bab and 18-83-16dbd also are located in areas of significant ground-water irrigation. Each is within 0.5 mi of an irrigation well; however, they are separated from these and other irrigation wells by streams and show more subtle, but discernible, response to irrigation pumpage (fig. 5). Water levels in well 15-83-34bab (fig. 5) are affected by flow in Cherokee Creek, which is about 200 ft east of the well, and by ground-water irrigation. Cherokee Creek is an intermittent stream and

Table 1.--Records of observation wells

[Well number: See text for explanation. Geologic unit: NP, North Park Formation; LS, lower sandstone; AL, alluvium. Use: S, stock; I, irrigation; N, not used; D, domestic; U, unused during study. Frequency of measurement: M, approximately monthly; C, hourly recorder. Ft, foot; mi, mile]

Well number	Owner	Geologic unit	Well depth (feet)	Use	Scheduled frequency of measurement	Remarks
13-81-22ccb	Gates Rubber Co.	NP	100	S	M	Pumped infrequently to water stock.
14-82-19ada	Bert and Fox Vyvey	NP	85	I,U	M	Well not used during 1980 and 1981.
14-83-03cab	Robert Helmer	NP	58	N	C	Well located in middle of irrigation field; affected by pumpage, and surface- and ground-water irrigation.
15-83-06bbc	John Crow	NP	101	I	M	Well used for irrigation in summer months.
15-83-24dcc	John Rouse	NP	153	N	C	Well within 300 ft of stock well; did not observe stock well pumping.
15-83-34bab	Robert Helmer	NP	61	N	C	Irrigation well about 0.25 mi away and on opposite side of Cherokee Creek.
15-84-10adb	Frank Carroll	NP	330	N	C	Irrigation well 300 ft from observation well.
15-84-14adc	Silver Spur Ranch	NP	([1])	S	M	Pumped infrequently to water stock.
16-83-34abd	Elk Hollow Ranch	AL	([1])	S,U	M	--
16-84-09cbc	Jim Berger	NP	171	N	C	Irrigation well 0.75 mi north; record possibly affected by fluctuations of flow in South Spring Creek, or irrigation lateral 10 ft from well.
16-84-30dda	Frank Walliser	NP	130	I,U	M	--
17-82-34acb	Deborah Chastain	NP	105	D	M	Pumped intermittently in 1980 and 1981.
17-83-23bac	Deborah Chastain	NP	85	D	M	--
17-83-28bcd	Edwin Sholine	NP	59	D,I	C[2]	Well not used during recorder operation; pump and electric motor installed; used to irrigate trees; affected by flow in Cedar Creek (approximately 50 ft away).
17-84-08dad	Roy Taylor (manager)	LS	([1])	S	M	Pumped infrequently.
17-85-23aac	Eugene Walck	LS	153	N	C	No pumping in vicinity.
18-83-16dbd	Saratoga Land and Cattle	NP	63	N	C	Irrigation wells about 0.5 mi north and about 0.75 mi south on opposite side of Lake Creek.
18-83-17cac	J. Burton Tuttle	NP	92	N	C	Irrigation from several nearby wells, the closest 0.1 mi away.
19-83-25ccc	T-A Ranchers (J. Runner)	NP	175	N	M	No pumping in vicinity; irrigation ditch within 1 ft of well contains water during summer (irrigation water from Pass Creek).
19-84-15dbd	Vern Vivion	LS	600	S	M	Usually pumped during winter months to fill reservoir and as needed to water stock.
20-84-25aab	Dan Wallis	LS	230	S	M	Pumped infrequently to water stock.

[1] Depth of well not known.

[2] Discontinued recorder operation 3-24-81; measured monthly thereafter.

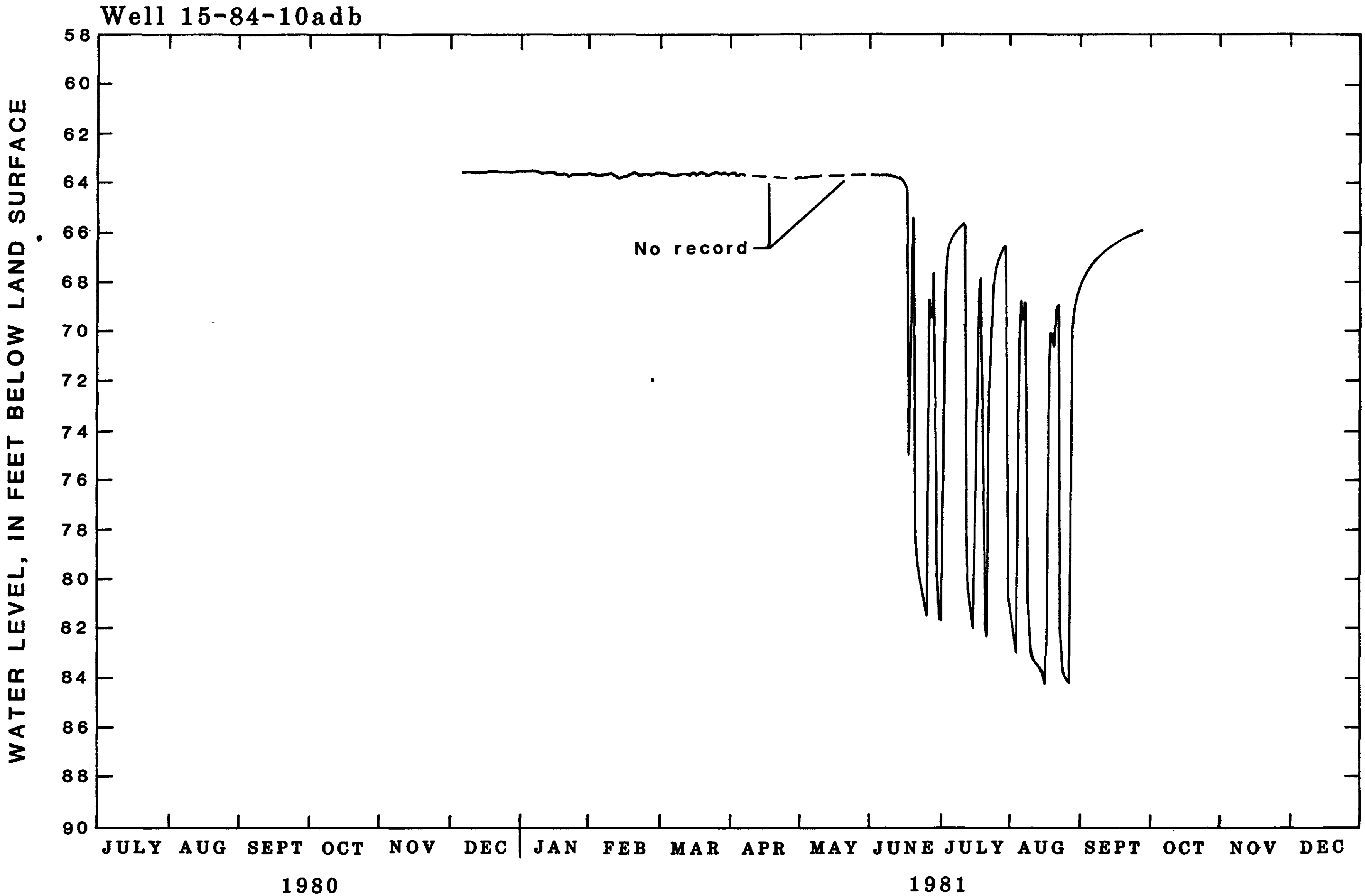

Figure 3.--Hydrograph for well 15-84-10adb.

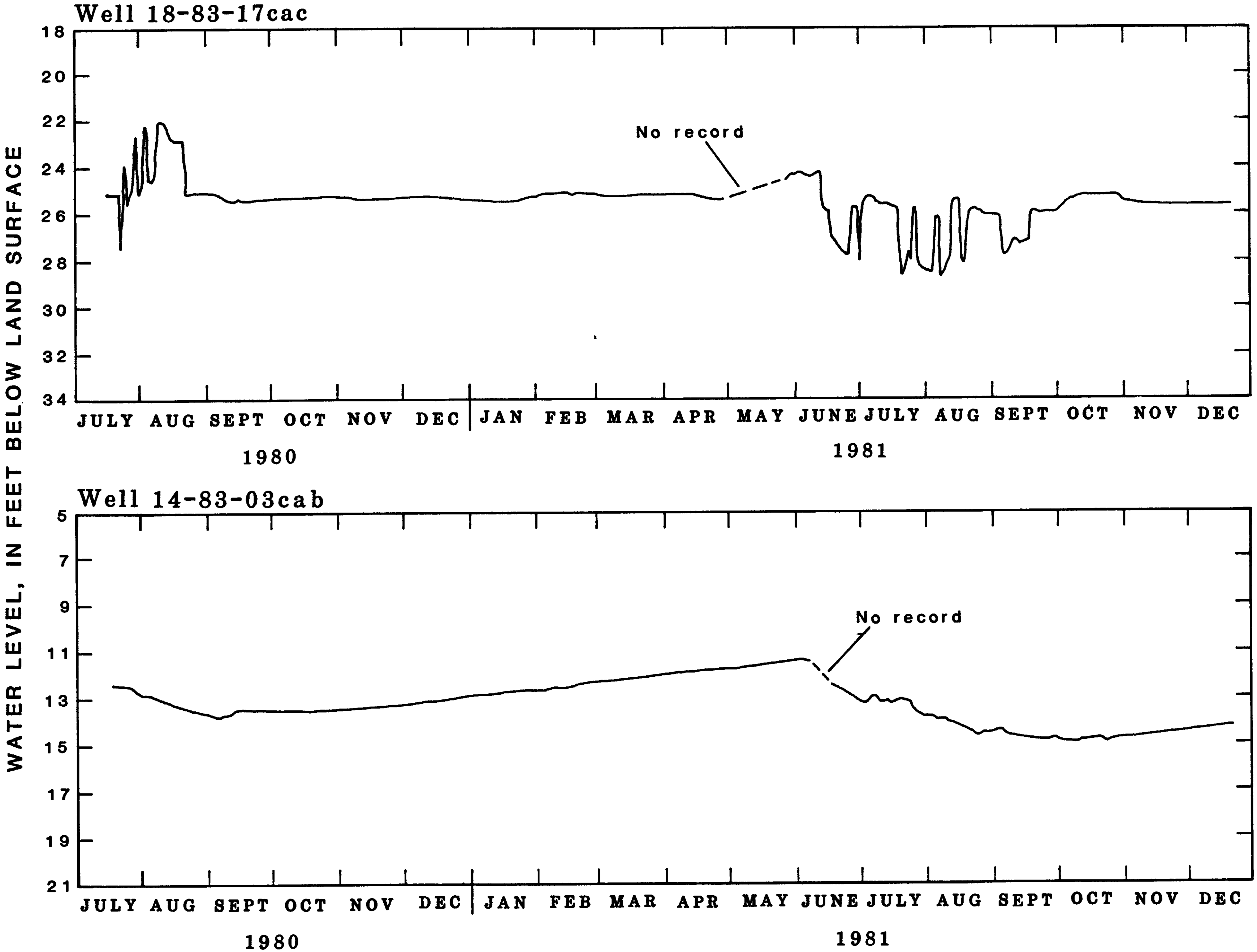

Figure 4.--Hydrographs for wells 18-83-17cac and 14-83-03cab.

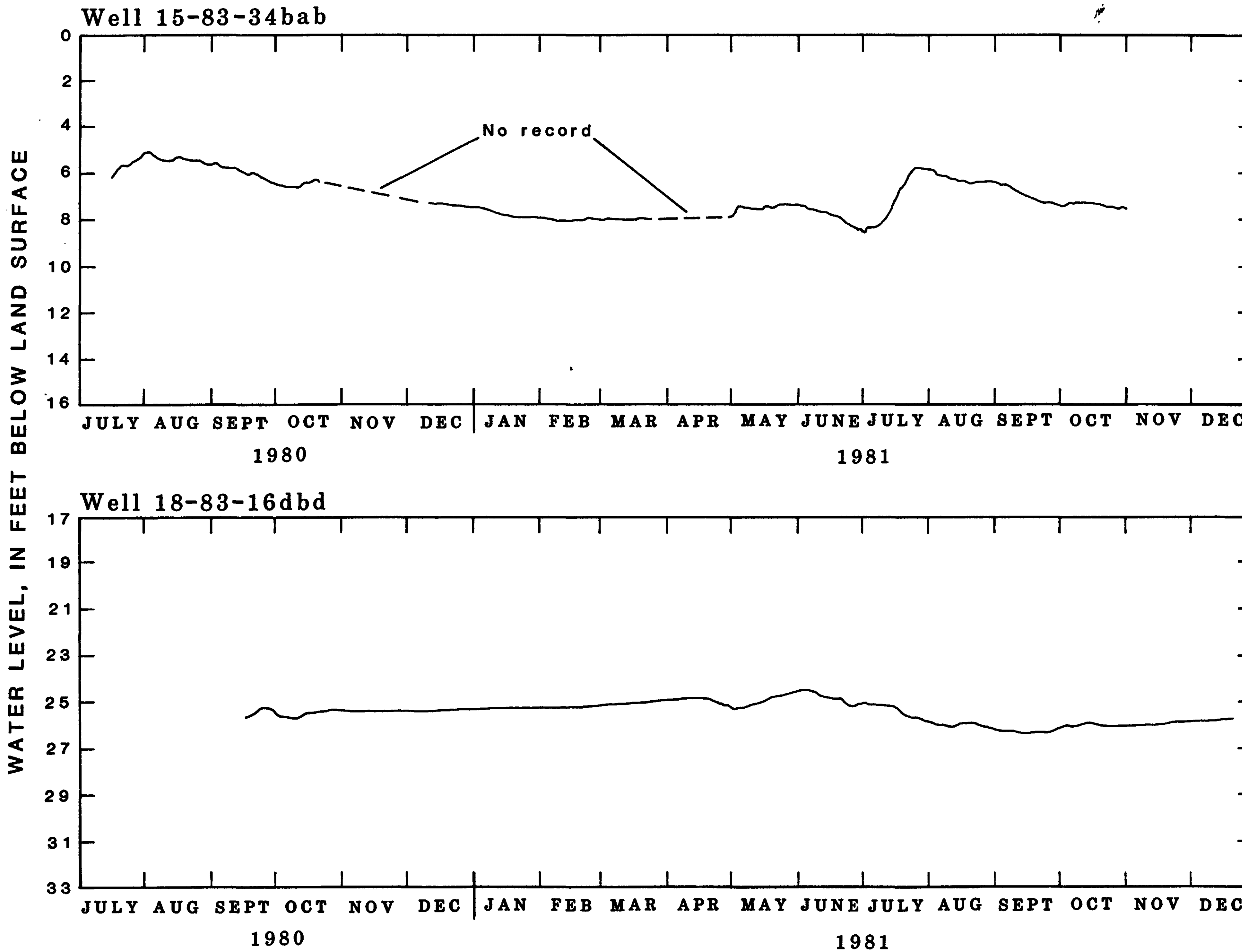

Figure 5.--Hydrographs for wells 15-83-34bab and 18-83-16dbd.

base flow is small; however, because ground water is pumped into the creek about 0.5 mi upstream from the well at different times during the irrigation season, flow in Cherokee Creek may affect water levels in well 15-83-34bab. Well 18-83-16dbd is within 0.2 mi of Dry Creek, which separates the well from irrigation wells to the east. Dry Creek has a very small base flow and probably does not affect water levels in well 18-83-16dbd as much as ground-water withdrawal for irrigation (fig. 5).

The remaining four wells with recorders are located where little or no ground-water pumpage occurs. Well 17-83-28bcd had a recorder from July 16, 1980, through March 24, 1981; the well is located within 50 ft of Cedar Creek and the water level probably is affected by streamflow (fig. 6). After March 24, 1981, a small submersible pump was installed in well 17-83-28bcd for domestic and minor irrigation use; monthly water-level measurements made after March 24, 1981, may indicate effects of recent pumpage. Well 16-84-09dbc is located next to an irrigation ditch on the edge of a terrace between North and South Spring Creek. An irrigation well is located approximately 0.5 mi north of the observation well. Very little flow was observed in the irrigation ditch near the well. The irrigation well was not operated during 1980, but approximately 275 acre-ft were pumped during 1981. There is significant surface-water irrigation on the terrace upgradient from the observation well and along North and South Spring Creek. The hydrograph for well 16-84-09cbc probably is affected by the nearby irrigation well, surface-water irrigation upgradient from the observation well, and changes in surface-water flow in North and South Spring Creek. The water level in well 17-85-23aac, located approximately 6 mi west of Saratoga, is not affected by irrigation or local streamflow (fig. 7). The hydrograph for well 15-83-24dcc (fig. 7), located about 7 mi east of Encampment, does not appear to show significant effects from surface-water irrigation located northeast of the observation well. Water levels in well 17-85-23aac and well 15-83-24dcc changed very little during the period of record; comparison of the hydrographs of these wells shows water-level fluctuations probably are caused by changes in atmospheric pressure.

Water levels in 12 wells were measured with a steel tape approximately once a month; 8 of these wells were pumped at some time during the year (table 1). Water levels were not measured when pumps were operating or when there was evidence of recent pumpage. The plotted points on hydrographs for these wells (figs. 8-13) indicate water levels on the day the wells were measured; dashed lines connecting the points are used to illustrate the water-level fluctuations and may or may not be indicative of actual water levels between measurements. Wells 15-84-14adc and 20-84-25aab contain electric pumps and are used to fill small stock tanks. Well 19-84-15dbd contains an electric pump and is used to supply water to a nearby stock pond at various times during the year, including the winter months. The hydrographs for these wells (figs. 9 and 13) show fluctuations in the water table caused by stock-water withdrawals.

The remaining wells are located in areas of significant surface-water irrigation. The hydrographs for these wells (figs. 8-12) show the effects of ground-water recharge from surface-water sources and of pumpage from the wells themselves. Wells 17-82-34acb and 17-83-23bac provide water for domestic use. Wells 13-81-22ccb and 17-84-08dad contain electric pumps and are used for stock. Well 15-83-06bbc contains an electric pump and is used to supplement surface-water irrigation. The remaining wells were not pumped during the study.

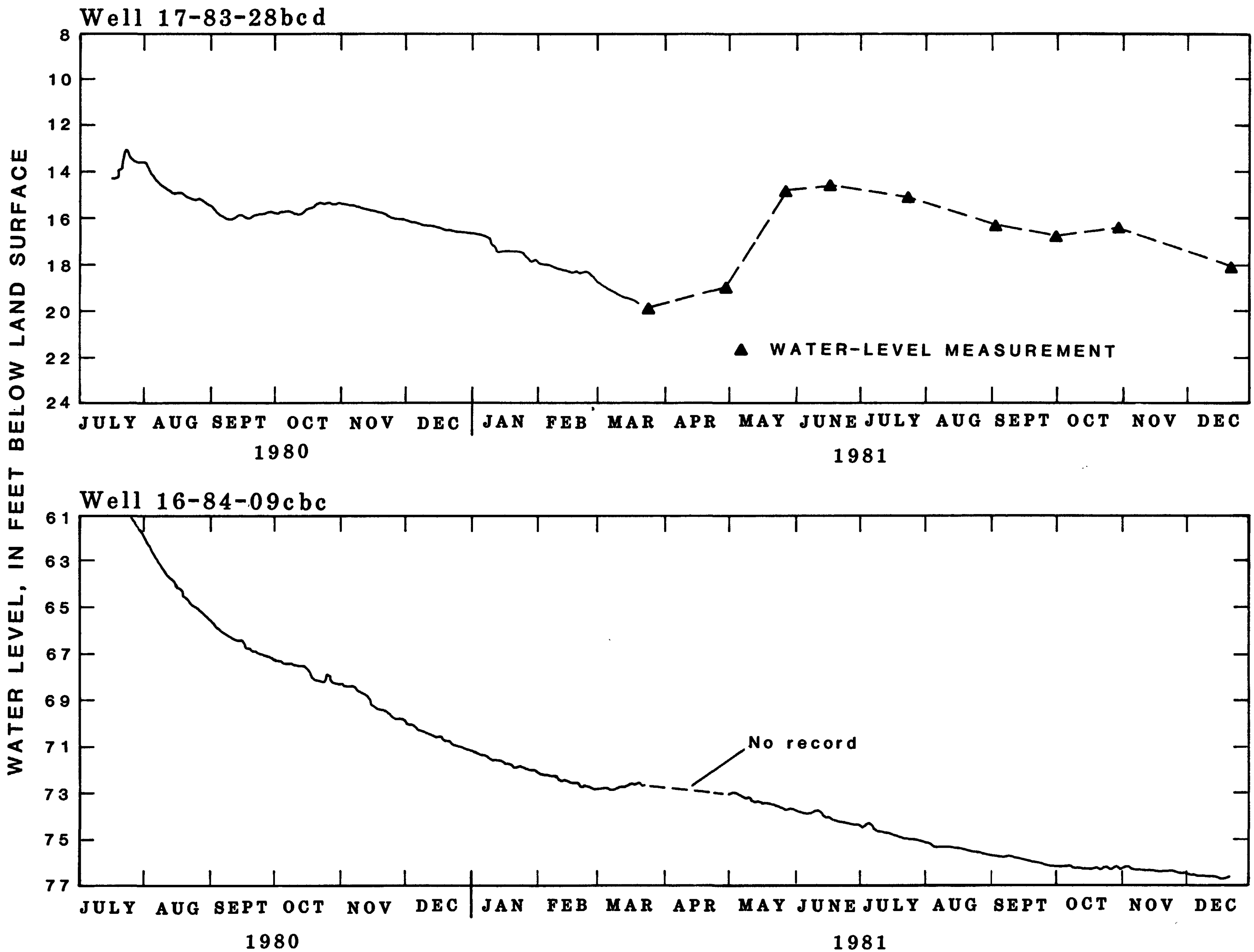

Figure 6.--Hydrographs for wells 17-83-28bcd and 16-84-09cbc.

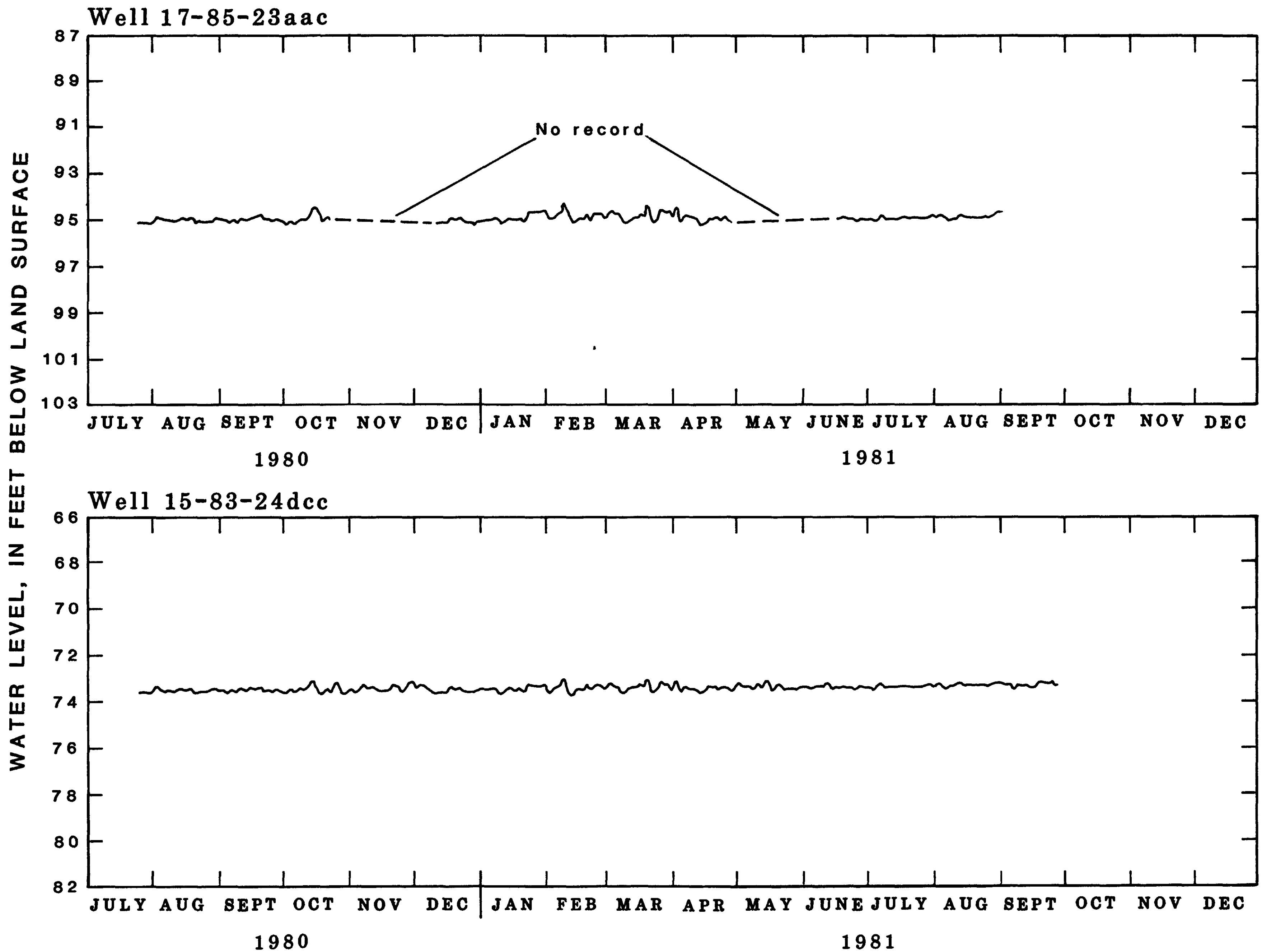

Figure 7.--Hydrographs for wells 17-85-23aac and 15-83-24dcc.

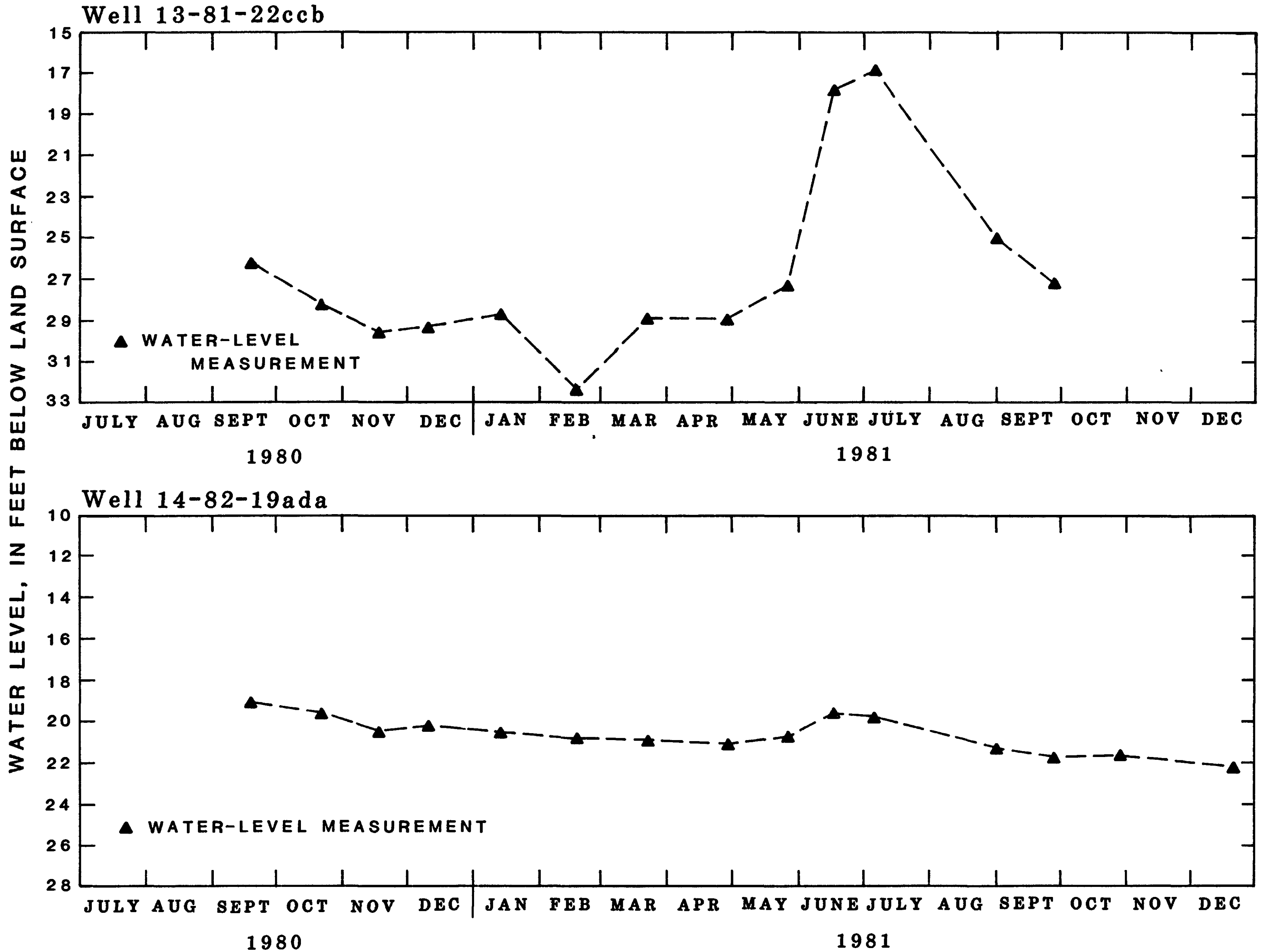

Figure 8.--Hydrographs for wells 13-81-22ccb and 14-82-19ada.

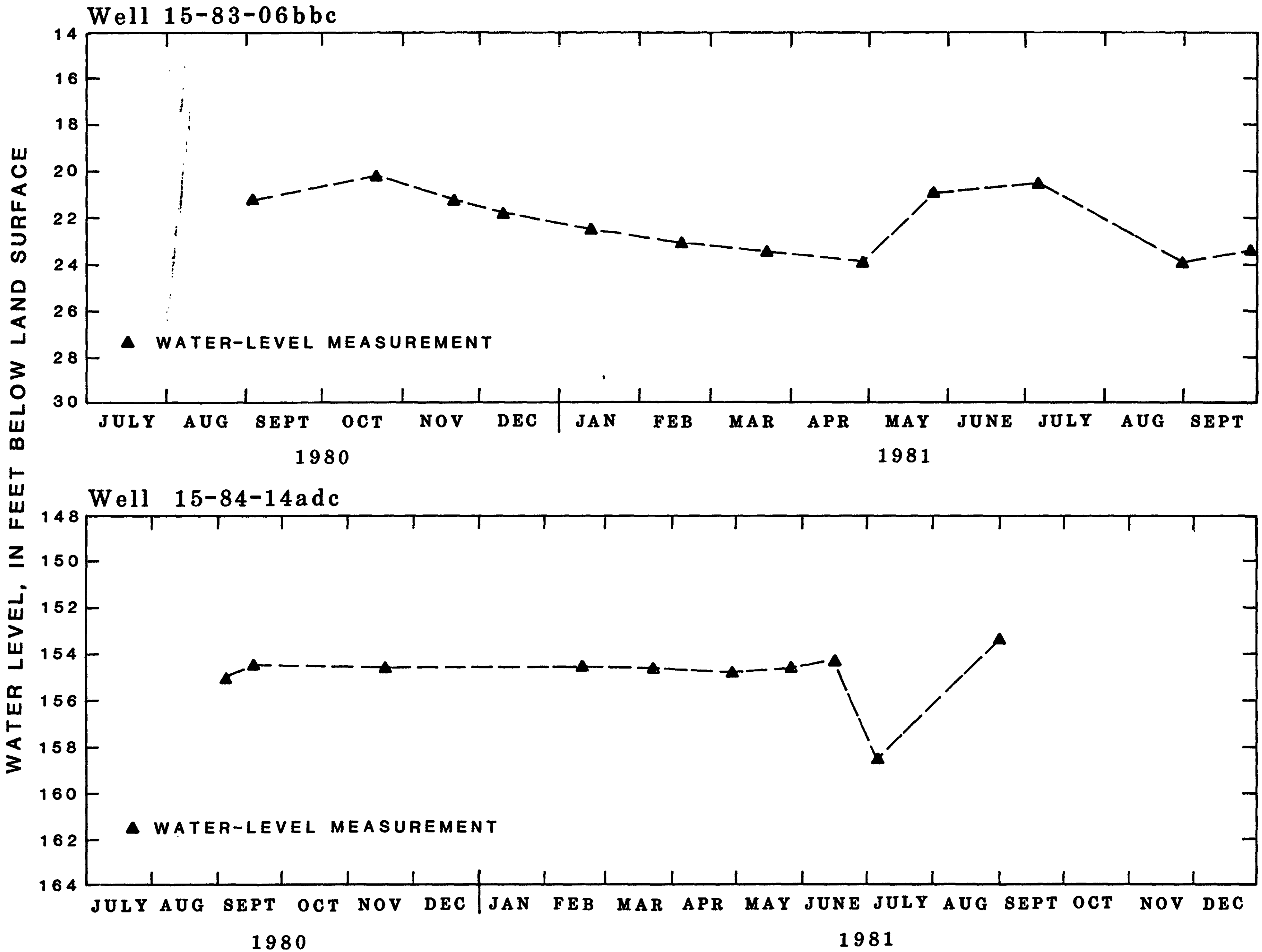

Figure 9.--Hydrographs for wells 15-83-06bbc and 15-84-14adc.

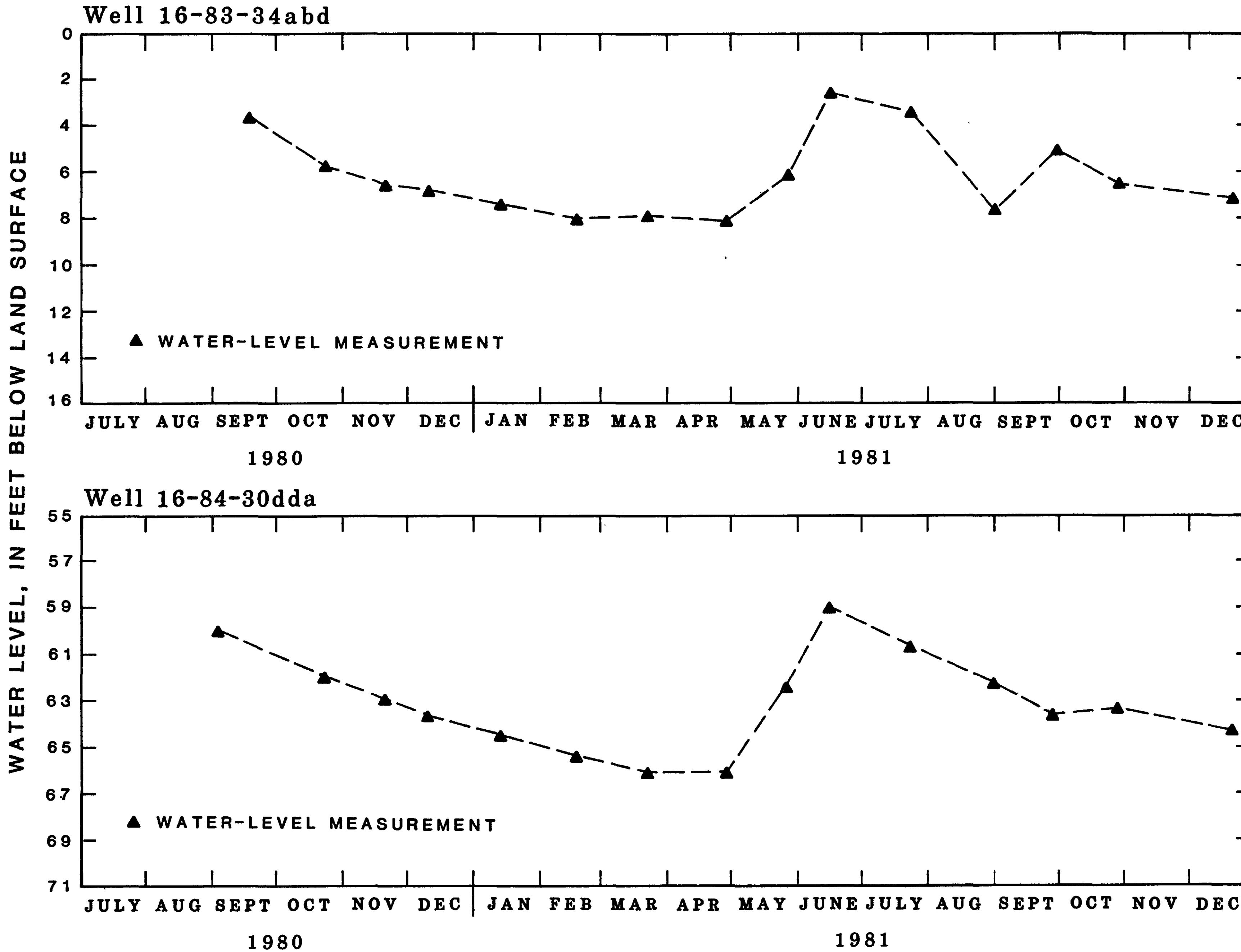

Figure 10.--Hydrographs for wells 16-83-34abd and 16-84-30dda.

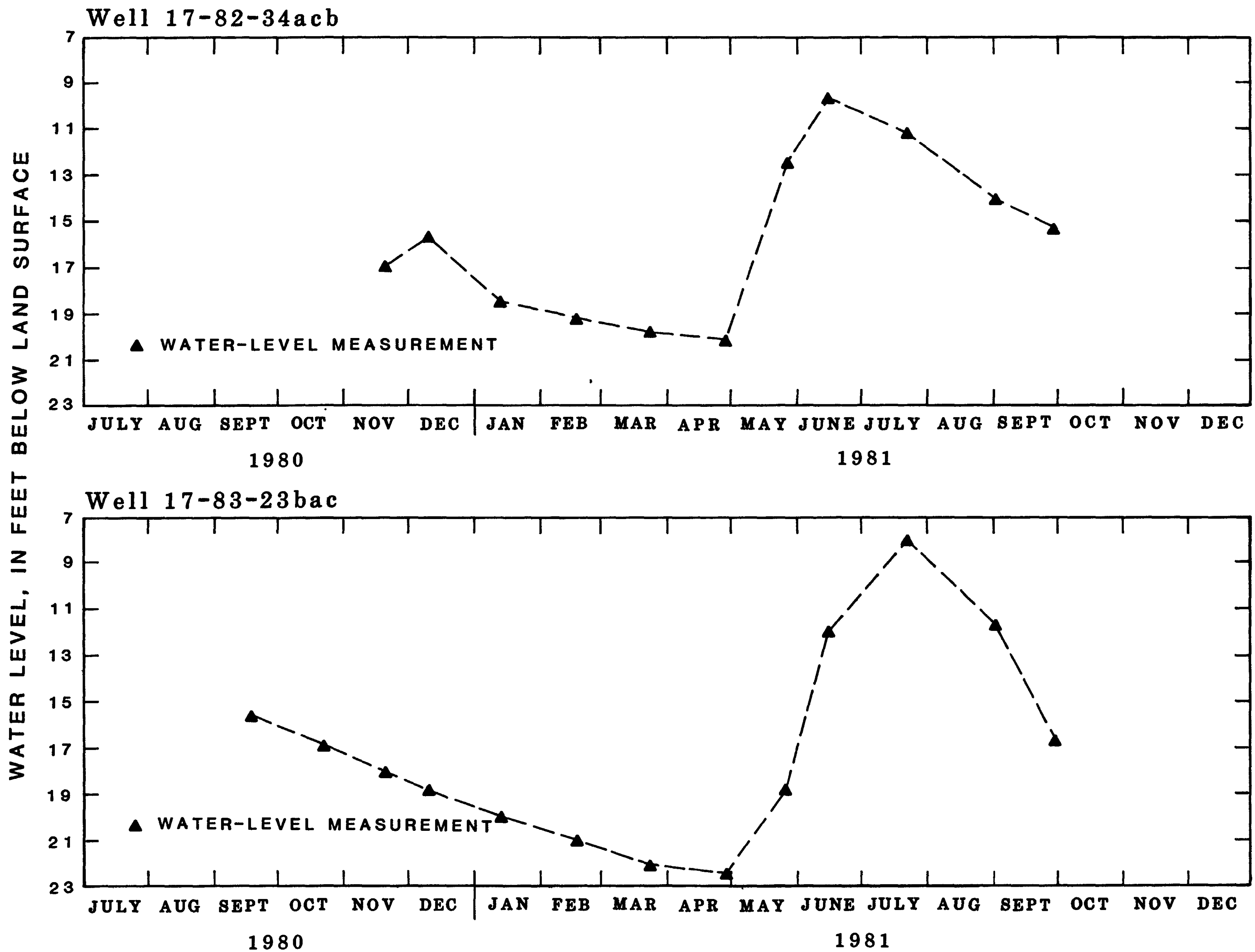

Figure 11.--Hydrographs for wells 17-82-34acb and 17-83-23bac.

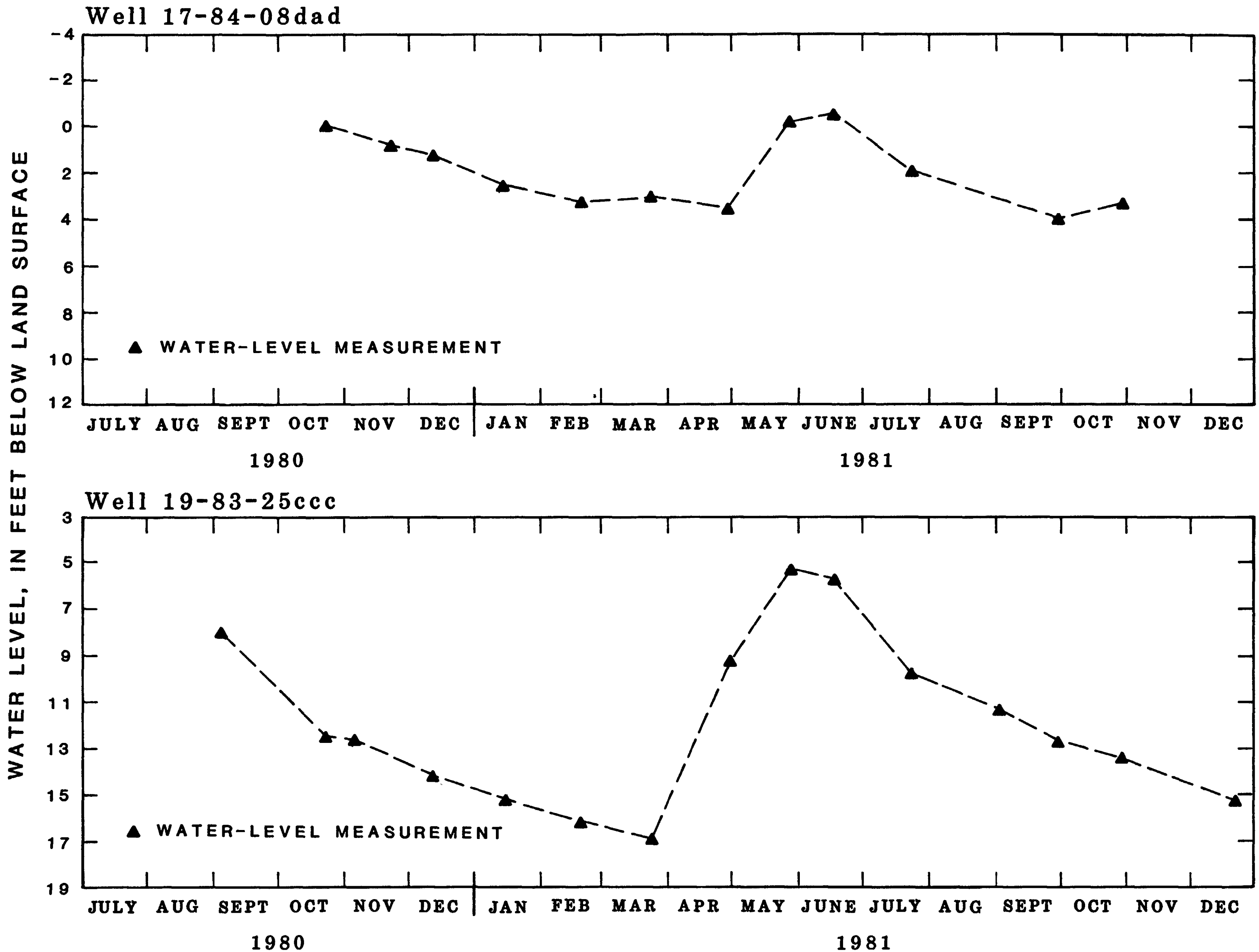

Figure 12.--Hydrographs for wells 17-84-08dad and 19-83-25ccc.

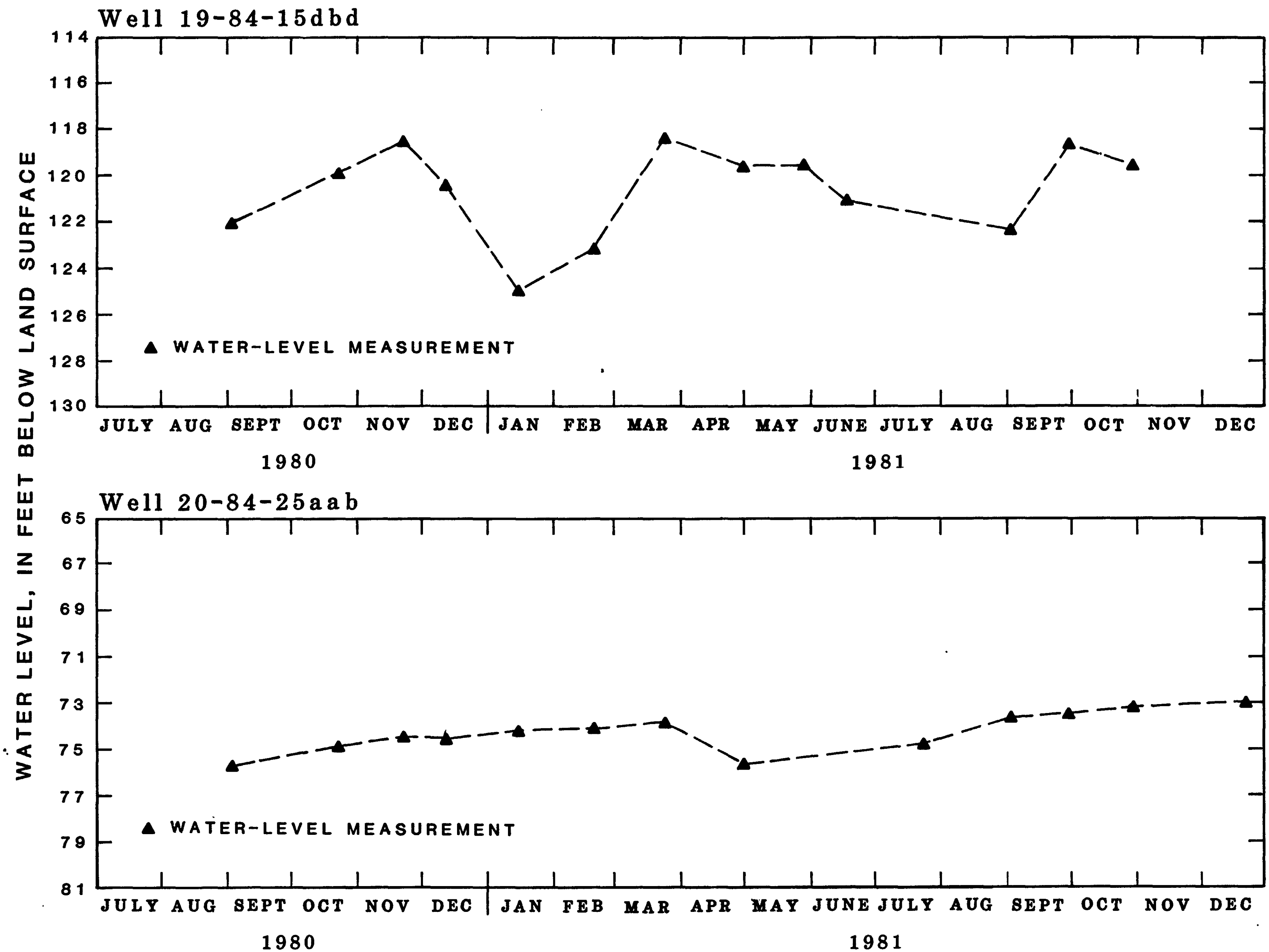

Figure 13.--Hydrographs for wells 19-84-15dbd and 20-84-25aab.

The period of record for all 12 wells is too short to project long-term trends in ground-water levels. Continued measurement of these wells will be necessary to identify trends in ground-water levels.

Computed Water Levels

A water-level-contour map can be used to determine the approximate direction of ground-water flow. Ground water flows in a line generally perpendicular to the contours from areas of higher hydraulic head to areas of lower hydraulic head.

Water-level contours in the shallow aquifer in the Saratoga Valley were drawn (pl. 2) using universal Kriging and a computer-driven plotter. Universal Kriging is a statistical method of interpolation that can be used to estimate ground-water altitudes, and errors in estimation, at specified locations based on known data points. It is particularly applicable for making estimates of water-level altitudes in areas where few data exist. A grid was drawn on a map of the Saratoga Valley with nodes established at 1-mi intervals. Kriged estimates of water-level altitudes were calculated at each node. A preliminary contour map of water-level altitudes with a contour interval of 20 ft was drawn by the plotter from 626 Kriged ground-water altitudes, 120 measured ground-water altitudes, and 115 stream altitudes obtained from topographic maps. The final map of the water-level surface was prepared by modifying the preliminary map in areas where the computer-generated contours differed from measured water levels.

Kriged estimates of error were calculated at each node on the grid. Estimated errors in water-level altitude ranged from zero at the points of measured water levels to ±7.0 ft in parts of the study area where few data were available.

The ground-water-level surface was best defined east and southeast of Encampment and around Saratoga because of the greater number of wells in these areas. Contours were not drawn in the northern and southern parts of the valley or east of the Precambrian rocks east of Saratoga because of lack of data. The water level ranges in altitude from 6,600 ft near the Walcott Junction to 7,600 ft along the Precambrian rock contact northwest and southeast of Encampment. The shape of the contours indicates that the North Platte River, Encampment River, and the downstream reach of Beaver Creek are gaining streams. The upstream reach of Pass Creek appears to be a losing stream. Ground-water flow generally is from topographically high areas toward the North Platte River, then northwest along the North Platte River in the southern 70 percent of the Saratoga Valley. In the northern 30 percent of the valley, flow generally is toward the west.

A water-level map produced by Kriging is useful as a tool in the preparation of the final water-level-contour map; however, results of Kriging need to be tempered to coincide with actual water levels. For a more detailed discussion on the theory and application of Kriging techniques, the reader should consult Skrivan and Karlinger (1980); Karlinger and Skrivan (1981); and Sophocleous and others (1982).

IRRIGATION

Agriculture, which is the primary industry in the Saratoga Valley, depends on irrigation. Water is diverted from the North Platte River and its tributaries to irrigate approximately 76,000 acres within the study area (Englert, 1980, p. 10-17). Maps of surface-water-irrigated acreage were provided by the Wyoming State Engineer and are compiled on plate 3.

Ground water is used to supplement surface-water irrigation in the valley during the summer and fall. As stated earlier, such ground-water use has increased since 1960. There are 30 registered irrigation wells in the Saratoga Valley, about two-thirds of which have been drilled since 1960 (pl. 3). Of these wells, 22 were used for irrigation during 1980 and 26 were used during 1981. The irrigation wells are concentrated in three parts of the valley: east of Encampment, north of Encampment, and north of Saratoga.

Pumpage measurements were made on 12 irrigation wells (table 2) in the Saratoga Valley. Six of the wells discharged into irrigation ditches, and six wells discharged into center-pivot and side-roll sprinkler irrigation systems. A Clampitron[1] flowmeter, a device that sonically measures the discharge through pipes, was used to obtain the discharge of all the measured wells. Clampitron-flowmeter measurements were verified at two wells by using a Hoff meter inserted in the discharge pipe. The Clampitron-flowmeter measurement was within 6 percent of one Hoff-meter measurement and within 1 percent of the other.

Electric-power consumption was recorded at the time Clampitron-flowmeter measurements were made in order to develop a relationship between acre-feet of water pumped and kilowatt hours used to pump the water. Computed values ranged from 0.00157 to 0.01333 acre-ft per 1 kWh. The acre-foot per kilowatt-hour relationship then was defined for nine other wells (table 2) for which electric-power records were available from Carbon Power and Light, Inc. Wells 18-83-21dad and 18-83-21aba had similar pump configuration and depth to water; the same relationship was assumed for both. Similarly, wells 15-83-06bcd and 15-84-10adb had approximately the same pump configuration and depth to water so the same relationship was used for them. The average relationship for the measured wells between Saratoga and Encampment was used for well 16-84-08aad. The average relationship for the measured wells east of Encampment was used for all unmeasured wells in that area for which electric-power records were available.

After the relationship between acre-feet and kilowatt hours was computed or defined for each well for which electric-power records were available, pumpage per year per well was calculated. The calculated value was the product of acre-feet per kilowatt hour and total annual kilowatts. The results of the calculations for 1980 and 1981 are shown in table 2. Discharges for wells 14-82-07abc and 14-82-07cdc were estimated from the total pumpage of the irrigation wells pumped using electric power.

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[1] Use of brand/trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 2.--Estimated pumpage of irrigation wells, 1980-81

[Well number: See text for explanation. Pump power: D, diesel; E, electric]

Well number	Measured well yield (gallons per minute)	Pump power	Estimated annual pumpage (acre-feet) 1980	1981
		East of Encampment		
14-82-07abc	--	D	100	125
cdc	--	D	100	125
14-83-03aac	--	E	0	29
bbc	130	E	[1] 50	[1] 27
bca	--	E	249	373
cab	--	E	115	101
cda	--	E	27	64
14-83-04adb	--	E	([1])	([1])
dad	--	E	61	212
15-83-34aca	--	E	0	101
ccd	--	E	121	148
cdc	320	E	105	97
dca	519	E	84	76
		Total	1,012	1,478
		North of Encampment		
15-83-06bbc	691	E	143	142
bcd	772	E	187	178
15-83-19bca	--	E	0	0
15-84-01cad	--	E	0	0
cdb	--	E	0	0
15-84-10adb	--	E	115	188
15-84-12bbb	--	E	0	0
16-83-31abb	201	E	0	8
16-84-08aad	--	E	0	275
		Total	445	791
		North of Saratoga		
18-83-15bcc	866	E	227	500
18-83-17add	--	E	[2]161	[2]244
cbc	1,160	E	118	309
dbc	947	E	([2])	([2])
18-83-18dad	1,050	E	133	215
dcc	1,570	E	204	400
18-83-21aba	--	E	205	121
dad	797	E	165	177
		Total	1,213	1,966
		TOTAL FOR VALLEY	2,670	4,235

[1] Power used by pumps in wells 14-83-03bbc and 14-83-04adb are measured by the same meter. Value shown is the combined yearly pumpage from the two wells.

[2] Power used by pumps in wells 18-83-17add and 18-83-17dbc are measured by the same meter. Value shown is the combined yearly pumpage from the two wells.

Approximately 2,700 acre-ft of ground water were pumped for irrigation during 1980 and 4,200 acre-ft during 1981, an increase of about 60 percent. Because much of the ground-water irrigation in the Saratoga Valley supplements surface water, ground-water requirements are affected by changes in surface-water flow. Streamflow in the North Platte River, Encampment River, and Pass Creek was more than 15 percent greater than average during 1980, whereas during 1981 flow in all three streams was at least 30 percent less than average. Four more wells were pumped during 1981 than during 1980. Total irrigated acreage decreased by less than 1 percent during 1981, compared with the previous year's total. The increase in ground-water pumpage during 1981 probably was the result of decreased surface-water flow.

SUMMARY AND CONCLUSIONS

Surface water supplies most of the irrigation-water requirements in the Saratoga Valley; approximately 76,000 acres are irrigated within the study area from the North Platte River and its tributaries. Ground-water pumpage supplements surface-water irrigation. Measured yields of irrigation wells during 1981 ranged from 130 to 1,570 gal/min. Approximately 2,700 acre-ft of ground water during 1980 and 4,200 acre-ft during 1981 were produced from the shallow aquifer for irrigation, an increase of about 60 percent during 1981. Development of ground water for irrigation is increasing in the Saratoga Valley. About two-thirds of the irrigation wells have been drilled since 1960.

Water levels were measured in about 140 wells in the study area during the summer and fall of 1980. Forty-one of these wells were measured in studies prior to 1969. Most of the water levels measured in 1980 were within 5 ft of the water levels measured prior to 1969. To determine short-term trends in ground-water levels in the Saratoga Valley, water levels were measured monthly in 12 wells and hourly records of water levels were obtained during the last 6 months of 1980 and all of 1981 for most of the 9 wells equipped with digital recorders. The period of record for all wells is too short to project long-range trends. Continued measurement of water levels at some of these wells would help determine the effects of pumping and development of the ground-water system, and should be useful in preparing a digital model of the flow system.

Lowry and others (1973) estimated the transmissivity from aquifer tests conducted on two wells and from ground-water/surface-water relationships. Transmissivity estimates ranged from 4,000 to 5,000 ft^2/d.

A water-level-contour map of the Saratoga Valley study area was prepared from 235 ground-water and stream altitudes using universal Kriging. The water-level-contour map indicates that ground water flows from the higher altitudes bordering the study area toward the North Platte River and downstream parallel to the North Platte River generally from southeast to the northwest.

REFERENCES CITED

de la Montagne, J. M., 1953, Cenozoic history of the Saratoga Valley area, Wyoming and Colorado: Laramie, Wyo., University of Wyoming unpublished Ph.D thesis, 140 p.

Englert, D. D., 1980, Annual report of the upper North Platte River and tributaries, 1980: Saratoga, State of Wyoming Board of Control report, 130 p.

Houston, R. S., and others, 1968, A regional study of rocks of Precambrian age in that part of the Medicine Bow Mountains lying in southeastern Wyoming <u>with a chapter on</u> The relationship between Precambrian and Laramide structure: Geological Survey of Wyoming Memoir No. 1, 167 p.

Karlinger, M. R., and Skrivan, J. A., 1981, Kriging analysis of mean annual precipitation, Powder River Basin, Montana and Wyoming: U.S. Geological Survey Water-Resources Investigations Report 80-50, 25 p.

Lowry, M. E., Rucker, S. J., IV., and Wahl, K. L., 1973, Water resources of the Laramie, Shirley, Hanna Basins and adjacent areas, southeastern Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-471, 4 sheets.

Skrivan, J. A., and Karlinger, M. R., 1980, Semi-variogram estimation and universal Kriging program: U.S. Geological Survey Computer Contribution, 98 p.

Sophocleous, Marios, Paschetto, J. E., and Olea, R. A., 1982, Groundwater network design for northwest Kansas, using the theory of regionalized variables: Ground Water, v. 20, no. 1, p. 48-58.

Weitz, J. L., and Love, J. D., 1952, Geologic map of Carbon County, Wyoming: Wyoming Geological Survey map, scale 1:160,000.