WATER-RESOURCES INVESTIGATIONS REPORT 94-4173
Kilpatrick, J.M., 1996, Temporal changes in the configuration of the water table in the vicinity of the Management Systems Evaluation Area site, central Nebraska

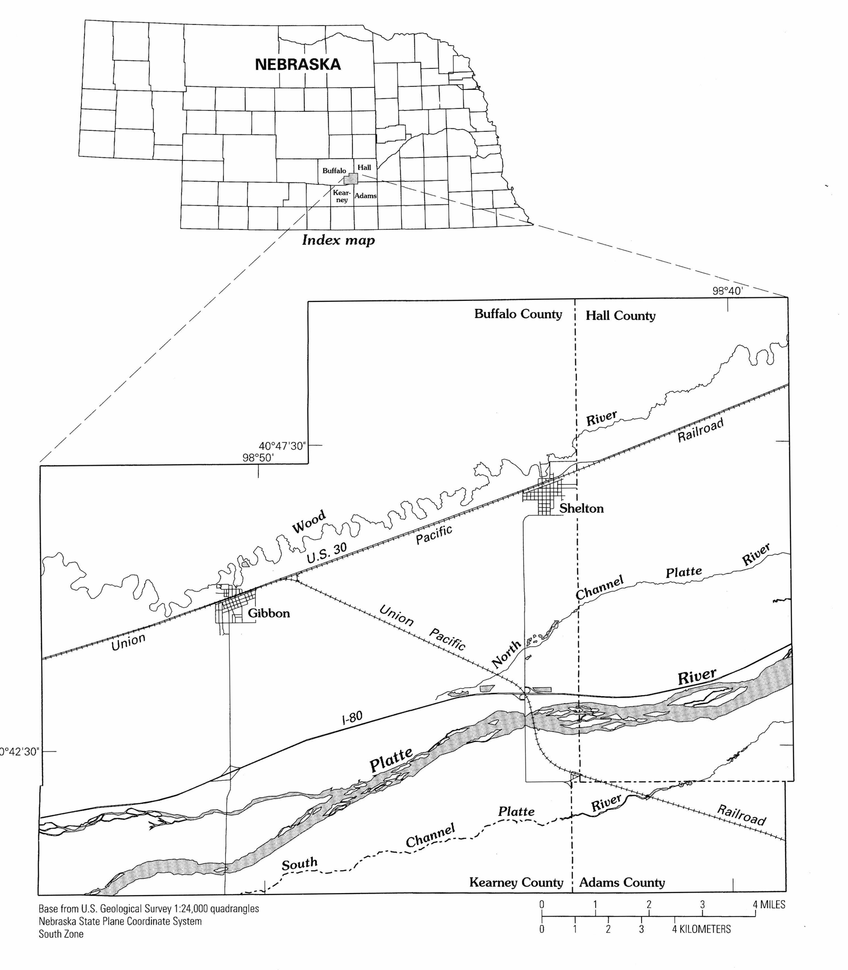

FIGURE 1.—Location of the study area for this report.

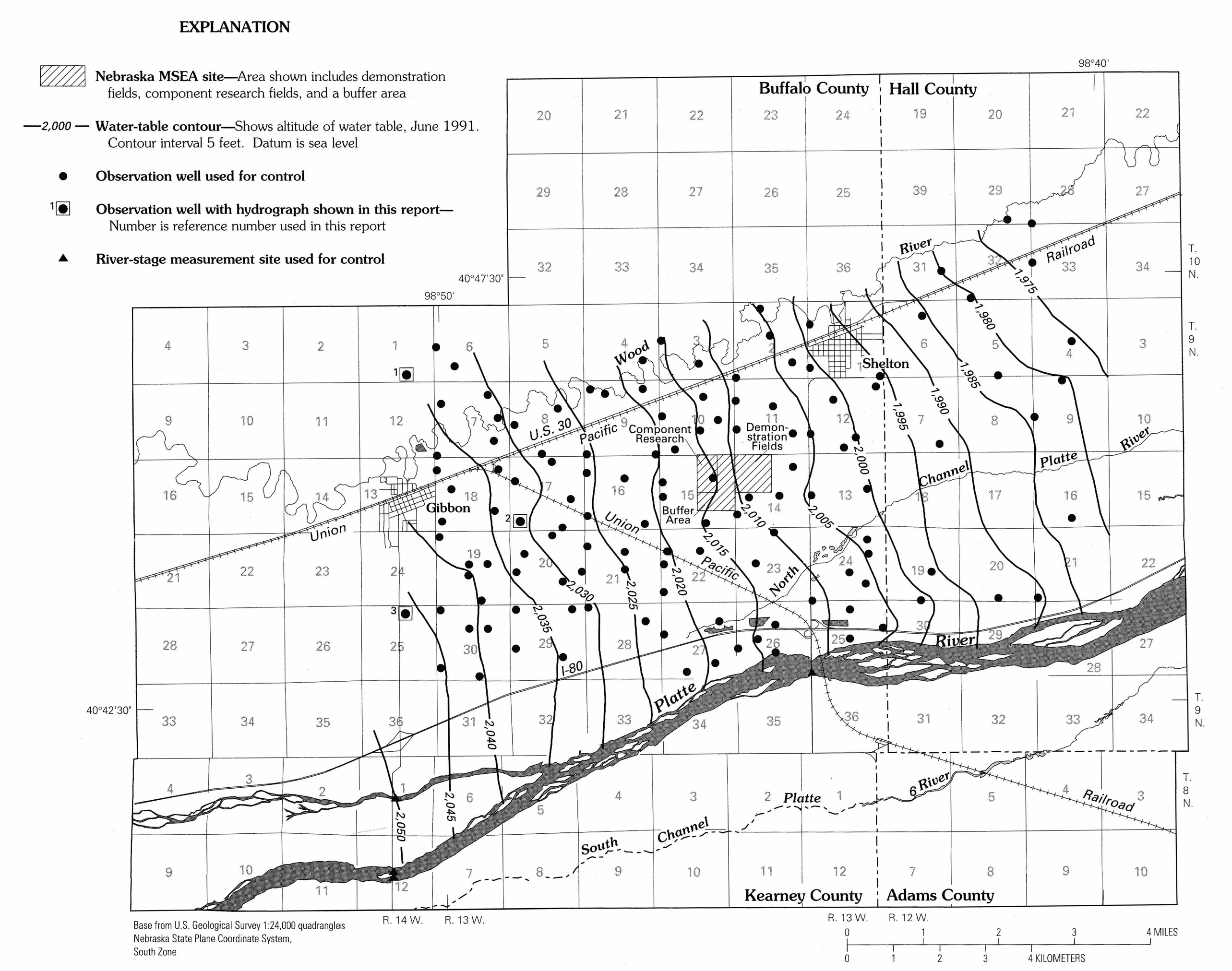

FIGURE 2.—Water table in study area in June 1991 and location of observation wells and river-stage measurement sites.

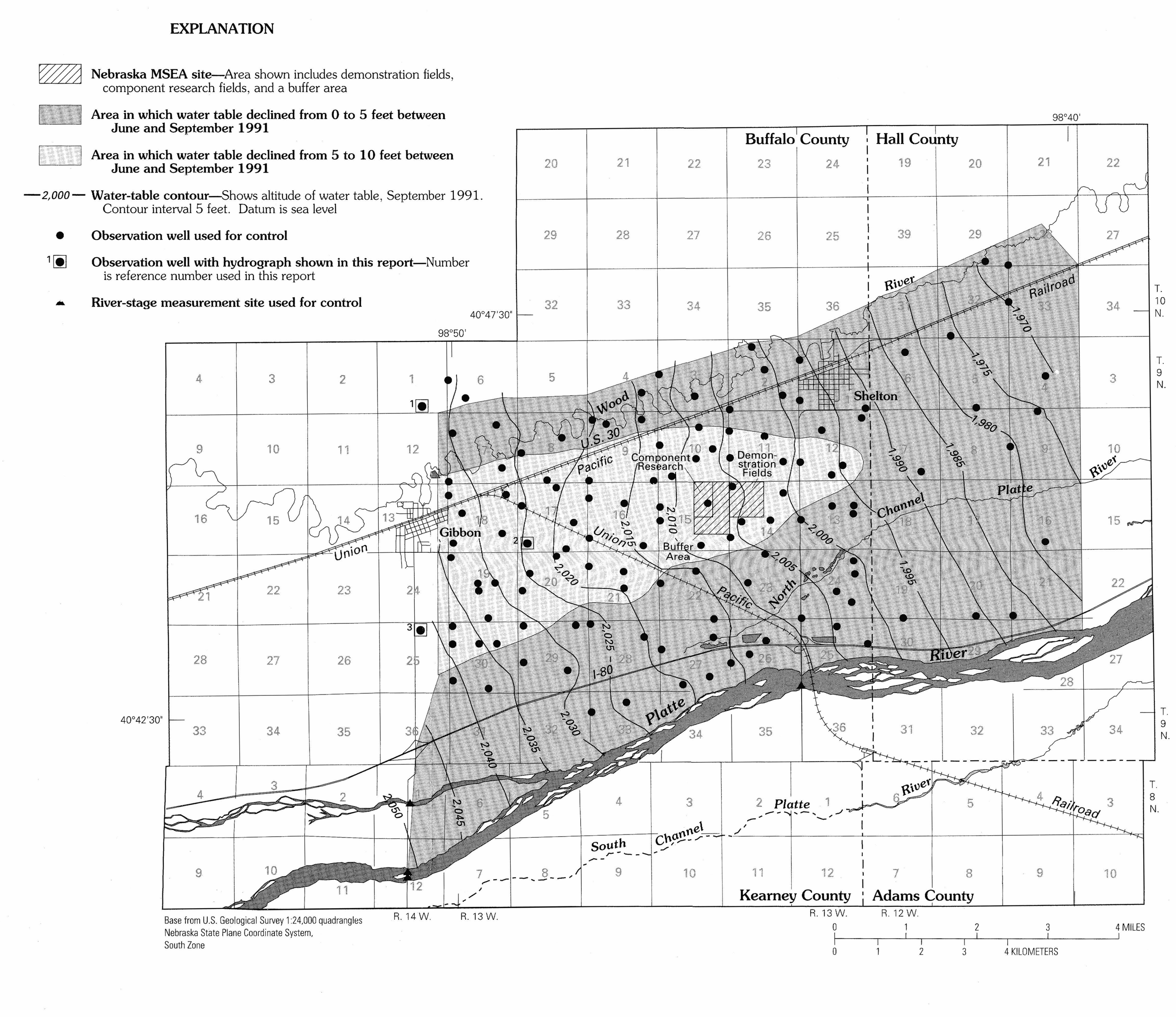

FIGURE 3.—Water table in study area in September 1991 and change in water-table altitude between June and September 1991.

ABSTRACT

To improve understanding of the hydrologic characteristics of the shallow aquifer in the vicinity of the Management Systems Evaluation Area site near Shelton, Nebraska, water levels were measured in approximately 130 observation wells in both June and September 1991. Two water-table maps and a water-level-change map were drawn on the basis of these measurements. In addition, historical data from U.S. Geological Survey computer files and published reports were used to determine the approximate configuration of the water table in 1931 and to draw one short-term and two long-term water-level hydrographs.

Comparison of the three water-table maps indicates general similarities. The average horizontal hydraulic gradient in the shallow aquifer is about 7.5 feet per mile, and the flow direction is to the east-northeast. The water table declined 2 to 10 feet between June and September 1991, with the greatest decline occurring in a wedge-shaped area south of the Wood River and north of the Platte River. The 1991 water-table configurations appear to indicate that the aquifer either was discharging to the Platte River in this reach or there was little flow between the river and the aquifer. Comparison of the 1931 and 1991 water-table maps indicates that, except for short-term variations, the water-table configuration changed little during this 61-year period. Two long-term water-level hydrographs confirm this conclusion, indicating that the shallow aquifer in this area has been in long-term, dynamic equilibrium.

INTRODUCTION

The Management Systems Evaluation Area (MSEA) program is part of a Federal interagency initiative to evaluate the effects of agricultural management systems on water quality. The program resulted from integration of the U.S. Department of Agriculture's (USDA) Research Plan for Water Quality and the U.S. Geological Survey's (USGS) Midcontinent Herbicide Initiative and is part of the President's Water Quality Initiative. The midcontinent Corn Belt was selected for study because it is an area where about 60 percent of the Nation's pesticides and nitrogen fertilizers are applied (Goolsby and others, 1991).

The Agricultural Research Service (ARS) and the Cooperative State Research Service (CSRS) of the USDA, the U.S. Environmental Protection Agency (EPA), and the USGS are collaborating on laboratory research and the study of small (about 20-mi^2) watersheds. The objectives of the work are to: (1) measure the effect of prevailing and modified farming systems on ground- and surface-water quality; (2) understand the processes and factors affecting the fate of selected agricultural chemicals; (3) assess the effect of selected agricultural chemicals on ecosystems; (4) assess the projected benefits to water quality of implementing modified farming systems; (5) evaluate the socioeconomic effects of using alternative farm management systems; and (6) transfer appropriate technology for use on the land. Five MSEAs were selected to represent some of the principal hydrogeologic settings and geographic diversity of prevailing farm management systems in the midcontinent region. MSEAs investigating alluvial settings are located in Minnesota, Nebraska, and Ohio. Those investigating loess and glacial till settings are located in Iowa and Missouri. Research is focused on ground-water processes in all areas, but surface-water processes also are being considered at the areas in Iowa and Missouri.

The goals of the MSEA investigators in Nebraska are to: (1) assess the effects of common farming practices and proposed best-management practices (BMP's) on ground-water quality, (2) develop new technologies or management methods to reduce ground-water contamination, and (3) evaluate the socioeconomic effects of these new technologies and management methods. USGS research in the MSEA study in Nebraska is related to the assessment of the effects of common farming practices and BMP's on ground-water quality.

The Nebraska MSEA site is located in southeastern Buffalo County, just southwest of the town of Shelton, Nebraska, in an area characterized by widespread and historic ground-water contamination with nitrate (Exner and Spalding, 1974). Because the concentrations of agricultural chemicals in the ground water represent a composite result of past and present agricultural practices, an accurate and detailed description of the hydrogeologic framework and a good understanding of the manner in which ground water moves through the aquifer at the site are required so that researchers can evaluate the effectiveness of different BMP's on reducing ground-water contamination. Because available hydrogeologic information in the vicinity of the site was insufficient for this purpose, the USGS began a study to characterize the hydrogeologic system in the vicinity of the Nebraska MSEA site and, in particular, to determine the characteristics of the aquifers and confining units present at the site, as well as the direction, quantity, and velocity of ground-water flow in the shallow aquifer during pumping and nonpumping seasons.

The purpose of this report is to present and describe the configuration of the water table in the vicinity of the Nebraska MSEA site during June 1991 and September 1991. A map of the change in water levels from June to September 1991 is presented and used along with a detailed 1991 hydrograph of a nearby well to illustrate seasonal fluctuation in water levels. In addition, to evaluate long-term water-level changes, a composite water-table map for 1931 is presented along with two long-term water-level hydrographs.

Description of the Study Area

The study area for this report encompasses an approximately 50-mi^2 (fig. 1) area around the Nebraska MSEA site that contains both flood plains and terraces along the Platte River Valley (fig. 2). Most of the soils found in the study area are permeable silt loams, which allow only a small volume of surface-water runoff. The area is cropped intensively, with more than 75 percent of the land devoted to the continuous, irrigated production of corn. Much of the remaining land is used to produce soybeans, which also are irrigated.

Geohydrology

The study area is underlain by between 45 and 75 ft of sand and gravel deposits of Quaternary age. In general, the bottom 35 to 40 ft of these deposits is saturated. The source of irrigation water is this shallow, saturated alluvium, which is tapped by more than 275 irrigation wells within the study area. This shallow, unconfined aquifer is underlain in much of the study area by 5 to 20 ft of silty clay. Most irrigation wells in the area do not penetrate this silty clay unit, which occurs between the sand and gravel deposits of Quaternary age and the Ogallala Formation of Tertiary age in this area. This silty clay unit thins along the southern edge of the study area near the Platte River, where the sand-and-gravel deposits of Pleistocene age generally are thickest, and is thought to confine the aquifer in the Ogallala Formation immediately below it. The Ogallala Formation within the study area generally consists of lenses and irregular beds of clay, silt, sand, gravel, and lime-cemented sandstone. It is commonly the source of water for domestic and stock use in the study area because concentrations of nitrate in water from the Ogallala aquifer are much lower than in water from the overlying shallow aquifer (Exner and Spalding, 1990).

Method of Study

Irrigation wells completed in the shallow aquifer were selected from well-registration records of the Nebraska Department of Water Resources for use as observation wells. Water levels were measured using steel tapes in 123 observation wells between June 10 and 13, 1991, and in 122 wells between September 9 and 12, 1991. The change in water levels was calculated for the 117 wells that were measured during both time periods. River stages also were measured during both of these time periods at several sites along the Wood River, the North Channel Platte River, and the Middle Channel Platte River. Stages were measured at 14 sites in June and at 12 sites in September 1991. Stages in the Wood River and the North Channel of the Platte River indicated that these streams were not hydraulically connected to the shallow aquifer. Therefore, only the 4 sites measured on the Middle Channel of the Platte River were used in mapping the water table. Water-table contours were drawn by hand taking into account the measured water levels and river stages, and, where fewer control data were available, the land-surface topography. Land-surface altitudes of observation wells were estimated from USGS 7 1/2-minute topographic quadrangles, and this possible error also was taken into account when water-table contours were drawn. The water-level-change map was drawn by taking into account the water-level change at each well and the difference between water levels where contour lines intersected when the June and September water-table maps were overlain. Historical water-level data were retrieved from USGS computer files and published reports.

WATER-TABLE CONFIGURATION, JUNE 1991

The water-table configuration drawn based on measurements made in June 1991, prior to summer irrigation, indicates a slope to the east-northeast with an average horizontal hydraulic gradient of approximately 7.5 ft/mi (fig. 2). There were no significant anomalies or drawdown cones in the water table at that time because 9 months without pumping allowed the water table to recover from declines caused by pumping during the previous irrigation season. The water table in the aquifer immediately adjacent to the Platte River generally was higher than in the river, indicating that the aquifer was discharging water to the river.

WATER-TABLE CONFIGURATION, SEPTEMBER 1991

The water-table configuration delineated by measurements made in September 1991 (fig. 3) is slightly different from the June 1991 water table. The ground-water-flow direction and gradient were about the same as that in June, but the September water table was between 2 and 10 ft lower. This is indicative of the intensive pumping and evapotranspiration that occurred in the study area during the 3-month period between water-level measurements. The stage of the Platte River appears to be approximately the same elevation as the water table in the adjacent aquifer, indicating that there was little flow between the aquifer and river.

SEASONAL CHANGES IN WATER-TABLE CONFIGURATION DURING 1991

Comparison of the two water-table maps for June and September 1991 yielded the water-level-change map also shown in figure 3. The area of the greatest seasonal water-level decline lies between the Wood River to the north and the Platte River to the south. This area is about 3 mi wide at the western edge of the study area and gradually tapers out to the east near the Buffalo-Hall County line. Smaller ground-water-level declines along the Platte and Wood Rivers resulted because less pumpage occurs in these areas and because these rivers, particularly the Platte, may at some times of the year provide some recharge to the aquifer. Less pumpage for irrigation probably is responsible for the smaller ground-water-level declines in Hall County as well. The short-term water-level hydrograph of observation well 1 (fig. 4) indicates that the greatest water-level decline in 1991 occurred from June through August. Water levels declined rapidly during these months and began to rise in early September.

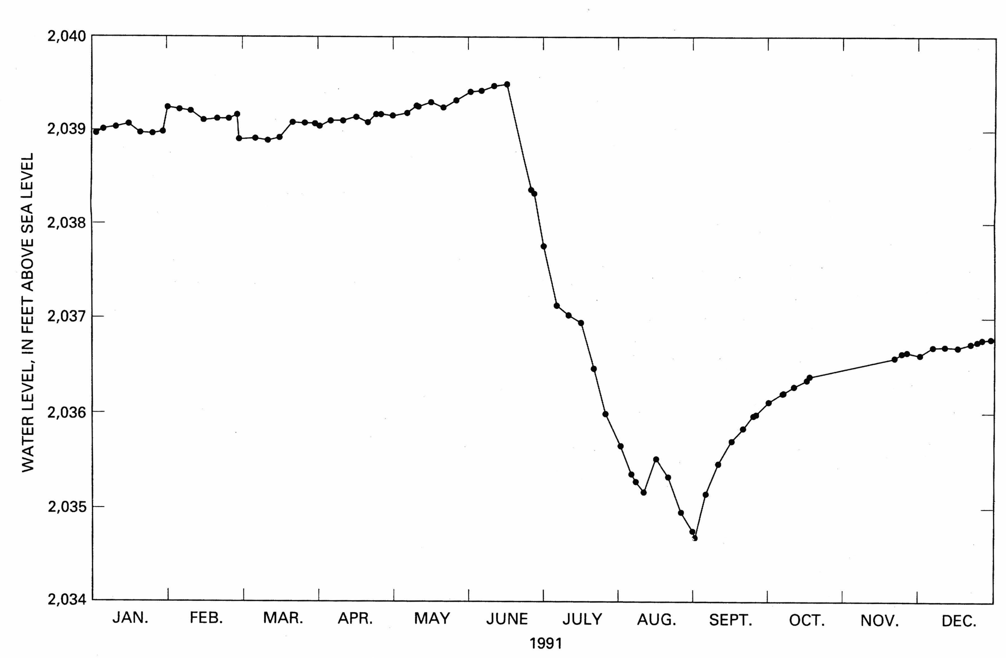

FIGURE 4.—Seasonal water-level fluctuations in observation well 1 (SE1/4, SW1/4, sec. 1, T. 9 N., R. 14 W.) during 1991.

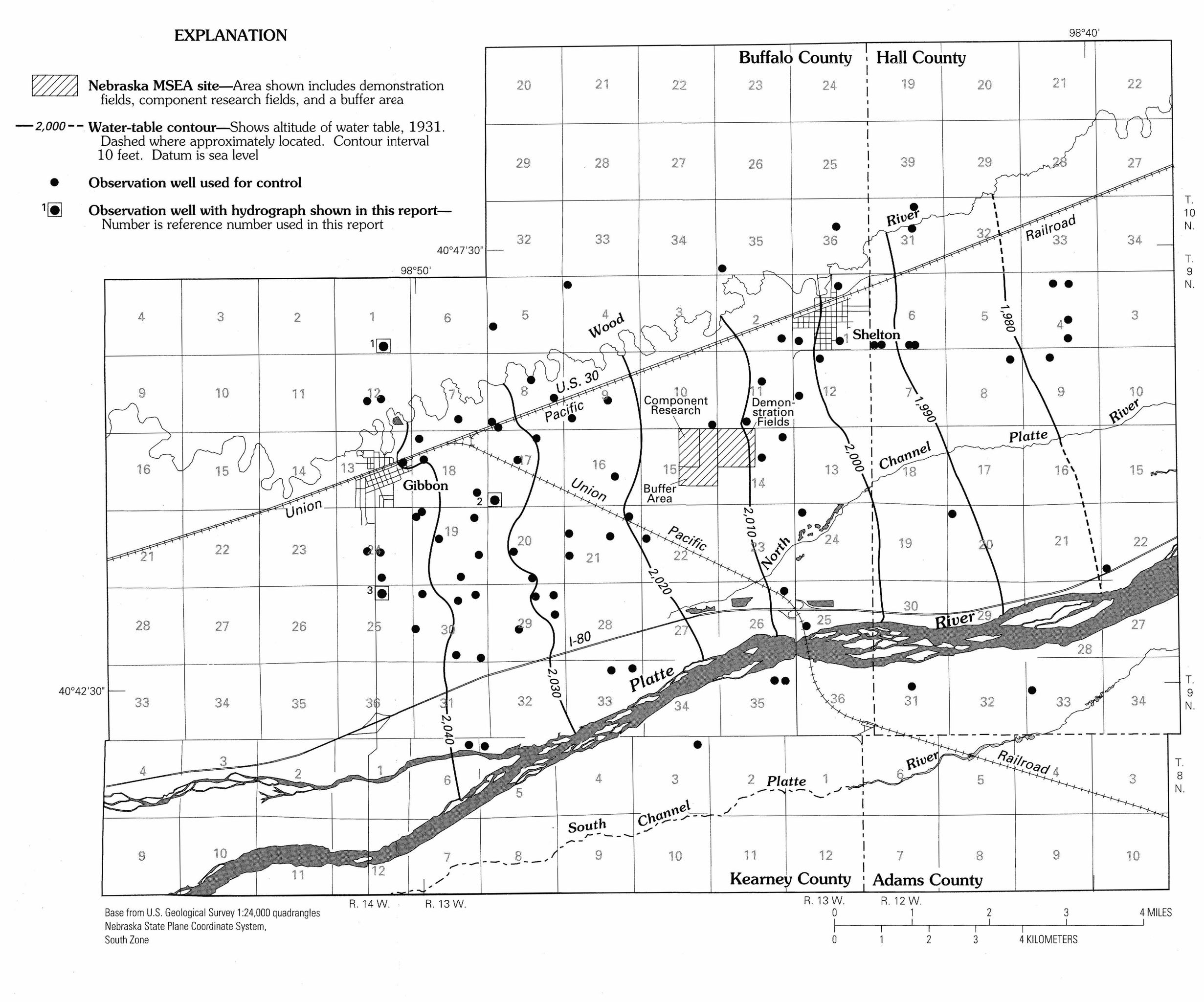

FIGURE 5.—Water table in study area in 1931 and location of observation wells.

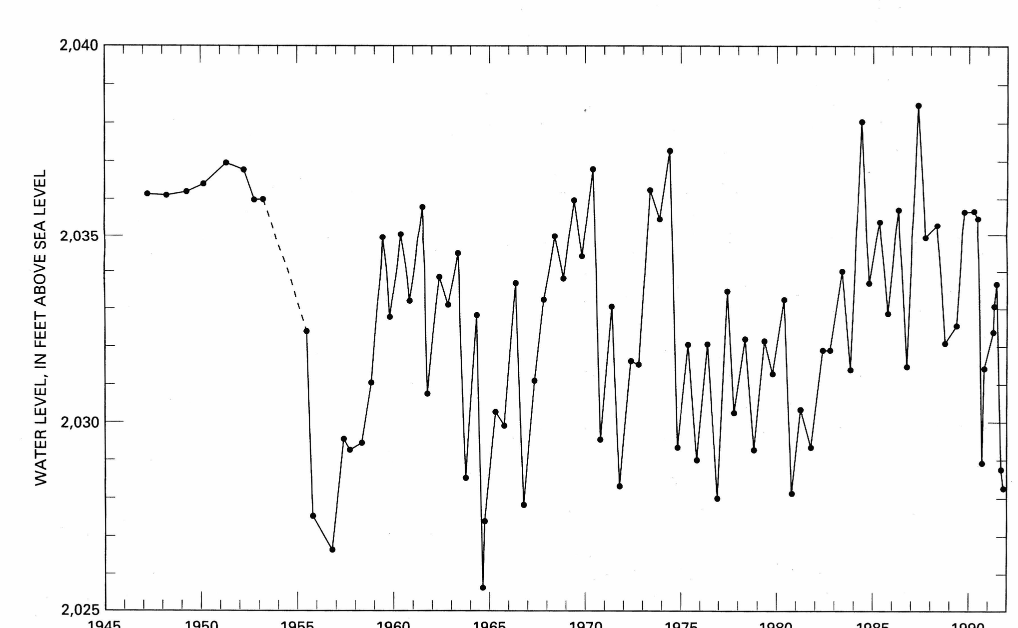

FIGURE 6.—Long-term water-level fluctuations in observation well 2 (SW1/4, SW1/4, sec. 17, T. 9 N., R. 13 W.), 1947–91.

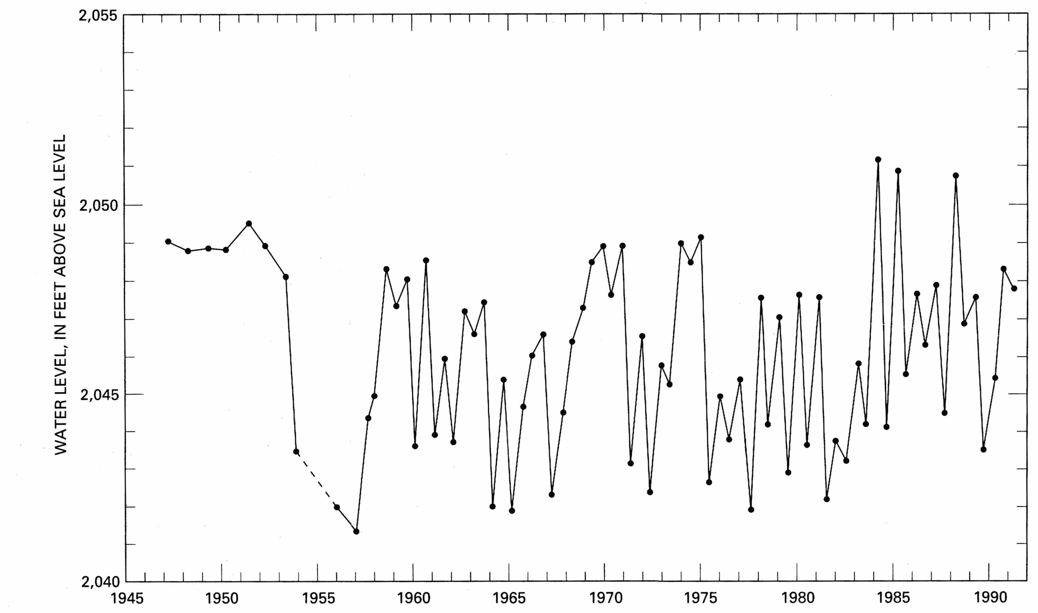

FIGURE 7.—Long-term water-level fluctuations in observation well 3 (NE1/4, NW1/4, sec. 25, T. 9 N., R. 14 W.), 1947–91.

WATER-TABLE CONFIGURATION, 1931

The water table in the aquifer in 1931 was contoured (fig. 5) based on data published in Lugn and Wenzel (1938) to evaluate the significance of any long-term change in water levels. These water levels were measured between May and November 1931; therefore, the water table drawn is a composite for this period and does not represent a particular season. The gradient and direction of ground-water flow are similar to those in 1991, particularly when compared to the June 1991 water table. A close look at the 1931 water table near the Platte River would seem to indicate that flow between the aquifer and river was insignificant.

LONG-TERM CHANGES IN WATER-TABLE CONFIGURATION

Upon comparison, there appears to be little difference between the water-table configurations drawn for 1991 and the one drawn for 1931 (figs. 2, 3, and 5). Consequently, it seems likely that the aquifer has been in long-term, dynamic equilibrium. Recharge to the aquifer has been approximately equal to discharge from the aquifer. This is illustrated also by the two long-term hydrographs in figures 6 and 7, which show both short-term and long-term water-level variations over time.

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square mile (mi^2)	2.590	square kilometer (km^2)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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TEMPORAL CHANGES IN THE CONFIGURATION OF THE WATER TABLE IN THE VICINITY OF THE MANAGEMENT SYSTEMS EVALUATION AREA SITE, CENTRAL NEBRASKA

By
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1996