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OFFICE: ...United States Geological Survey

PWS-0201-0001

Time-Series Ground-Water-Level and Aquifer-System Compaction Data, Edwards Air Force Base, Antelope Valley, California, January 1991 through September 1993

By Lawrence A. Freeman

U.S. GEOLOGICAL SURVEY
Open-File Report 96-186

Prepared in cooperation with
EDWARDS AIR FORCE BASE

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS AND ACRONYMS

Conversion Factors

Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
pound per square inch (psi)	703.1	kilograms per square meter
pound per square inch (psi)	2.30667	feet of water at 4.0 degrees Celsius
yard (yd)	.9144	meter
millibar (mbar)	.0336	height of water, in feet

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F=1.8(°C)+32$$

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Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD 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.

Local barometric pressure: Barometric pressure is shown as recorded without correction to sea level.

Abbreviations and Acronyms

A	Ampere
ADAPS	Automated DAta Processing System
DBLS	Depth to water Below Land Surface
DC	Direct Current
DECODES	DEvice COnversion and DElivery System
GLS	Generalized Least Squares
GPS	Global Positioning System
LVDT	Linear Voltage Displacement Transducer
mbar	Millibar
mV	Millivolt
Mw	Magnitude
NWIS	National Water Information System
PST	Pacific Standard Time
USGS	U.S. Geological Survey
V	Volt
W	Watt

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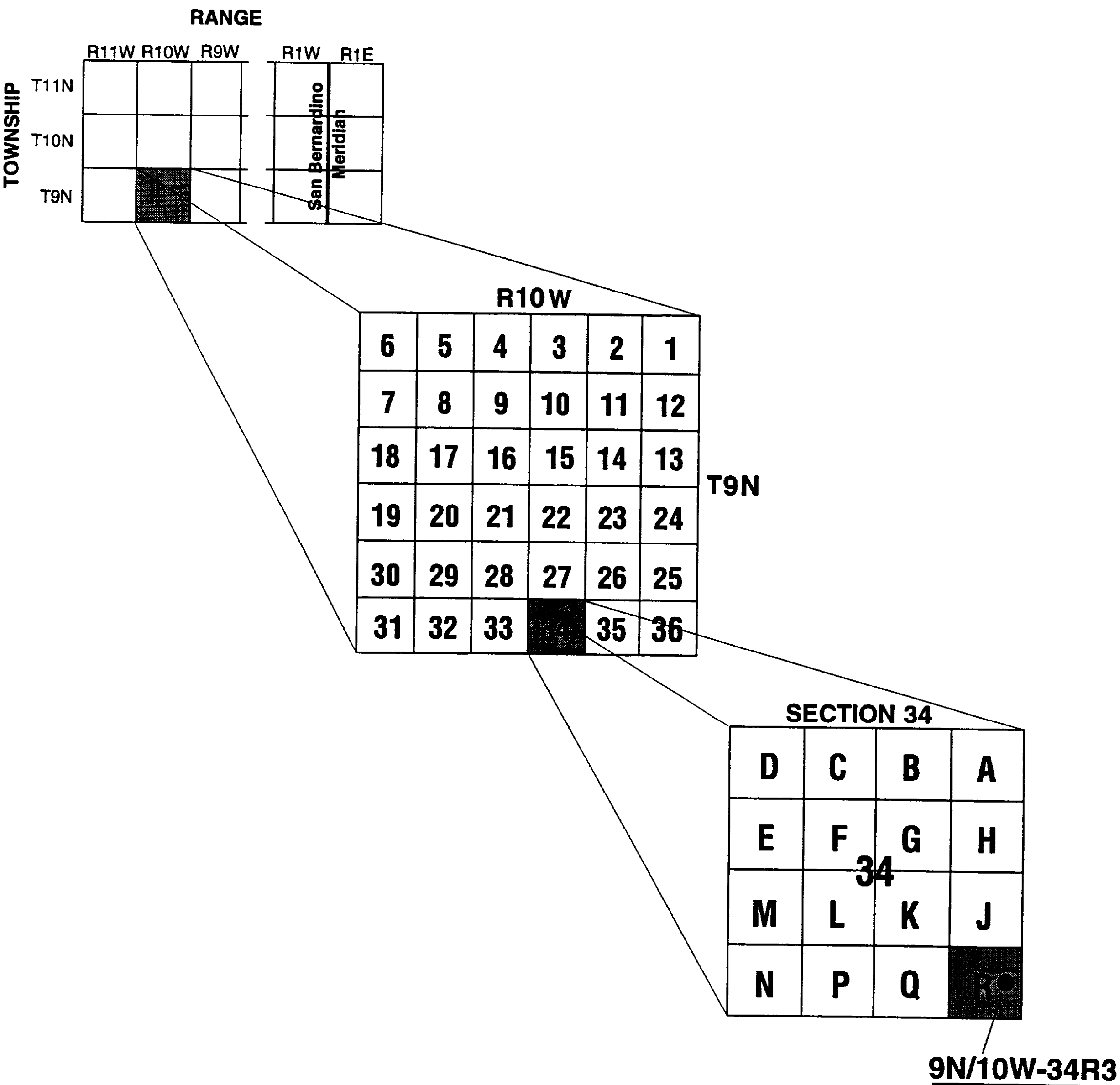
Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). All wells in the study area are referenced to the San Bernardino base line and meridian (S). Well numbers consist of 15 characters and follow the format 009N010W34R003S. In this report, well numbers are abbreviated and written 9N/10W-34R3. Wells in the same township and range are referred to only by their section designation, 34R3. The following diagram shows how the number for well 9N/10W-34R3 is derived.



Time-Series Ground-Water-Level and Aquifer-System Compaction Data, Edwards Air Force Base, Antelope Valley, California, January 1991 through September 1993

By Lawrence A. Freeman

Abstract

As part of a study by the U.S. Geological Survey, a monitoring program was implemented to collect time-series ground-water-level and aquifer-system compaction data at Edwards Air Force Base, California. The data presented in this report were collected from 18 piezometers, 3 extensometers, 1 barometer, and 1 rain gage from January 1991 through September 1993. The piezometers and extensometers are at eight sites in the study area. This report discusses the ground-water-level and aquifer-system compaction monitoring networks, and presents the recorded data in graphs. The data reported are available in the data base of the U.S. Geological Survey.

INTRODUCTION

Long-term withdrawal of ground water at Edwards Air Force Base has resulted in aquifer-system compaction. This has produced three predominant problems:

1. Land-surface deformation resulting in the formation of earth fissures and erosion caused by altered surface-water drainage gradients;
2. Permanent loss of ground-water-storage capacity of the aquifer system (Ikehara and Phillips, 1994); and
3. Structural damage to man-made facilities as a result of land surface subsidence.

Land subsidence has created earth fissures and cracks in the bed of Rogers Lake. The dry lakebed is used by Edwards Air Force Base as a space shuttle landing site and as an emergency landing site for various types of experimental and test aircraft. Earth fissures and cracks are a hazard to airfield activity. Fissures also can create direct pathways for lake water and surficial contaminants to enter shallow aquifers. Land-surface deformation, in the form of a tilt, has occurred because of the uneven distribution of subsidence at the base. This has altered surface-water drainage gradients and caused erosional features that did not exist historically (Blodgett and Williams, 1992). The permanent and continuing loss of ground-water storage capacity due to aquifer-system compaction has made it increasingly difficult to pump equivalent amounts of water during each pumping season. After the pumping season ends, water levels may recover to nearly the same elevation as the previous season. However, the actual amount of water available in storage is reduced due to compaction of the aquifer system. When pumping resumes, ground water levels decline rapidly and return to the previous years' low levels. Ground-water pumps must operate longer, and lift the water greater distances in order to obtain the same amount of water. This results in increased pumping costs (Londquist and others, 1993).

Structural damage as a result of land subsidence commonly includes damage to roads, runways, sewer systems, wells, and water distribution systems (Blodgett and Williams, 1992). Repair or replacement costs can be high. Subsidence has caused structural weaknesses or changes from the original design and has increased the structure's susceptibility to damage from natural disasters, such as floods and earthquakes.

In 1989, the U.S. Geological Survey (USGS), in cooperation with Edwards Air Force Base, began a series of investigations to evaluate geohydrologic factors related to the deformation of the bed of Rogers Lake. The study area is located on Edwards Air Force Base, which is located in Antelope Valley, California (fig. 1). Defining the geohydrologic processes at Edwards Air Force Base that are related to the spatial distribution and rate of land subsidence, as well as the causes and locations of earth fissuring, is the primary objective of the USGS investigations. Land subsidence and surface deformation associated with ground-water withdrawals are problems occurring nationally and globally. Determining ground-water management alternatives that could mitigate aquifer-system compaction at Edwards Air Force Base is a secondary objective.

Purpose and Scope

The purpose of this report is to present data that can be used to determine the relationship of ground-water levels to the land subsidence and aquifer-system compaction that is occurring on, and adjacent to, Edwards Air Force Base. The data reported were collected January 1991 through September 1993 from a ground-water monitoring network at Edwards Air Force Base. Computed hourly data were derived from data collected by specialized instrumentation and automatic recording devices, and include ground-water levels, aquifer-system compaction, barometric pressure, and precipitation. This report also includes a brief discussion of the methods used to collect and process the data.

The data presented in this report are provided graphically, in two sections. Daily mean values for the period of record are included in the section, "Data for periods of record at instrumented sites." Hourly data for periods of selected geohydrologic events are presented in the section, "Data for periods of special interest." Plots for periods of selected geohydrologic events may have two or more types of data on each plot. The purpose of including these plots is to demonstrate the temporal and spatial responses shown by certain data for the selected geohydrologic events and to provide the users of these data with several examples of what can be determined by the use of hourly values.

Previous Studies

The U.S. Geological Survey has completed several reports from studies made in cooperation with Edwards Air Force Base (Moyle, 1960; Weir, 1962, 1963, 1965; Giessner and Robson, 1965; Giessner and Westphal, 1966; Tyley, 1967; and Koehler, 1969). In addition, several recent studies by the USGS have reported on land subsidence, land-surface deformation, and hydrogeology of Edwards Air Force Base and vicinity. Blodgett and Williams (1992) reported measured land subsidence at Edwards Air Force Base that occurred between 1961 and 1989 through 1991, and they reported on features of land-surface deformation affecting the lakebed of Rogers Lake. Ikehara and Phillips (1994) also measured land surface elevation at Edwards Air Force Base in 1992 as part of the larger Antelope Valley study, and recalculated subsidence. Londquist and others (1993) summarized the regional hydrogeologic setting of Antelope Valley and reported on geologic, geophysical, and hydrologic data, including aquifer-system compaction, collected by the USGS from 1989 through 1991. Rewis (1993) reported on additional lithologic, borehole geophysical, and monitoring-well construction data collected by the USGS from 1991 through 1992. Land use and water use in the Antelope Valley was reported on by Templin and others (1995). The 1992 seasonal potentiometric surface maps of the Lancaster and North Muroc ground-water subbasins in the vicinity of Edwards Air Force Base (fig. 2), based on monthly ground-water-level measurements, were shown in Rewis (1995). The extent of USGS hydrogeologic investigations at Edwards Air Force Base and vicinity from 1989 through 1992 is summarized in Prince and others (1995).

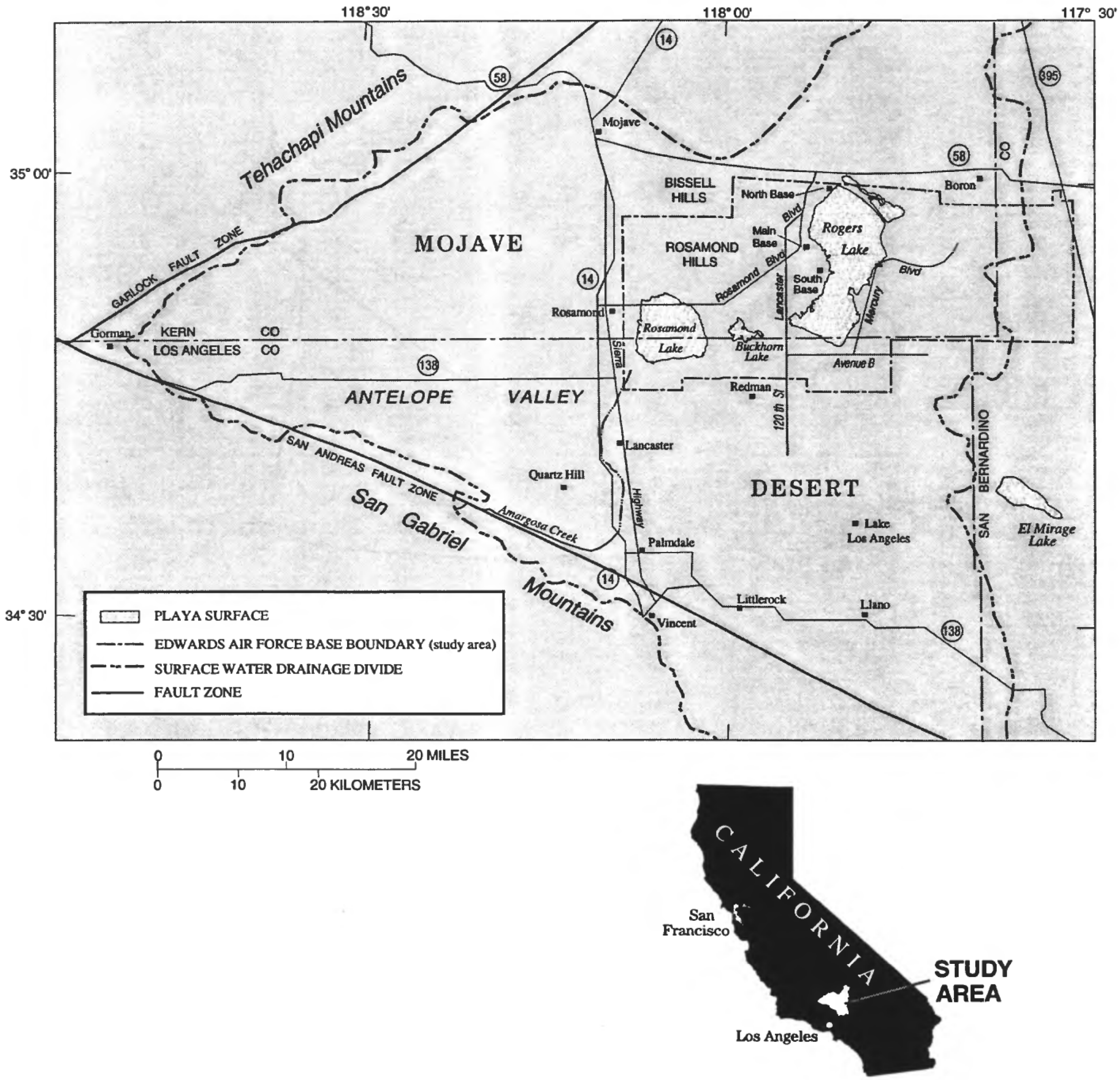


Figure 1. Location of Edwards Air Force Base study area (modified from Londquist and others, 1993).

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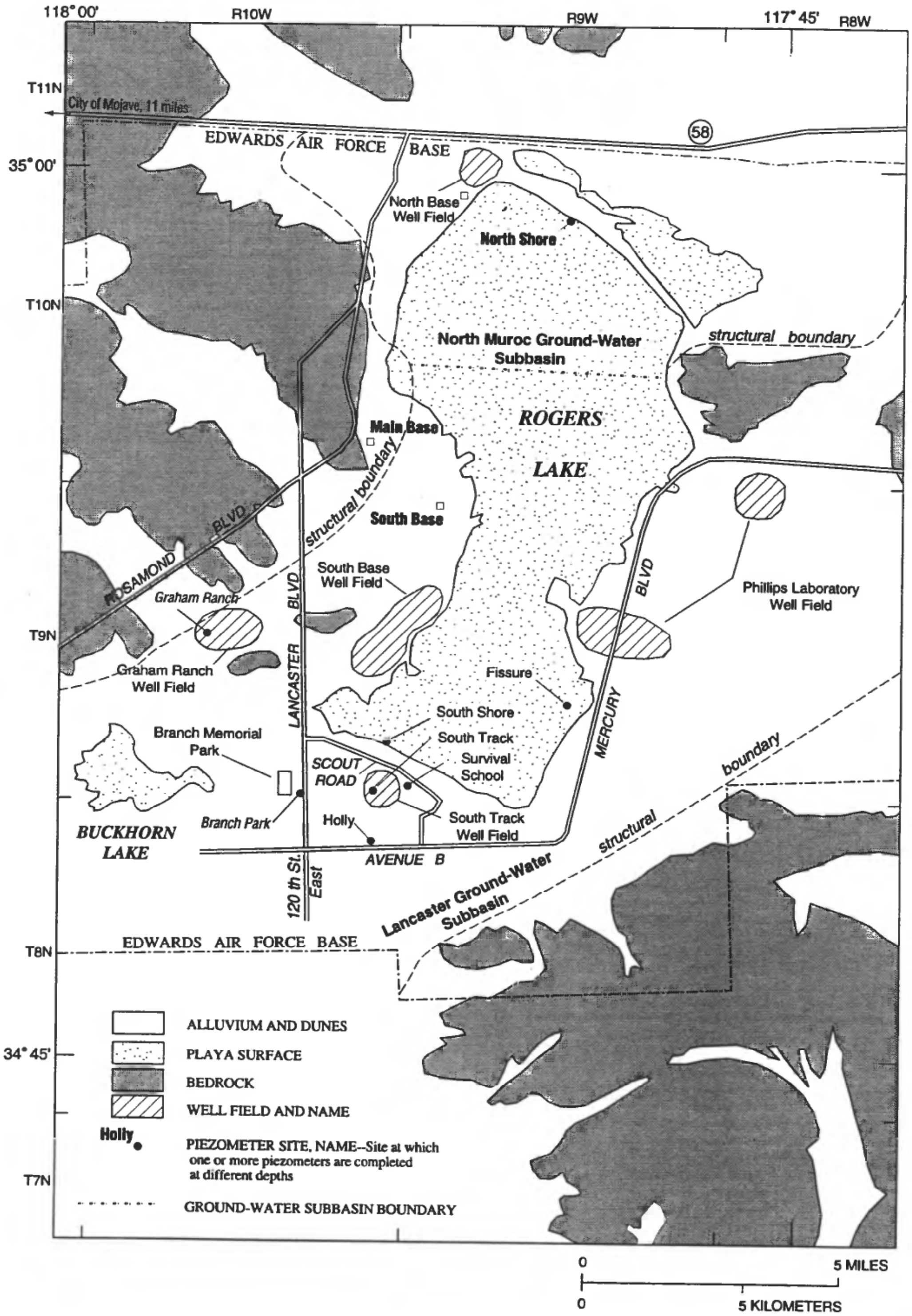

Figure 2. Location of sites on Edwards Air Force Base where time-series records of ground-water-level and aquifer-system compaction data were collected (modified from Rewis, 1993).

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Acknowledgments

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GROUND-WATER-LEVEL MONITORING SITES

Ground-water levels were monitored at eight sites in the Edwards Air Force Base study area. The monitored sites were selected from a large network of existing domestic and abandoned wells and the observation wells that were drilled by the USGS. This section of the report discusses criteria for site selection, locations of sites, instrumentation, and data collection.

Site Selection

There were several considerations in determining where to locate the ground-water-level monitoring sites. Monitoring water-level fluctuations in the proximity of the South Track Well Field (fig. 2), and at several distances from this important pumping center, was the primary consideration. This production well field is near the location of maximum measured land subsidence at Edwards Air Force Base (Londquist and others, 1993). Secondly, ground-water-level data were needed at the two extensometer sites, Holly and Fissure, located near the South Track and Phillips Laboratory Well Fields, respectively (fig. 2). In addition, sites were needed to monitor ground-water levels in the principal and deep aquifers (Londquist and others, 1993) over a large representative area in the vicinity of Rogers Lake. Finally, a small unnamed ground-water basin in the Graham Ranch area (fig. 2) was of interest because it offered a possible alternative supply of ground water for Edwards Air Force Base. This ground-water subbasin is isolated from the Lancaster ground-water subbasin, which is the primary water supply for Edwards Air Force Base (Londquist and others, 1993).

A series of exploration wells were drilled by the USGS from 1989 through 1992. The initial purpose for these wells was to obtain geological and geophysical information (Londquist and others, 1993; and Rewis, 1993). These wells were then configured as single or nested piezometers (fig. 3) for the purpose of determining seasonal water-level changes, seasonal potentiometric surfaces, and hydraulic gradients of the different aquifers. A piezometer differs from a well in that it is constructed to determine the water level of a discreet zone or thickness of the aquifer system. A well is typically constructed to withdraw water from more than one aquifer or aquifer zone and, therefore, reflects a composite hydraulic head (Fetter, 1988).

After more than a year of making periodic ground-water-level measurements, enough information had been gathered to determine the best sites for time-series data collection, and which of the individual piezometers at the sites would provide the most useful information.

Site Locations and Operational History

Eight sites were selected for this study and are listed in table 1 and shown in figure 2. Site name, state well number, USGS site-identification number, piezometer number, land surface datum, elevation, and screened interval of each piezometer are listed in table 1.

Table 1. Time-series ground-water-level data-collection sites at Edwards Air Force Base

[USGS, U.S. Geological Survey. ft, feet. Site identification No., as listed in California District National Water Information System (NWIS) site file. Land surface datum elevation and depth of screened interval as listed in California District Ground Water Site Inventory data base]

Local site name	State well No.	USGS site identification No.	Piezometer No.	Land surface datum (ft)	Depth of screened interval (ft)
Holly	8N/10W-1Q1	344835117531301	1	2,301.85	[1]980-1,010
	-1Q2	344835117531302	2	2,301.72	[1]605-635
	-1Q3	344835117531303	3	2,301.72	[1]430-460
	-1Q4	344835117531304	4	2,301.72	[1]85-115
Fissure	9N/9W-28A1	345056117501401	1	2,271.08	[2]735-745
	-28A3	345056117501403	3	2,271.08	[2]320-340
	-28A5	345056117501405	5	2,271.08	[2]40-60
Graham Ranch	9N/10W-16R2	345212117561802	2	2,312.8	[1]494-564
	-16R3	345212117561803	3	2,312.8	[1]300-340
South Track	9N/10W-36P2	344922117543301	1	2,290.90	[2]435-455
	-36P3	344922117543302	2	2,291.21	[2]90-110
Survival School	9N/10W-36J1	344932117525401	1	2,283.00	[2]870-890
	-36J2	344932117525402	2	2,283.00	[2]503-523
Branch Park	9N/10W-34R3	344923117550302	2	2,290.4	[1]480-510
	-34R5	344923117550305	4	2,290.6	[2]60-80
South Shore	9N/10W-25P1	345016117532301	1	2,269.49	[2]450-470
	-25P2	345016117532302	2	2,269.49	[2]100-120
North Shore	10N/9W-10B1	345856117485501	1	2,278.57	[2]282-302

[1]Londquist and others (1993)
[2]Rewis (1993)

The Holly site was the first site where instrumentation was installed for ground-water-level monitoring. Maximum land subsidence on Edwards Air Force Base has been measured near this site (Londquist and others, 1993). The name for this site is derived from the name of a bench mark at the site. Originally, four piezometers were monitored for ground-water-level changes, but because of the failure of the flotation systems installed in June 1990, and the failure of submersible transducers installed in January 1991, little useful information was obtained. Piezometers 1 and 2 were reinstrumented with new transducers in June 1992.

The Fissure site was the second site where instruments were installed for ground-water-level monitoring. The site was given its name because of nearby earth fissures and is located on the playa of Rogers Lake (fig. 2). Transducers in piezometers 1, 3, and 5 were installed during June 1991; the transducers in piezometers 1 and 3 failed, providing little useful data, and were reinstrumented in July 1992.

The Graham Ranch site was the third site where instruments were installed for ground-water-level monitoring. Time-series data have been collected from two of the three piezometers. In June 1991,

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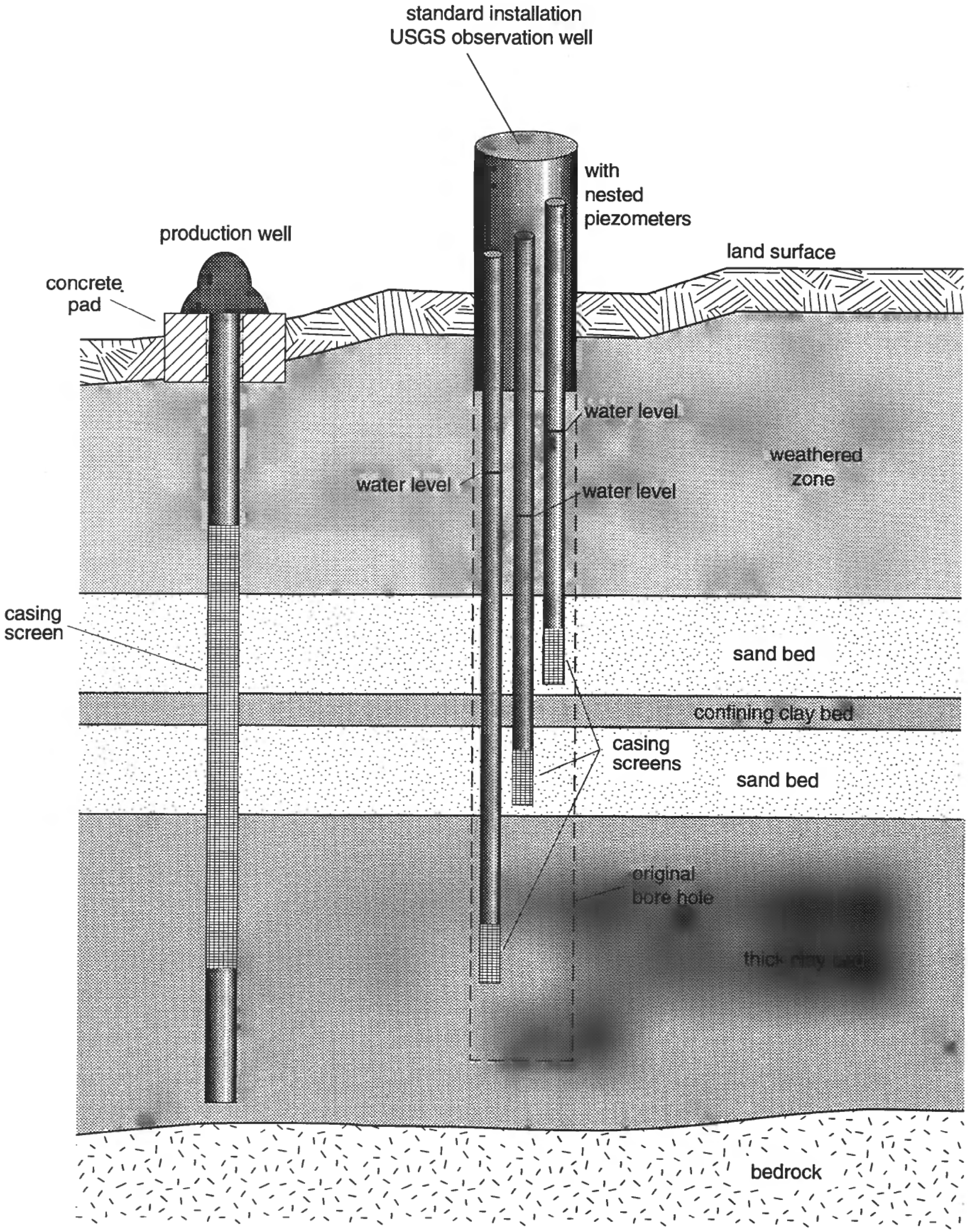

Figure 3. Standard piezometer installation at Edwards Air Force Base, comparing basic configurations of a production well and a USGS observation well.

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piezometer 3 was instrumented. Data were collected through January 1992, when the buried instrument shelter was flooded, destroying the data logger and transducer. In June 1992, piezometer 2 was instrumented for ground-water-level monitoring. This site was monitored to determine how daily and seasonal production-well pumping was affecting ground-water levels. There are two production wells within 0.25 mi of the Graham Ranch piezometers.

The South Track site is located adjacent to the production wells that comprise the South Track Well Field. The two piezometers at this site were instrumented for ground-water-level monitoring in July 1992. Piezometer 1 was instrumented to record the large daily changes in the deep aquifer ground-water level caused by pumping from the adjacent production wells. Piezometer 2 was instrumented to monitor ground-water levels in the principal aquifer at this site.

The Survival School site was instrumented for ground-water-level monitoring in July 1992. It is located in a small wash, approximately 150 yds south of the Edwards Air Force Base Survival School training center. The South Track Well Field is about 0.5 mi west of this site (fig. 2). There are four piezometers at this site and transducers are installed in piezometers 1 and 2.

The Branch Park site ground-water-level monitoring instrumentation was installed in September 1992. Of the four piezometers at this site, piezometers 2 and 4 have transducers. This site is located on a small playa at Branch Memorial Park, which is near the south entrance to Edwards Air Force Base. There is a small fishing pond that is located at the park. Water seepage from this pond apparently has an effect on the water level in the shallow piezometer at this site. The ground-water levels collected through September 1993 in both piezometers indicate no daily effects due to pumping at the South Track Well Field. The ground-water levels in piezometer 4 are constantly rising, which is contrary to ground-water-level trends from all other sites in the study area.

Ground-water-level monitoring instrumentation was installed in piezometers 1 and 2 at the South Shore site in September 1992. The site is located at the shoreline of the south end of Rogers Lake (fig. 2), the lowest area of the playa. Although this site has the greatest potential for flooding, it did not flood during the period of this report. During winter storm runoff, surface water drainage floods the normally dry playa. High precipitation years such as the winter of 1992-93, accentuate this flooding, and along with wind-driven waves, cause the water level in the lake to come close to the tops of the piezometers at this site.

The North Shore site is named for its location near the northern-most end of Rogers Lake (fig. 2). The ground-water-level monitoring instrumentation was installed in December 1992. There are two piezometers, but only piezometer 1 has a transducer. Ground-water-level data for North Shore do not show any daily affect from pumping at the North Base Well Field.

Selection and Operation of Instrumentation

The data-collection needs of the study required a sensitive and stable water-level sensor with good longevity in field installations. Submersible pressure transducers were selected to monitor the ground-water levels and needed to function properly over a range of seasonal and daily water-level changes that ranged from a few tenths of a foot to more than 20 ft (Freeman, 1994). There also was the potential for large daily water-level fluctuations at the South Track site due to its proximity to the production wells. All instrumentation used in the study was capable of sensing and recording ground-water-level data to 0.01-ft accuracy, which was required by the USGS for surface-water data (Cobb, 1989).