CONTOUR MAP SHOWING MINIMUM DEPTH TO GROUND WATER, UPPER SANTA ANA RIVER VALLEY, CALIFORNIA, 1973-1979

By

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SUMMARY

A contour map showing minimum depths to ground water in the upper Santa Ana River valley region was constructed by contouring the shallowest water-level measurements reported to the California Department of Water Resources for the period from 1973 through 1979. The map identifies areas where ground-water conditions may be conducive to seismically-induced liquefaction. However, the contour map is not a liquefaction-hazard map: although the mapped areas of shallow ground water most likely contain some water-saturated sedimentary materials that may be susceptible to liquefaction when shaken by an earthquake of sufficient magnitude and duration, the presence and distribution of these susceptible materials have not been demonstrated in this study.

Three generalized trends in ground-water behavior can be recognized in the 20 shallow-water zones identified on the contour map:

(1) Five of the 20 zones experienced shallow-water levels persistently throughout the 1973-1979 period. These areas include the shallow zones southwest of La Verne, along the southwest base of the San Bernardino Mountains, near Mill creek, east of Yucaipa, and in San Timateo Canyon. Although water levels in these areas fluctuated from season to season and from year to year, they remained consistently shallower than 50 ft below land surface throughout the 1973-1979 period.

(2) Five of the 20 zones experienced water levels shallower than 50 feet intermittently during most of the 1973-1979 period, but experienced persistently shallow levels in 1978 and 1979 following several wet seasons with greater than average rainfall that began in late 1977. These areas include the shallow zones on the San Antonio Canyon alluvial fan, in Cajon Wash, in Reche Canyon, in the San Bernardino metropolitan area, and in the greater Santa Ana River area. Intermittently shallow ground water in these areas can be attributed either to their frequent recharge from natural and artificial sources or to their unique geohydrologic characteristics (including perched and (or) confined ground-water conditions or proximity to adjacent ground-water barriers).

(3) In six of the shallow-water areas, water levels shallower than 50 feet subsurface occurred mainly in 1978 and 1979; water levels rarely were shallower than 50 ft during 1973 through 1977. These areas include the shallow zones in San Antonio Wash, near Upland, in Lytle Creek Canyon, on the Lytle Creek fan, on the Santa Ana floodplain, and in the vicinity of Muscoy. Shallow ground water in these areas can be attributed to the onset in late 1977 of an extended period with greater than average annual precipitation and, in some locations, to increased water-conservation activities in 1978 and 1979.

In four of the shallow-water areas, water-level records are too short or incomplete to evaluate the persistence of shallow-water levels. These areas include the shallow zones south of Pomona, in the vicinity of Claremont, near Mentone, and in Riverside. Additional monitoring of ground-water levels would be required to properly assess the persistence of shallow ground water in these areas.

In most of the 20 areas of shallow ground water identified on the map, the water table rose during the latter part of the 1973-1979 period. This shallowing trend occurred mainly because of two factors: (1) Wetter-than-normal winters in 1977-1978 and 1978-1979 increased the volume of surface runoff and natural recharge in the upper Santa Ana River valley region and contributed to increased water conservation stemming from accelerated water-spreading activities conducted by local water agencies; and (2) commencing in 1972, ground water in the valley region has been replenished by artificial recharge of imported water derived from the California State Water Project. Together, the accelerated natural and artificial recharge of ground-water basins in 1977, 1978, and 1979 resulted in rising water tables throughout the valley region.

Water-level records more recent than September 1979 were not uniformly available for this study. However, examination of selected recent water-level data indicates that, for most of the areas of shallow ground water shown on figure 4 and on the contour map, ground water has remained shallower than 50 ft below land surface through December 1982. In some areas, ground water has risen even more. For example, in the San Bernardino metropolitan area, rising water locally has invaded basements, undermined roadways, and affected foundation construction (San Bernardino City Building and Safety Department and San Bernardino City Water Department, oral commun., October 1981 and March 1982). Where post-1979 water levels have continued to rise, the areas underlain by shallow ground water have expanded and are now larger than the areas shown on the contour map of this report.

Each of the 20 areas where ground water was shallower than 50 ft below land surface during the 1973-1979 period can be expected to have shallow water whenever climatic conditions and water-management policies are similar to those in the 1970's. Because of the potential occurrence of shallow ground water, the sedimentary materials in these areas should be evaluated for their susceptibility to seismically induced liquefaction.

INTRODUCTION

A contour map showing minimum depth to ground water was constructed for the upper Santa Ana River valley region. This map and the location of the study area (fig. 1) are shown on sheet 1. The contour map represents the first of several steps in our ongoing study of susceptibility to seismically induced ground failure by liquefaction in the valley region. Depth to ground water is one of three variables that influence susceptibility to liquefaction. The other two variables are the physical properties of the sedimentary deposits and the severity of seismic shaking. Our approach for determining liquefaction susceptibility in the study area is similar to the procedure developed by Youd and others (1978). In future studies we will evaluate the sediment properties of the region and the severity of seismic shaking that can be expected locally and integrate these results with the data on depth to ground water presented in this report to produce a liquefaction-susceptibility map.

The contour map showing minimum depth to ground water is based on water-level measurements recorded by the California Department of Water Resources (CDWR) for the period from about September 1973 through about September 1979. The data from 1973-1979 were convenient to examine because CDWR twice annually provides updated microfiche summaries of water-level data for the preceding 6-year period. At the start of this study, the most recent available update was for the 1973-1979 period. This period contained both drier-than-normal years (1975-1977) and wetter-than-normal years (1978-1979); thus, we could examine the impact of both types of climatic regimes on ground-water-distribution patterns.

For evaluating liquefaction susceptibility, ground-water levels measured during the 1973-1979 period are significant for two reasons: (1) Climatic conditions and water-management policies during this period resulted in ground-water conditions that are similar to those existing in the upper Santa Ana River valley region through approximately December 1982; and (2) the distribution of ground water at shallow depths during this period corresponds well to the distribution of naturally occurring shallow ground water observed during the later years of the 19th century.

Correspondence between recent and historic ground-water patterns is significant because ground-water levels for much of this century have departed from naturally controlled levels. Prior to the modification of natural ground-water patterns by extensive human activities, the distribution of ground water in the upper Santa Ana River valley was controlled by long-term steady-state geohydrologic conditions that in places produced naturally occurring bodies of near-surface ground water (for example, the areas of marshy ground portrayed by Mendenhall, 1905, and Fife, 1976). During the first half of this century, these prevailing conditions were modified considerably due to extensive ground-water withdrawal for irrigation and for industrial, municipal, and domestic uses; as a result, regional water tables during those years generally were considerably lower than under natural conditions. During the 1973-1979 period, two factors apparently combined to restore historically high water levels: (1) Changes in water-use and water-management policy were initiated in 1972 with the advent of extensive artificial recharge of regional ground-water reservoirs, and (2) wetter-than-normal winters occurred in 1978 and 1979. These two factors have produced rising ground-water levels that are reflected in the 20 areas of shallow ground water depicted on the contour map. To the extent that the climatic conditions and water-management policies of the 1973-1979 period persist and to the extent that the historical steady-state conditions that produced full ground-water reservoirs recur, we believe that the 20 areas depicted on the contour map are likely to contain shallow ground in the future.

Purpose

The purpose of this study is to identify areas in the upper Santa Ana River valley region where ground-water conditions may be conducive to seismically induced liquefaction. Liquefaction-induced ground failure occurs in areas underlain by loose granular cohesionless unconsolidated sediment that is saturated with water (Seed and Idriss, 1971; Seed, 1976; Youd and Perkins, 1978; Youd and others, 1978). However, the probability that liquefaction will occur decreases as thickness of overburden increases; liquefaction rarely occurs at depths greater than 50 ft below land surface. Accordingly, this contour map emphasizes areas where ground water shallower than 50 ft occurred during the 1973-1979 period.

This contour map is not a liquefaction-hazard map. The mapped areas of shallow ground water most likely will contain some water-saturated sedimentary materials that may be susceptible to liquefaction when shaken by an earthquake of sufficient magnitude and duration. However, the presence and distribution of these susceptible materials have not been demonstrated in this study.

Uses and limitations

This study provides a generalized picture of where ground-water conditions in the past have been favorable for the occurrence of liquefaction. The study can be used by municipal and county agencies as a guide for determining where detailed site-specific studies related to liquefaction hazards may need to be conducted.

The generalized regional scope of this study prevents its indiscriminate use as a site-specific guide. The contour map depicts the general distribution of ground-water levels occurring across the valley region, but the map does not identify actual water levels occurring at any specific site and thus cannot be used as a definitive guide to site-specific water levels. Several factors prevent use of this map for site-specific evaluations of ground-water contitions:

(1) Interpolation of contours between data points inherently is not a site-specific procedure. The ground-water contours were drawn on the basis of data from a small number of water wells, and water levels in areas between wells are generalized and inferred. Between the water wells, water levels presumably occurred within the ranges indicated by the contours, but in some places the levels in fact may have been shallower or deeper than the map indicates.

(2) The accuracy with which the ground-water contours represent the actual water depth between data points depends on the distribution of the water wells: where water wells are widely spaced, the ground-water contours depict the actual water depth between wells less accurately than where water wells are more closely spaced. The greater the distance between wells, the more likely that local variations in depth to ground water are undetected.

(3) Due to the well-location methods used in this study, some wells on the ground-water map could be mislocated by as much as half the diagonal width of a one-sixteenth section (933 ft) (see Well-location nomenclature). As a result, depth-to-water contours that are drawn by interpolating between mislocated wells also are located inaccurately. However, the resultant error probably is small relative to errors that may result from other factors discussed in this section.

(4) Some CDWR well records are incomplete or have questionable reliability. Where data on minumum depth to ground water for the 1973-1979 period are erroneous for these reasons, we usually identified the erroneous data and took steps to minimize any effect on the contour map. However, occasionally an erroneous minimum value may have gone undetected and locally may have influenced the contour map.

(5) Sparse hydrogeologic data and scant information about the depth and length of perforated well casings hinder our ability to evaluate how closely water levels in a well correspond to water levels occurring in the adjacent ground. Except where discussed in the text, we have assumed that water levels measured in a given well closely reflect water levels occurring in the adjacent ground, although this assumption may not always be correct. Under certain hydrogeologic conditions, and depending on the placement of perforations in the well casing, water levels in the ground actually may differ significantly from water levels in a local well. For example, where a well taps a confined aquifer having a potentiometric surface near the ground surface, the shallow water-level measurements may indicate a shallow water table where in fact one does not exist. In this example, water levels would occur at or near the surface in the well because ground water from the deeper confined aquifer has been driven up the well to the elevation of the potentiometric surface. A shallow well driven adjacent to the deep well would provide a cross check for this condition.

(6) Because we obtained only limited hydrogeologic data and minimal information about the length and depth of perforated well casings, this report does not show the maximum extent of perched ground water in the valley region. Our map shows perched ground water in the Riverside area; however, perched ground water probably occurs intermittently at many other localities throughout the upper Santa Ana River valley. For example, during high-intensity storms,

near-surface sediment underlying large tracts of ground may become saturated and may remain so for days or weeks. In addition, perched water at shallow levels may occur where ground water rises up a well casing, reaches a perforated interval, and then exits the well casing to penetrate surrounding sediment. This process would be most likely in areas where water wells tap ground water under artesian head. These perched water bodies would be undetectable unless penetrated by a test boring or an actively monitored water well. Thus, identifying perched ground-water bodies throughout the upper Santa Ana River valley region is difficult. Perched ground water that might occur after a storm or that might have escaped from perforated well casings would expand the zones of shallow ground water shown on our map or would create new bodies of shallow ground water where none was identified by us. Where these new expanses of perched ground water invade susceptible sedimentary materials, additional tracts of ground might become subject to liquefaction.

These factors caution prospective users not to apply this contour map to site-specific investigations in the upper Santa Ana River valley region. The map provides only a generalized picture of where we believe shallow ground water can be expected to occur based on the intermittent observation of shallow ground water in each of the 20 areas during the 1973-1979 period. The map thus identifies areas where sediments might be studied to assess their susceptibility to seismically induced liquefaction.

METHODOLOGY

For nearly a century, observation and measurement of ground-water reservoirs in the upper Santa Ana River valley have shown that ground-water levels have fluctuated as a result of variation in such factors as vegetation cover, temperature, precipitation, land use, the amount and rate of ground-water withdrawal, and the amount and rate of artificial recharge by water importation. Among these factors, changes in water-use and water-management policies especially can contribute to rapid short-term variation in local ground-water tables. Because of these fluctuations in ground-water level, the shape and size of areas of shallow ground water change from season to season, year to year, and decade to decade. These fluctuations complicate the evaluation of liquefaction susceptibility.

A ground-water map useful for the study of liquefaction susceptibility should show those areas where shallow ground water has occurred in the past, and where it is likely to occur in the future. A contour map showing minimum depths to ground water for a specific period achieves this goal. Such a map is different from most hydrologic maps. It does not show how the water table actually looked at any particular instant during the reporting period, nor does it show the average or typical ground-water conditions during the reporting period. Instead, this map shows what a hypothetical ground-water table would look like if the shallowest water level measured in each well during a particular period of record were used as the basis for constructing the map. Such a map is useful to an evaluation of liquefaction susceptibility because it delineates areas that at one time or another during the reporting period were underlain by shallow ground water. Once identified, each area of shallow ground water can be evaluated for its persistence--that is, the probability that shallow ground water can be expected to occur under particular climatic, hydrogeologic, and water-management conditions.

The minimum-depth concept is illustrated schematically in figures 2A through 2I (sheet 1), where ground-water patterns beneath a hypothetical municipality are shown for individual years from 1973 through 1979. The shallowest water level measured during each year is indicated at the well site; areas where ground water shallower than 50 ft occurred are enclosed by a 50-ft contour.

During 1973 and 1974, water levels were deeper than 50 ft at all water wells; therefore, no 50-ft contour can be constructed (figs. 2A, 2B). During 1975, water levels shallower than 50 ft were measured in several wells; two distinct areas of shallow ground water within the municipality are identified in figure 2C. During 1976 through 1979, shallow ground water under the municipality is reflected by water-level measurements at many wells (figs. 2D, 2E, 2F, and 2G). However, the areas of shallow ground water have different shapes, sizes, and locations for each year. The problem created by variations in the water table now can be appreciated. Within the hypothetical municipality, what method should be used to indicate (1) where shallow ground water has occurred in the past, (2) where shallow ground water potentially exists today, and (3) where shallow ground water may occur in the future?

Figure 2H represents a composite of ground-water patterns for the years of record. This composite shows that within the hypothetical municipality, most areas were underlain by shallow ground water at least once during the 1973-1979 period, an observation relevant to liquefaction susceptibility. The methodological question is how to conveniently and concisely show that most areas of the municipality were underlain by ground water shallower than 50 ft at least once during the 1973-1979 period, even though the distribution of shallow water varied from year to year. For example, as seen in figure 2G, the northeastern part of the municipality was a zone of shallow ground water in 1979, while at the same time the southwestern sector was not; as seen in figures 2C through 2F, this situation was reversed in 1975 through 1978, when the southwestern sector was a zone of shallow ground water while the northeastern sector was not. A single contour map showing minimum depths to ground water for the entire 1973 through 1979 period solves this dilemma and also provides a single product that municipal agencies can use as a basis for more detailed ground-water investigations.

Figure 2I represents a contour map showing generalized minimum depths to ground water for the entire 1973-1979 period. The 50-ft contour encircles any and all areas that presumably were underlain by ground water shallower than 50 ft during the 1973-1979 period. Although the contour pattern in fig. 2I was constructed using the contour patterns presented in figures 2A through 2H, a similar map would result from selecting the single shallowest water level measured at each well during the 1973-1979 period and contouring this data set. By either procedure, the single contour map of minimum depths to ground water in figure 2I conveniently and concisely shows where shallow ground water has occurred in the past and where it may occur in the future. Statistical studies of short-term and long-term water level behavior can be conducted for this area in order to demonstrate the persistence of shallow water in all or parts of the zone enclosed by the 50-ft contour.

Advantages and disadvantages of the minimum-depth method

In our study of ground-water patterns in the upper Santa Ana River valley, we used the minimum-depth-to-water technique. When evaluating liquefaction susceptibility, tradeoffs are incorporated in the application of this technique, but we believe the benefits outweigh the shortcomings.

A chief disadvantage arises because the minimum-depth method assigns no probabilities to the depth-to-water values indicated by the contours--that is, from the minimum-depth map the reader has no means of evaluating the persistence of the indicated shallow-water levels. Moreover, because probability values are not assigned to areas of shallow ground water, maps based on the minimum-depth technique do not distinguish between areas where water levels are shallow much of the time and areas where water levels are shallow only infrequently. Although these shortcomings are inherent to the minimum-depth method, their significance can be minimized if areas of shallow ground water identified by the method are accompanied by statistical studies that evaluate the persistence of shallow ground water in each area. Our study of ground-water patterns in the upper Santa Ana River valley region incorporates statistical data of this kind.

A chief advantage is that the minimum-depth technique identifies shallow ground water in areas where the depth to ground water occasionally shallows to less than 50 ft--even though depth to ground water typically exceeds 50 ft. By identifying these areas, the minimum-depth method contributes information more useful to the recognition of hazards due to shallow ground water than does the alternative technique of ground-water evaluation--long-term averaging.

Average ground-water contours for the upper Santa Ana River valley region could be determined by a statistical study of long-term ground-water patterns (incorporating all water-level records). However, this method is inappropriate to the evaluation of liquefaction susceptibility because of shortcomings intrinsic to the averaging technique, and because recent hydrologic conditions and recent water-management policies within the region have resulted in ground-water trends that are atypical with respect to the average behavior of the regional ground-water body during most of this century.

The main shortcoming of the statistical-averaging technique is its tendency to mask the effect of skewed ground-water readings produced by episodes of very shallow or very deep water tables. Long-term averaging may disguise the presence of shallow water levels that occur intermittently in a well whose typical water levels are significantly deeper. For example, in a well having many water-level measurements deeper than 50 ft and few but significant measurements considerably shallower than 50 ft, the mean depth would be weighted heavily by the deeper values and would disguise the presence and significance of the shallow values. Whatever the explanation for these shallow measurements--for example, seasonally perched water following wet periods, rising water due to decreased ground-water withdrawal, or rising water due to water importation and artificial recharge--their presence and their significance to liquefaction susceptibility would tend to be disguised and diluted by the averaging method. Because of this masking problem, a contour map based on average long-term ground-water records in the upper Santa Ana River valley region would show fewer and smaller areas of shallow ground water than would a map based on the minimum-depth method.

A liquefaction-susceptibility evaluation based on a statistical average of long-term ground-water patterns would not permit an appropriate evaluation of the extent of shallow ground water presently in the valley region because statistical averaging would conceal rising ground-water trends that have occurred in the late 1970's and early 1980's. During this recent period, water levels have departed from long-term trends and approached worst case conditions because the region experienced several wet winters (for example, 1977-1978, 1978-1979, and 1981-1982), and because in the early 1970's a water-management policy of water importation and artificial ground-water recharge was implemented under the auspices of the San Bernardino Valley Municipal Water District (Martin, 1979). Together, the wet winters and artificial recharge have caused water tables to rise throughout much of the upper Santa Ana River valley region.

Because of these evolving hydrologic conditions, we used the minimum-depth technique to summarize ground-water patterns during the 6-year period between 1973 and 1979. This approach best identifies where shallow ground water has occurred in the past and where it is likely to recur in the future, provided that climatic patterns and water-use patterns similar to the 1973-1979 period recur. We have included with the contour map statistical data (tables 1 and 2, sheets 1 and 2, respectively) and qualitative discussions that evaluate the persistence of each area of shallow ground water. In this way, the reader can obtain some feeling for the likelihood of occurrence of shallow ground water in a particular area.

DATA POOL AND DATA USAGE

Source of well data

For the wells shown on this map, information on depth to ground water was obtained from CDWR water-well records. CDWR monitors ground-water levels and water quality in the State of California using an extensive grid of selected wells.

Well-location nomenclature

CDWR uses two numbering systems for identification of wells--the Areal Designation System and the State Well Numbering System. Using these systems, the reader easily can identify the approximate location of a well. The exact location of a well is filed with CDWR district offices, but well-location information is only approximate in well-record inventories routinely available to us and to the public.

The Areal Designation System distinguishes a series of major drainage provinces that are subdivided further into hydrologic units, hydrologic subunits, and hydrologic subareas. A coding system based on a series of letters and numbers describes the location of a well to the nearest subarea. For example, a well located in a particular subarea would be identified by CDWR in the following way:

Drainage province---------Y
Hydrologic unit------------01 (written Y-01.E2)
Hydrologic subunit---------E
Hydrologic subarea--------2

The Areal Designation System is augmented by the State Well Numbering System, which utilizes a coding technique based on township, range, and section subdivisions of the Public Land Survey to more accurately identify the location of a well than is possible with the Areal Designation System alone. With the appropriate sequence of letters and numbers, the State Well Numbering System enables the location of a well to the nearest sixteenth section:

Township-------------------01N
Range----------------------04W
Section---------------------28 (written 01N/04W-28J02 S)
Tract-----------------------J
Sequence number----------02
Base and Meridian---------S

Within this system, each section is subdivided into sixteen tracts, each constituting approximately 40 acres:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Because more than one well may have been drilled within a tract, sequence numbers generally are assigned to wells in chronological order (for example, three wells located in Tract R would be labeled as wells R01, R02, and R03 in the order that they were cataloged by CDWR).

Well-location information routinely provided by CDWR allows wells to be located only to the nearest tract, so on the contour map we arbitrarily plotted each well in the center of the appropriate tract. However, for some wells we modified this procedure. Where data on depth to ground water and the position within a tract of a previously identified ground-water barrier suggest that the well location cannot be in the center of the tract, we shifted the location to the appropriate side of the barrier and thus to some noncentral location within the tract. All wells monitored by CDWR in the upper Santa Ana River valley region during the 1973-1979 period are plotted on the contour map.

Because the Areal Designation System and the State Well Numbering System produce a bulky identification code that is difficult to display on a 1:48,000-scale location map, we have assigned each locality where one or more wells are plotted a simple location number in the sequence 1 through 698. These sequential numbers are identified as map location numbers and are listed with their Areal Designation and State

Well numbers in table 3 at the end of this pamphlet. The map location numbers are assigned sequentially within topographic quadrangle maps (fig. 3, sheet 1).

Well-data evaluation and selection

For each map-location number, the 1973-1979 water-level records of each well were examined to determine the minimum depth to ground water. To construct the contour map, we mainly used the shallowest value reported from the wells in each location. However, where CDWR notation indicated that the shallowest value was questionable, or where our own observations led us to question the accuracy of the value, we rejected the shallowest value and selected the next shallowest value instead.

For some wells, rejection of the entire record was necessary because it was questionable or so incomplete that we could not be certain if any of the water-level values actually represented a reasonable minimum-depth figure. For example, some wells with incomplete records yield anomalously deep minimum-depth values, but were monitored only during dry years such as 1976 and 1977. Examination of records from nearby wells that were monitored throughout the entire recording period showed that the dry years produced deep water levels in all local wells; however, in wells that were monitored continuously, water levels shallowed during wetter portions of the recording period. Because our goal was to delineate the actual minimum depths to ground water over the 1973-1979 period, we discarded incomplete well records having anomalously deep minimum water levels.

For each map-location number, table 3 shows the minimum acceptable value of depth to ground water recorded during the 1973-1979 period.

Data-contouring procedure

Minimum values of depth to ground water were contoured by hand using standard geometrical-interpolation methods. For water depths greater than 100 ft, the contour interval on this map is 50 ft. For water depths less than 100 ft, the 10-, 30-, 50-, and 75-ft contours are shown. The 10-, 30-, and 50-ft contours respectively delineate ground-water zones of less than 10 ft, 10-to-30 ft, and 30-to-50 ft below land surface. These water-level intervals may be significant in the evaluation of liquefaction susceptibility (Youd and Perkins, 1978; Youd and others, 1978). For this reason, ground-water zones shallower than 50 ft below land surface are highlighted on the contour map; throughout the text we refer to these zones as areas of shallow ground water. The 75-ft contour is included to indicate areas that might be occupied by shallow ground water in the future if the regional ground-water table were to rise.

Geometric-interpolation techniques were used because we wanted an objective method for contouring ground-water depths. The absence of subsurface geologic control, the low density of water wells, and the incompleteness and questionable accuracy of some well records generally precluded contouring the well data by subjective methods based on hydrogeologic observations. However, where hydrologic or geologic evidence indicated that contour patterns produced by geometric interpolation were unreasonable, we subjectively modified the contours to conform to this evidence. For example, some contour patterns produced only by geometric interpolation resulted in local ground-water highs that were not located reasonably with respect to known sources of ground-water recharge, such as the mouths of stream canyons. In such areas, we would modify the interpolated contours if a more reasonable interpretation of ground-water patterns was possible without forcing the contours to contradict the available data.

GROUND-WATER BARRIERS

Previous workers have proposed numerous partial ground-water barriers in the upper Santa Ana River valley region; our ground-water map incorporates some of these proposed barriers. We retained a barrier if it explained differences in water-level measurements between adjacent wells. For example, if water-level values from wells clustered in two adjacent areas differ significantly or if their water-level fluctuations behave in two independent patterns, a partial barrier to ground-water flow within the aquifer system most likely exists between the two areas. Where such discrepancies occur in our data, we were able to utilize ground-water barriers proposed by other workers, although in places a slight modification of these barriers was necessary to best fit our contour patterns. We did not incorporate previously recognized ground-water barriers where our water-level data did not require them. None of our water-level data required us to propose additional ground-water barriers.

The eight ground-water barriers shown on our contour map are modified from many sources. The Chino and San Jose barriers are modified from Eckis (1934). The Indian Hill barrier is modified from an unpublished report by Geotechnical Consultants, Inc. (1980). The Red Hill barrier is modified from Eckis (1934) and from Fife (1974). Barrier H and the Rialto-Colton barrier are modified from Dutcher and Garrett (1963). The San Jacinto barrier is modified from Dutcher and Garrett (1963), Fife (1974), Morton (1978), and Miller (1979). The Casa Blanca barrier is modified from Burnham and Dutcher (1960). The reader is referred to these studies for descriptions of the ground-water barriers.

BEDROCK

Both consolidated sedimentary rocks and crystalline rocks in the study area are designated as bedrock; these areas are identified on the ground-water map. Although the bedrock generally is nonliquefiable, it may locally contain areas susceptible to liquefaction. Depths to ground water are not shown in the bedrock areas.

HISTORICAL AREAS OF MARSHY GROUND

Historical bog, swamp, and marshland areas in the upper Santa Ana River valley region are shown by Fife (1976) on the basis of an irrigation map by Hall (1888). Fife (1976) indicates that these wetlands occurred in four general areas: (1) in the Prado Flood Control Basin and along the adjacent Chino Creek; (2) near the city of Cucamonga in the vicinity of Red Hill; (3) northeast of the San Jacinto barrier, in and adjacent to the city of San Bernardino; and (4) west of the city of Yucaipa in the Dunlap Acres area. No bogs, swamps, or marshlands exist in the upper Santa Ana River valley today, although the contour map shows that very shallow ground water occurs in several areas of historically marshy ground. Small decreases in depth to ground water in these areas easily could re-establish surface wetlands.

DISCUSSION AND INTERPRETATION

At least once during the 1973-1979 period, water levels in wells were shallower than 50 ft below land surface in 20 areas within the upper Santa Ana River valley region (shaded areas on contour map and fig. 4, sheet 1). We arbitrarily assigned names to these areas corresponding to local geographic features. In this section we discuss two aspects of each zone of shallow ground water: (1) the most likely origin of each zone, and (2) within the limits of the data, the persistence of shallow ground-water within each zone. The persistence, or frequency of occurrence, of shallow ground-water is significant because it is one indication of the degree of environmental hazard, whether due to ground-water flooding or due to ground liquefaction.

Tables 1 and 2 supplement our discussion of shallow-water persistence. Table 1 statistically evaluates the well records from areas of shallow ground water other than the greater Santa Ana River area and perched ground water in the Riverside area. The persistence of shallow ground water is evaluated for three different periods: a statistical evaluation of the entire 1973-1979 period summarizes average ground-water conditions during the 6-year period of record, and evaluations of two separate 18-month periods--from April 1976 through September 1977 and from April 1978 through September 1979--provide a comparison between ground-water levels that occurred during a relatively dry period (1976-1977) and ground-water levels that occurred during a relatively wet period (1978-1979). Table 2 provides data summarizing the depth to shallow ground water in the greater Santa Ana River area from 1973 through 1979, as well as the persistence of shallow water in this zone.

Areas of shallow depth to ground water

Southwest of La Verne

Shallow ground water occurs at the west end of the study area, southwest of La Verne. Shallow water levels here may result from recharge to the ground-water system by water stored in Puddingstone Reservoir, west of the study area. Alternatively, shallow water levels might occur here if southwestward-flowing ground water is effectively dammed behind impermeable rocks in the San Jose Hills on the west boundary of the map area. With only limited hydrogeologic data, we are unable to adequately evaluate the cause of shallow ground water in this area.

Ground water almost always was shallow here during the 1973-1979 period and was especially shallow in 1978 and 1979 (table 2). Three of the four wells in this area have average water levels shallower than 42 ft below land surface. In one of the two wells at location 119, 100 percent of the water-depth measurements are shallower than 30 ft, and in one of the two wells at location 120, 100 percent of the water-depth measurements are shallower than 50 ft. These data indicate that shallow ground water persisted in this area over the 1973-1979 period. Water levels were especially shallow during the wet years of 1978 and 1979, when the water depths in all four wells decreased to the shallowest levels of the 1973-1979 period. The contour map reflects the minimum-depth values that were recorded in 1978 and 1979.

South of Pomona

Shallow ground water south of Pomona may result from southward-migrating ground water being impeded by the Chino barrier and the Puente Hills. In the absence of hydrogeologic data and data on perforation intervals, we are unable to adequately evaluate the origin of shallow ground water in this area.

Evidence for shallow ground water here is provided by only one well (loc. 228), and this well only has an 8-month record of water-level measurements extending from April 1974 to January 1975 (table 1). During this period, all of the water-level measurements were shallower than 30 ft below land surface, and the average water depth was 20.6 ft.

Claremont

Percolation of runoff from San Antonio and Thompson Creeks and spreading operations conducted by the Pomona Valley Protective Association (PVPA) and the city of Pomona Water Department (PWD) contribute to replenishment of ground water in the vicinity of the Claremont shallow ground-water area and may contribute to the occurrence of shallow ground water here. However, the geohydrologic conditions controlling ground-water levels are not clear, mainly because only one well (loc. 168) is monitored in this area. This well was free-flowing for much of the reporting period, although adjacent sediment to our knowledge is not saturated with free ground water at or near the ground surface. This contrast suggests that the water levels at well loc. 168 do not reflect water levels in the surrounding sediments, but instead reflect the position of a potentiometric surface for a confined aquifer. Thus, the well at location 168 could have free-flowing conditions even though surrounding sediments could be unsaturated to great depth. Saturation of surrounding sediments at shallow depths could occur here under any of three conditions: (1) if confined water was driven up the casings of wells in the area and escaped into the adjacent sediment through perforated intervals; (2) if water worked its way upward into shallow levels by penetrating leaky aquitards; or (3) if ground water of another aquifer system occurred at shallow depths here. These conditions could be evaluated if test wells were driven into the shallow-water zone. Because we do not have subsurface geologic information and because data on well-perforation intervals are not available, we are unable to evaluate the actual depth to ground water occurring in sediments in the Claremont area.

Evidence of shallow ground water in the vicinity of Claremont is provided by only one well (loc. 168). Water levels were measured in this well each year from 1974 through 1979 (table 2), but only measurements made after mid-1978 are reliable. Most measurements obtained before mid-1978 were made while the well was being pumped. During pumping, water levels ranged from 52.0 to 116.0 ft below land surface. In mid-1978, after pumping ceased, water levels rose until the well became freeflowing. Flow continued from mid-1978 until the end of the 1973-1979 period.

Although the data are not conclusive, these figures suggest that shallow ground water will occur in this area when pumping operations are shut down, and ground-water levels can be expected to deepen by 116 ft or more depending on the duration and rate of pumping operations.

San Antonio wash

Shallow water that occurs northeast of Claremont, in the vicinity of San Antonio Creek channel, probably reflects surface runoff from San Antonio and Thompson Creeks and spreading operations by PVPA and PWD north of the shallow-water zone. Shallow-water conditions here probably result from downslope-migrating ground water that is impeded by the adjacent San Jose and Indian Hill barriers. In addition, perched or confined conditions may influence ground-water levels here. In the absence of subsurface geologic information and in the absence of data on perforation intervals, we cannot adequately evaluate the origin or extent of shallow ground water in this area.

During the 1973-1979 period, ground water rarely was shallow in the eight wells in this area that provide acceptable water-level data; shallow water levels occurred only in 1978 and 1979 (table 1). From 1973 to March 1978, most water-level measurements were deeper than 100 ft below land surface. Early in 1978, water levels began to rise, and by mid-1978 water levels in each well were shallower than 50 ft. During the second half of 1978 and in the first months of 1979, water levels progressively deepened; water depths measured during 1979 usually were between 60 ft and 150 ft below land surface. Only once was shallow ground water measured in 1979 (loc. 161); this measurement was 26.5 ft in April 1979.

The contour patterns in San Antonio Wash are based on the shallow ground-water levels measured in 1978. The factors that produced shallow water here during this year are not clear, especially considering the relatively deeper water levels of the pre-1978 period. However, summaries of surface-water spreading activities provided to us by J. C. Lundie of the Pomona Water Department (written commun., May 1983) show that large amounts of surface runoff generated during the wet season of 1977-1978 were conserved by the PVPA through spreading activities directly upslope from the zone of shallow ground water indicated in the vicinity of San Antonio Canyon Wash. Shallow ground water can be expected in this area if hydrologic conditions similar to those in 1977-1978 recur; otherwise, ground-water levels similar to those in the pre-1978 period should prevail.

Upland

Near Red Hill in the Upland area, shallow ground water occurs northeast of and upslope from the Red Hill barrier, which probably impedes downslope-migrating ground water. In addition, perched or confined aquifers may promote shallow water depths in this area, as suggested by comparisons between water levels here and water levels in adjacent areas. Discrepancies between local levels and levels in adjacent wells suggest that little or no hydrologic connection exists between shallow ground water in the Upland area and ground water in adjacent areas. This relation indicates that some of the wells in the area may tap perched or confined aquifers. In the absence of subsurface geologic information and data on perforation intervals, we cannot evaluate the hydrology of this area.

For the 1973-1979 period, evidence of shallow ground water is provided by one of two wells at location 142 (table 1). In this well, shallow water levels occurred only in 1978 and 1979. Before 1978, water levels in the well fluctuated from 101.0 to 172.0 ft below land surface. In February 1978, the water level rose to 85.0 ft and in March was 35.0 ft below land surface. From March 1978 through the last measurement of the 1973-1979 period, all of the water-depth measurements in this well ranged from 19.0 to 35.0 ft below land surface.

The contour patterns in the Upland area are based on the shallow water levels measured during 1978 and 1979. What produced the shallow ground water in this area during these years is not clear, especially considering the relatively deeper water levels of the pre-1978 period. Shallow ground water can be expected in the Upland area if hydrologic conditions similar to those in spring 1978 recur; otherwise, water levels similar to those in the pre-1978 period should prevail.

San Antonio Canyon fan

Northwest of Claremont, a narrow northeast-trending zone of shallow ground water occurs along the base of the San Gabriel Mountains on the west margin of the San Antonio Canyon alluvial fan. Shallow ground water may accumulate in this area for three possible reasons: (1) Close to the mountain front, bedrock of low permeability may be very near the ground surface and may not allow ground water to percolate very far into the subsurface; (2) aquicludes within the sediment of San Antonio Canyon fan may cause shallow ground water to become perched intermittently; and (3) the shape and distribution of shallow ground water here may reflect recharge from many tributary streams flowing down to San Antonio Canyon fan from the northwest, as well as recharge from spreading operations conducted at Thompson Creek and on the San Antonio Canyon fan under the auspices of PVPA. On the basis of available subsurface data, the influence of each of these phenomena on local ground-water patterns is unclear.

The persistence of shallow ground water varies from well to well in this area. In some wells, shallow ground water occurred continuously during the 1973-1979 period. In other wells, shallow ground water occurred only in the final 2 years of the 1973-1979 period.

At locations 3, 13, and 18, shallow ground water was persistent during much of the 1973-1979 period (table 1). Here, 100 percent of the water-depth measurements from 1973 through 1979 are shallower than 50 ft below land surface. Moreover, at location 3, 77 percent of the water-depth measurements are shallower than 30 ft below land surface.

At locations 1, 4, 146, and 147, no shallow ground water occurred from 1973 through 1977 (table 1). However, water levels rose in these wells in 1978, and in three of the four wells depth to water became shallower than 30 ft below land surface. In 1979, shallow ground water was measured in all four wells. Thus, during the 1973-1979 period, shallow ground water occurred in these four wells only during the last 2 years.

Lytle Creek canyon

In the north-central part of the study area, shallow ground water occurs in Lytle Creek canyon. Here, a relatively thin accumulation of sediment covers impermeable bedrock of the valley floor. Shallow ground water may form after periods of greater-than-average precipitation and runoff, when the thin cover of canyon sediment is recharged with ground water. During the 1973-1979 period, shallow ground water occurred in this area only during or shortly after the rainy season.

Ground water was shallow in this area during parts of 1974, 1978, and 1979 (table 1). At all other times during the 1973-1979 period, water-depth measurements ranged from 51.4 to 108.5 ft below land surface. In 1974, ground water was shallow only in February (locs. 28 and 30, 49.4 and 48.4 ft, respectively). In 1978 and 1979, water levels in this area were measured only at location 28. In 1978, water depths at this location ranged from 44.4 ft to 30.4 ft in February and April; in 1979, a prolonged period of shallow ground water extended from February through July, when water depths ranged from 37.4 to 49.4 ft.

If the correlation of shallow ground water with periods of heavy rainfall and heavy discharge from Lytle Creek is valid, then ground water shallower than 50 ft can be expected in this area only during or after wetter-than-normal periods.

Lytle Creek fan

Shallow ground water occurs on the upper part of Lytle Creek fan after periods of greater-than-average precipitation, when the alluvial-fan aquifer is recharged by rainfall and by ground water and surface water from Lytle Creek canyon. Impermeable sediment in the subsurface also may contribute to shallow water levels in this area by limiting downward migration of ground water.

During the 1973-1979 period, shallow ground water occurred in this area only during parts of 1974, 1978, and 1979 (table 2). At other times, water-depth measurements ranged from 50.1 to 82.0 ft below land surface. Ground-water levels were monitored in three wells here (one well at loc. 32 and two wells at loc. 33).

In 1974, shallow ground water occurred simultaneously in all three wells only in April (depths ranged from 47.0 to 48.5 ft); shallow ground water occurred in one of the three wells in May and June (depths both months measured at 50.0 ft). A more prolonged period of shallow ground water occurred in the three wells from March through July 1978, when all but one water-level measurement ranged from 25.0 to 48.0 ft below land surface. Later in 1978, shallow ground water occurred in December (49.5 ft in one well at loc. 33). A third episode of shallow ground water occurred from March through May 1979, when water levels ranged from 42.0 to 50.0 ft below land surface in the two wells at location 33 and from 47.0 to 54.0 ft below land surface in the well at location 32.

The origin and significance of shallow ground water in the Lytle Creek fan area is not clear. However, shallow ground water occurs here after periods of heavy rainfall and discharge from Lytle Creek; if this observation is valid, then ground water shallower than 50 ft can be expected in this area during or after periods of greater-than-normal precipitation.

Cajon Wash

Shallow ground water occurs where Cajon Wash enters the study area. Here, water levels may fluctuate with variations in annual or seasonal precipitation and (or) with variations in the quantity of water imported by the State Water Project. In the absence of adequate hydrogeologic information for the area, we are unable to evaluate what influence these variations have on local ground-water levels.

Evidence of shallow ground water in Cajon Wash during the 1973-1979 period is provided by the well at location 27 (table 1). Water levels were not monitored during all years of the 1973-1979 period, but records exist for 1973, 1977, 1978, and 1979. In both 1973 and 1977, all water levels were deeper than 80 ft below land surface. During parts of 1978 and 1979, water levels were shallower than 50 ft. The shallowest ground water occurred in 1978, when 71 percent of the measurements were shallower than 50 ft below land surface and 57 percent of the measurements were shallower than 30 ft below land surface; water levels ranged from 2.7 to 83.3 ft below land surface during this period.

Just outside of the study area but upstream in Cajon Wash, two wells were monitored from 1973 to 1979; their

Areal Designation and State Well numbers are Y-01.E2 02N/05W-19Q01 and 19K02. Water levels in these two wells were much shallower and more persistent than water levels at location 27, and shallow ground water was present almost continuously during the 1973-1979 period.

The intermittent occurrence of ground water shallower than 50 ft at location 27 is compatible with the more pervasive occurrence of shallow ground water in the wells upstream in Cajon Wash. Ground water most likely will be shallower than 50 ft in the Cajon Wash area during periods of greater-than-normal recharge.

Southwest base of the San Bernardino Mountains

A narrow strip of shallow ground water extends along the base of the San Bernardino Mountains from Cajon Wash eastward to the vicinity of Waterman Canyon. Because wells are sparsely distributed in this area and because we have not located these wells more accurately than the nearest sixteenth-section, we are not able to determine the actual size and shape of this area of shallow ground water or to confirm whether shallow water occurs pervasively throughout the entire area. Factors that control the local distribution of ground water here are difficult to evaluate for three reasons: (1) We are uncertain to what extent range-front faults impede ground water, especially upstream from where the faults cross the mouths of canyons; (2) we do not know to what extent impermeable sediment and bedrock influence ground-water flow patterns; and (3) we are uncertain to what degree the distribution of sources of ground-water recharge (principally runoff from the San Bernardino Mountains and recharge from outfalls of the State Water Project) influences local ground-water patterns. Thus, the contours shown in this area probably do not accurately reflect ground-water patterns that would result from the configuration of faults, geologic rock units, and recharge sources. Instead, the contours reflect geometric interpolation of water-level data from a sparse number of imprecisely located wells and therefore are generalized at best.

During the 1973-1979 period, ground-water levels were persistently shallow in the three wells monitored in this area (table 1; two wells occur in Devil Canyon, loc. 45, and one well occurs near Waterman Canyon, loc. 50). In all three wells, 100 percent of the water levels measured during the 1973-1979 period were shallower than 50 ft below land surface. In the Waterman Canyon well, 100 percent of the water levels were shallower than 30 ft below land surface; in Devil Canyon, ground-water depths shallower than 30 ft occurred in only one well, where 88 percent of the 1973-1979 water depths were shallower than 30 ft below land surface.

Santa Ana floodplain

Shallow ground water occurs where the Santa Ana River exits the San Bernardino Mountains and enters the San Bernardino Valley. The shape and location of this water zone suggest that discharge from the Santa Ana River largely controls water levels in this area. Outfall from State Water Project outlets near the Santa Ana River (Martin, 1979) also may partly control local ground-water patterns, and to a lesser degree runoff from Oak Creek and Plunge Creek may contribute to ground-water recharge. We have not evaluated how influential each of these factors is in controlling local ground-water levels.

Of the nine well locations within the shaded area, evidence of shallow ground water is provided by only three wells--two occurring at location 515 and a third occurring at location 467. Although well records at the other seven locations (464, 468, 471, 475, 477, 478, 479) are fairly complete for early years in the 1973-1979 period, the records do not contain water-level data for the years since 1976 and in some cases since 1974. Accordingly, we cannot determine whether these seven wells produced the same shallowing trends in the 1977-1979 period that were produced at locations 467 and 515. Thus, we cannot accurately define the size and shape of the area of shallow ground water. This area owes its portrayed size and shape to modified geometric interpolation from well data at locations 467 and 515 and from well data at locations outside of the area of shallow ground water. The shape of the contours were modified to be consistent with probable recharge sources. In the interpolation process, we did not use minimum-depth values for the seven incomplete well records. These seven wells probably produced shallowing trends during 1978, so the shape and size of the shaded area on the Santa Ana River floodplain reflects this.

Where the Santa Ana River leaves the San Bernardino Mountains, water levels in the two wells at location 515 ranged from 50 to 99 ft below land surface during most of the 1973-1979 period. However, shallow water levels occurred intermittently in these wells during four different years (table 1): (1) In 1974, shallow water levels occurred in both wells during March and April, when water depths ranged from 43.1 to 43.8 ft below land surface; (2) in February 1977, shallow ground water occurred in one of the wells (46.8 ft); (3) during 1978, prolonged episodes of shallow ground water occurred at both wells, and the percentage of measurements shallower than 50 ft ranged from 82 percent in one of the wells to 93 percent in the other well; and (4) in 1979, shallow ground water occurred again, although water levels that year were monitored in only one of the two wells at location 515. In this well, all 1979 water-depth measurements were shallower than 50 ft.

Downstream and to the west of the point where the Santa Ana River leaves the San Bernardino Mountains, the well at location 467 produced shallow water levels only during parts of 1978 and 1979 (table 1). From October 1973 through March 1978, ground-water levels here ranged from 103.3 to 179.9 ft below land surface. In April 1978, the ground-water level began to rise, a trend that continued until the first shallow-water level was recorded in August 1978 (41.4 ft). From August through October, water depths remained shallow and ranged from 40.3 to 46.2 ft below land surface. From October 1978 through March 1979, water levels ranged from 52.1 to 57.2 ft below land surface, with the exception of one water-level measurement of 48.1 ft. In April 1979, ground water rose to 34.9 ft below land surface, a trend that continued through July 1979, when the latest water-depth measurement available was 27.1 ft below land surface.

On the contour map, the distribution of ground water downstream from the point where the Santa Ana River exits the San Bernardino Mountains reflects shallow water levels recorded mainly during 1978 and 1979. All of the nine wells in this area showed ground-water levels deeper than 50 ft below land surface during much of the early part of the 1973-1979 period. Only in 1978 did water levels begin to rise pervasively, especially in wells near the mountain front.

Mill Creek

The presence of shallow ground water in Mill Creek Canyon and southwest of the canyon in the channel of Mill Creek wash suggests that ground-water recharge by surface water flowing in Mill Creek mainly is responsible for the shallow water levels. Recharge from outfalls of the State Water Project may supply additional ground water to this area.

In the Mill Creek area, shallow ground water persisted during most of the 1973-1979 period. For example, in three of the six wells in the area (loc. 517, 520, and 524), 100 percent of the water-depth measurements were shallower than 50 ft, and the average water depth ranged from 10.5 to 27.6 ft (table 2). In the other three wells (loc. 519, 521 and 522), water levels were not as consistently shallow, although they also demonstrate the persistence of shallow ground water in the Mill Creek area. In these three wells, the measurements shallower than 50 ft ranged from 54 to 76 percent, and the average depth to water ranged from 42.7 to 43.7 ft (table 2).

Mentone

The factors contributing to shallow ground water near the city of Mentone are unclear, especially considering that water levels in some adjacent areas are substantially deeper than water levels in the Mentone area. The contrast in water levels suggests that the Mentone shallow-water zone may be produced by an isolated hydrologic system of perched ground water, although we have not confirmed perched conditions here.

Shallow ground water is indicated in this area by only one well that was monitored from September 1978 to May 1979 (loc. 498, table 1). Only the September 1978 measurement of 49.9 ft was shallower than 50 ft; the measurements during the other months of record ranged from 62.3 to 76.8 ft.

East of Yucaipa

Ground-water recharge from Wilson and Oak Glen Creeks and the damming effect of the Casa Blanca barrier probably are responsible for shallow ground water here. However, we have not confirmed this.

During the 1973-1979 period, most water-level measurements in this area were shallower than 50 ft below land surface, and many measurements were shallower than 30 ft below land surface. In the two wells monitored here (loc. 532 and 533), many of the water-level measurements are questionable because they were obtained while the wells were pumping. When the wells were not pumping, 50 percent of the water-level measurements at location 532 and 91 percent of the water-level measurements at location 533 were shallower than 50 ft below land surface (table 1). Moreover, at location 532, 15 percent of the water-level measurements were shallower than 30 ft below land surface, and at location 533, 49 percent of the water-level measurements were shallower than 30 ft.

Statistical data for shallow ground water east of Yucaipa suggest that ground water shallower than 50 ft below land surface can be expected here when pumping operations are suspended.

San Timoteo Canyon

South of the Redlands area, shallow water levels in part of San Timoteo Canyon probably occur because water flowing down San Timoteo Creek easily replenishes the local ground-water supply. In addition, impermeable sedimentary layers and bedrock may occur at shallow depths in the subsurface and may limit the depth of ground-water migration.

The shaded area of shallow ground water in San Timoteo Canyon is based on water-level data from two wells. These wells occur outside the boundary of the study area and are not shown on the contour map; their Areal Designation and State Well numbers are Y-01.F2 02S/02W-20K01 and 02S/03W-24B01. In the first well, ground-water levels persisted at shallow depths during the 1973-1979 period. Although monitored only once each year from 1974 to 1978, 100 percent of the water-level measurements were shallower than 30 ft, the water depth ranged from 21.8 to 29.3 ft below land surface, and the average water depth was 24.9 ft below land surface. In the second well, water depths were not as persistently shallow, but usually were shallower than 50 ft below land surface. In this well, water levels were measured only in 1973 and 1974, 67 percent of the water depth measurements were shallower than 50 ft below land surface, and the average depth to ground water was 42.4 ft.

This area owes its portrayed size and shape to modified geometric interpolation between the two wells located outside the study area and wells located adjacent to the area of shallow ground water. The position of the local contours was modified to be consistent with probable recharge sources.

Reche Canyon

Shallow ground water occurs south of Loma Linda in Reche Canyon. Ground water in this area most likely is replenished by downward percolation of surface water flowing in creeks on the valley floor and by downslope flow of ground water through valley-filling sediment of the canyon. Low-permeability bedrock probably occurs at shallow depths in this part of Reche Canyon, thus limiting the depth of ground-water percolation.

During the 1973-1979 period, many of the water-level measurements in this area were shallower than 50 ft below land surface. Water levels were monitored in three wells during this period (locs. 432, 453, 514, table 1). At location 432, measurements were made only in September 1973, when the water level was 46.0 ft below land surface. At location 514, water levels were measured once in 1974 (37.0 ft) and once in 1975 (64.3 ft). Only at location 453 were water levels measured in each year of the 1973-1979 period. Here, 57 percent of the water-depth measurements were shallower than 50 ft below land surface, and the average water depth was 46 ft. Shallow water occurred in the wells at this location in 1973, 1974, 1978, and 1979.

Muscoy

In the Muscoy area, shallow ground water occurs on the northeast side of the San Jacinto barrier, where the barrier intersects Cajon Wash. Shallow water levels here probably are caused by ground water flowing down Cajon Wash and backing up behind the San Jacinto barrier. However, we have not confirmed this interpretation.

In this area, shallow ground water did not occur until the final two years of the 1973-1979 period, when water levels became persistently shallow. Eight wells are located in this area (loc. 58, 61, 62, 66, 71, 88, 92, and 317), and seven of these eight wells provide evidence of shallow water. Water levels in the eighth well are anomolously deep (loc. 58). For this reason, we regard this well as unrepresentative of water levels in the area, so we disregarded its water-level records.

In the seven acceptable wells, water levels recorded from 1973 through March 1978 ranged from 90.0 to 248.0 ft below land surface. Beginning in about April 1978, ground water in these wells began to rise. Shallow water levels occurred in most of the wells by the end of 1978, and by January 1979 shallow water levels had occurred in all of the wells. From January 1979 through the end of the 1973-1979 period, 75 percent of the water-depth measurements were shallower than 50 ft, and all of the water-depth measurements ranged from 8.0 to 61.1 ft below land surface.

San Bernardino

In the vicinity of San Bernardino, a large area of shallow ground water occurs northeast of the San Jacinto ground-water barrier. This barrier is created by the San Jacinto fault zone. In the south part of the metropolitan area, the Santa Ana Wash crosses the fault zone. Several workers have suggested that ground water migrating downslope in the vicinity of this wash does not flow easily through the fault zone, and that the zone is responsible for the backup of shallow water in the area (Mendenhall, 1905; Dutcher and Garrett, 1963).

In addition, shallow ground water in the San Bernardino metropolitan area also may be caused by confined ground water which has sufficient artesian head so that it can rise to shallow levels behind the San Jacinto barrier (Mendenhall, 1905; Dutcher and Garrett, 1963; Hardt and Hutchinson, 1980). In this model, artesian aquifers consist of sand and gravel layers; aquitards, which separate the artesian aquifers, consist of clay and silty-clay layers that are relatively impermeable. Northwest of the area of shallow ground water, toward the base of the San Bernardino Mountains, the aquitards become thinner and eventually pinch out. Recharge of the aquifers mainly occurs in the area between the zone of aquitard pinch out and the base of the mountains.

In the vicinity of the shallow ground-water levels, water in the aquifers is confined under artesian head by the aquitards. The height of the artesian head within each aquifer defines the elevation of the potentiometric surface of that aquifer. For each confined aquifer, the potentiometric surface elevation is different; generally, the greater the depth of a particular confined aquifer, the higher the elevation of its potentiometric surface. This situation creates a pressure differential between aquifers, which requires water to flow upward from the aquifer having the higher potentiometric surface. If this hypothesized ground-water model applies to the San Bernardino area, then upward flow of ground water from deeper aquifers can occur across aquitards and may contribute shallow ground water to unconsolidated sediment underlying the San Bernardino metropolitan area.

The presence of confined aquifers casts uncertainty on the origin and significance of water levels that are measured in wells within the area of shallow ground water. For example, where a confined aquifer having a potentiometric surface near the ground surface is penetrated by a well that is perforated at the confined level, shallow water-level measurements may suggest the presence of a shallow water table where in fact one does not exist. For wells used in this study, we do not have well-depth or perforation-interval data. Consequently, we have not evaluated influences that confined aquifers may have on ground water in the San Bernardino area. However, on the basis of the general agreement between our data and those of the San Bernardino Municipal Water Department (1981; Martin, 1979) and of the known occurrence of free ground water at shallow levels in trenches and geotechnical test borings, we believe that the ground-water contours shown on our map reasonably represent the distribution of free ground water in the San Bernardino area for the 1973-1979 period.

In this area, water levels and trends in water-level behavior vary considerably from well to well. However, three general trends can be characterized (table 1): (1) In the majority of wells, water depths prior to 1978 generally ranged between 50 and 150 ft below land surface; (2) in most wells, ground water began to rise in 1978; and (3) shallow water levels occurred in most wells only in 1978 and (or) 1979. Recent data unavailable for this report indicate that the trend toward rising water tables has continued through December 1981 and that the zone of shallow ground water shown on our map has increased in area.

Historical and geohydrologic data document the long-term occurrence of water levels at or above the ground surface in the San Bernardino metropolitan area. At various times during the 19th and 20th centuries, tracts of marshland and boggy ground, together with springs, lakes, and ponds, have occurred here (Fife, 1974; Fife and others, 1976, p. 21-25). Evidence for long-term cycles of wetland and dryland development also can be seen in the geologic record where test borings in the shallow subsurface show that peat-bearing deposits and clay deposits of marsh and lake origin are interlayered with sand and pebble deposits of fluvial origin. On the basis of these historical and geological precedents for shallow ground water in the San Bernardino area, the rising ground-water trends beginning in 1978 constitute a significant restoration of hydrologic patterns that can be expected when wetter-than-normal winters coincide with episodes of reduced ground-water withdrawal and increased artificial recharge.

Greater Santa Ana River

Shallow ground water occurs along the course of the Santa Ana River from the San Jacinto ground-water barrier southwestward to Prado Dam. In addition, several broad areas of shallow ground water occur along the margins of the Santa Ana River: (1) west and northwest of the river, in the Glen Avon area; (2) east and southeast of the river, in the Riverside-Casa Blanca-Arlington-La Sierra area; and (3) southeast of the river in the Corona area. In all of these areas, shallow depths to low-permeability bedrock probably limit downward percolation of water and lead to ponding of ground water at shallow levels. This is especially likely where bedrock is shallowest and where natural and artificial recharge occurs frequently or at high rates. Within and marginal to the Santa Ana River, ground water is recharged from the river itself. Elsewhere, recharge occurs during rainfall periods, by runoff from surrounding bedrock areas, and by agricultural irrigation and other artificial recharge activities.

Santa Ana River channel.--Ground water in the vicinity of the Santa Ana River generally was shallow during the 1973-1979 period, although water-depth patterns did vary (table 2). For wells within the 10- and 30-ft contours, water levels generally were shallower than 50 ft during the 1973-1979 period, although some deeper water levels occurred. Among wells located between the 30- and 50-ft contours, shallow ground water was not so persistent, and water levels deeper than 50 ft below land surface occurred with varying frequency during the 1973-1979 period. These water-level patterns suggest that shallow ground water can be expected relatively frequently in and very near the Santa Ana River, but that both the frequency of shallow ground water and the depth to ground water fall off with distance from the river channel.

Areas flanking the Santa Ana River.--In the Glen Avon area, in the greater Riverside area, and in the Corona area, ground water has been shallower than 50 ft intermittently throughout the 1973-1979 period (table 2). For wells located within the 10-ft, 10- to 30-ft, and 30- to 50-ft contours, water-level behavior generally has been similar to behavior along the Santa Ana River. However, in these outlying areas, ground-water recharge rates and withdrawal rates have varied, and water levels have fluctuated over greater ranges with greater frequency. In general, however, shallow ground water can be expected relatively frequently in these outlying areas.

Riverside

In Riverside, anomalously shallow water in the well at location 686 probably indicates perched or confined conditions. Because there is very little data at location 686, and because the data is discussed throughly here, we have omitted statistical analysis of this data from table 1. Water depth was measured four times in this well, with the four measurements taken from October 1973 through March 1975. During this period, water levels ranged from 13.6 to 15.4 ft below land surface. This range of water depths is anomalously shallower than the range of water depths that were measured in adjacent wells during the same period. In adjacent wells, water depths ranged from 74.1 to 115.8 ft below land surface (loc. 683, 685, 688 and 691). This discrepancy in water levels suggests that shallow water in the well at location 686 results because the well taps either a perched aquifer or a confined aquifer. If the well taps a perched aquifer, depth to water in the well would accurately represent the level of ground water in the adjacent sediment. However, if the well taps a confined aquifer, depth to water in the well would indicate the depth to the potentiometric surface of the confined aquifer and would not indicate the depth to free ground water in the adjacent area. On the contour map, we chose to show perched ground water at this locality because we had no evidence suggesting that an artesian aquifer occurs here. However, we have not confirmed that perched ground-water conditions occur at this locality.

CONCLUSIONS

In the upper Santa Ana River valley, ground water shallower than 50 ft below land surface has occurred in 20 areas during 1973-1979. Shallow ground water can be expected in these areas whenever climatic conditions and water-management policies are similar to those of the 1970's. Because of the potential occurrence of shallow ground water, the sedimentary materials in these areas should be evaluated for their susceptibility to seismically induced liquefaction.

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Metropolitan area. Gail E. Kroth contoured initial versions of the water-depth map. Eduardo A. Rodriguez assisted in drafting the contour map, and Curtis M. Obi assisted in making the statistical analyses summarized in tables 1 and 2.

REFERENCES

Burnham, W. L., and Dutcher, L. C., 1960, Geology and ground-water hydrology of the Redlands-Beaumont area, California, with special reference to ground-water outflow: U.S. Geological Survey Ground-water Branch, Long Beach, California, 1 volume and plates, 352 p.

Dutcher, L. C., and Garrett, A. A., 1963, Geologic and hydrologic features of the San Bernardino area, California--with special reference to underflow across the San Jacinto fault: U.S. Geological Survey Water-Supply Paper 1419, 114 p.

Eckis, Rollin., 1934, Geology and ground water storage capacity of valley fill: California Division of Water Resources Bulletin No. 45, 279 p.

Fife, D. L., 1976, Map showing surface waters and marshes in the late 1800's, and generalized depth to ground water (1960), upper Santa Ana Valley, southwestern San Bernardino County, California, in Fife, D. L., Rodgers, D. A., Chase, G. W., Chapman, R. H., and Sprotte, E. C., 1976, Geologic hazards in southwestern San Bernardino County, California: California Division of Mines and Geology Special Report 113, scale 1:48,000, plates 4A, 4B.

Fife, D. L., Rodgers, D. A., Chase, G. W., Chapman, R. H., and Sprotte, E. C., 1976, Geological hazards in southwestern San Bernardino County, California: California Division of Mines and Geology Special Report 113, 40 p.

Geotechnical Consultants, Inc., 1980, Hydrogeologic evaluation, Chino ground water basin, step 1-facilities plan, water reclamation project: unpublished report, 100 p.

Hall, W. H., 1888, Detailed irrigation map of San Bernardino: California Engineering Department Report to the Legislature.

Hardt, W. F., and Hutchinson, C. B., 1980, Development and use of a mathematical model of the San Bernardino Valley ground-water basin, California: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-576, 80 p.

Martin, R., 1979, Bunker Hill artesian zone study: San Bernardino Valley Municipal Water District unpublished report, 53 p.

Mendenhall, W. C., 1905, The hydrology of San Bernardino Valley, California: U.S. Geological Survey Water-Supply Paper 142, 124 p.

Miller, F. K., 1979, Geologic map of the San Bernardino North Quadrangle, California: U.S. Geological Survey Open-File Report 79-770.

Morton, D. M., 1978, Geologic map of the San Bernardino South Quadrangle, San Bernardino and Riverside Counties: U.S. Geological Survey Open-File Report 78-20.

San Bernardino Municipal Water Department, 1981, The effects of rising ground water levels within the Bunker Hill artesian zone San Bernardino, California: unpublished report, 35 p.

Seed, H. B., 1976, Evaluation of soil liquefaction effects on level ground during earthquakes, in Liquefaction Problems in Geotechnical Engineering: American Society of Civil Engineers National Convention, September 27-October 1, 1976, preprint 2752, p. 1-104.

Seed, H. B., and Idriss, I. M., 1971, Simplified procedure for evaluating soil liquefaction potential: Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, v.97, no. SM9, p. 1249-1273.

Youd, T. L., and Perkins, D. M., 1978, Mapping liquefaction-induced ground failure potential: Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, v. 104, no. GT4, p. 433-446.

Youd, T. L., Tinsley, J. C., Perkins, D. M., King, E. J., and Preston, R. F., 1978, Liquefaction potential of the San Fernando Valley: International Conference on Microzonation for Safer Construction-Research and Applications, 2d, Proceedings, v.1, p. 267-278.

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979

[For map location numbers containing more than one well, the state well number of the well having the shallowest ground water is listed first, followed by additional wells having deeper water levels]

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
1	Y-01.B3	01N/08W-24E01	Flow	1979
2	Y-01.B3	01N/08W-24L01	116.0	1979
3	U-05.E3	01N/08W-26D01	2.0	1978
4	U-05.E2	01N/08W-27H01	28.2	1978
5	Y-01.B4	01N/07W-29E01	216.5	1978
6	Y-01.B3	01N/08W-25M01	84.5	1978
7	Y-01.B3	01N/08W-25L01	98.6	1978
8	Y-01.B3	01N/08W-25K02	90.0	1978
	Y-01.B1	01N/08W-25K03		
9	Y-01.B4	01N/07W-28M01	233.4	1979
10	Y-01.B3	01N/08W-26P01	112.5	1978
11	Y-01.B3	01N/08W-25Q01	--	--
12	Y-01.B4	01N/07W-29R03,04	267.0	1979
13	U-05.E3	01N/08W-33A01	3.0	1978
14	Y-01.B3	01N/08W-34A02,01,03	115.1	1978
15	Y-01.B3	01N/08W-36D01	144.1	1978
16	Y-01.B3	01N/08W-34H01	98.1	1978
17	Y-01.B3	01N/08W-35E01	138.6	1978
18	U-05.E3	01N/08W-33L01	27.7	1975
19	Y-01.B3	01N/08W-34L01	100.0	1978
20	Y-01.B3	01N/08W-34K01	74.1	1978
21	Y-01.B3	01N/08W-35K02,01	95.0	1978
22	Y-01.B1	01N/08W-35J03	83.0	1978
	Y-01.B3	01N/08W-35J01,02		
23	Y-01.B4	01N/07W-27H01	289.1	1976
24	Y-01.B4	01N/07W-27Q02,01	198.0	1974
25	Y-01.B4	01N/07W-33A01	183.6	1974
26	Y-01.B4	01N/07W-34A05	202.1	1975
27	Y-01.E2	02N/05W-33K01	2.7	1978
28	Y-01.D2	01N/05W-06G01	30.4	1978
29	Y-01.E2	01N/05W-03H02,01	54.0	1978
30	Y-01.D2	01N/05W-06K02	48.4	1974
31	Y-01.D2	01N/05W-07H01	51.5	1978
32	Y-01.D3	01N/05W-17G01	36.0	1978
33	Y-01.D3	01N/05W-17K01,02	25.0	1978
34	Y-01.D2	01N/05W-16K01	--	--
35	Y-01.E9	01N/05W-15K01	154.7	1979
36	Y-01.E9	01N/05W-15Q02	--	--
37	Y-01.D2	01N/05W-22C02	156.4	1978
38	Y-01.E9	01N/05W-22A01	140.6	1978
39	Y-01.D2	01N/05W-22F01,02,03	127.7	1979
40	Y-01.D4	01N/05W-29A01	--	--
41	Y-01.D4	01N/05W-30G01	327.1	1979
42	Y-01.D4	01N/05W-28J01	419.0	1975
43	Y-01.B1	01N/06W-35A01	448.4	1979
44	Y-01.D4	01N/05W-31A01	309.2	1979
45	Y-01.E2	01N/04W-06H02,01	25.5	1974
46	Y-01.E2	01N/04W-07F01	126.2	1978
47	Y-01.E2	01N/04W-08M01	115.5	1973
48	Y-01.E2	01N/04W-08P01	131.3	1979
49	Y-01.E2	01N/04W-16E03,01,02,04	146.9	1979
50	Y-01.E2	01N/04W-14R08	9.9	1978
51	Y-01.E9	01N/05W-23A01,02	54.0	1979
52	Y-01.E2	01N/04W-21B02	125.4	1979
53	Y-01.E2	01N/04W-23B01	124.6	1975
54	Y-01.E9	01N/05W-23H01	62.2	1979
55	Y-01.E9	01N/05W-24E01	104.0	1978
56	Y-01.E2	01N/04W-23E01	229.9	1976
57	Y-01.E2	01N/04W-23G01	223.4	1976
58	Y-01.E9	01N/05W-23K01	--	--
59	Y-01.E2	01N/04W-23M01	209.7	1974
60	Y-01.E2	01N/04W-23K01	182.6	1974
61	Y-01.D2	01N/05W-23P04	--	--
62	Y-01.E9	01N/05W-23Q01	8.0	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
63	Y-01.E2	01N/04W-20N01	194.7	1978
64	Y-01.E2	01N/04W-23Q02	246.7	1976
65	Y-01.E2	01N/04W-23R02	189.4	1979
66	Y-01.E9	01N/05W-26A03	21.0	1979
67	Y-01.E2	01N/04W-27B01	209.2	1979
68	Y-01.E2	01N/04W-27A01,02	194.6	1978
69	Y-01.E2	01N/04W-26A02,01,03	236.5	1974
70	Y-01.E2	01N/04W-25C04,02	195.0	1979
71	Y-01.E9	01N/05W-25E01	22.0	1979
72	Y-01.E2	01N/04W-29E01	197.0	1979
73	Y-01.E2	01N/04W-29F01	144.0	1979
74	Y-01.E2	01N/04W-27G01	210.6	1979
75	Y-01.E2	01N/04W-26E02	205.5	1974
76	Y-01.E2	01N/04W-28J02	172.8	1979
77	Y-01.E2	01N/04W-27M02,01	174.3	1979
78	Y-01.E2	01N/04W-26M01	172.5	1977
79	Y-01.E2	01N/04W-25M03	141.7	1978
80	Y-01.E2	01N/04W-28R01	--	--
81	Y-01.E2	01N/04W-27N01	163.3	1979
82	Y-01.E2	01N/04W-26N02	185.0	1979
83	Y-01.E2	01N/04W-26P03	164.0	1979
84	Y-01.E2	01N/04W-25P04	168.3	1979
85	Y-01.E2	01N/04W-31A01	198.0	1979
86	Y-01.E2	01N/04W-32D03,04	177.5	1979
87	Y-01.E2	01N/04W-35C01,02,03	146.3	1979
88	Y-01.E9	01N/05W-36H04	44.0	1979
89	Y-01.E2	01N/04W-31E01	100.5	1975
90	Y-01.E2	01N/04W-31H01	158.0	1978
91	Y-01.E2	01N/04W-34G03,01	125.3	1975
92	Y-01.E9	01N/05W-36J03	36.1	1979
93	Y-01.E2	01N/04W-33M01	128.5	1979
94	Y-01.E2	01N/04W-35M03	124.1	1979
95	Y-01.E2	01N/04W-35L01,06	127.3	1979
96	Y-01.E2	01N/04W-25A01	210.0	1977,1979
97	Y-01.E2	01N/03W-30C02	193.1	1974
98	Y-01.E2	01N/03W-30J05	314.2	1974
99	Y-01.E2	01N/03W-29M01	288.1	1976
100	Y-01.E2	01N/03W-30N01	211.7	1979
101	Y-01.E2	01N/03W-29N01	260.0	1979
102	Y-01.E2	01N/03W-28P01	320.1	1977
103	Y-01.E2	01N/03W-27N02,05	18.0	1978
104	Y-01.E2	01N/03W-31C02	--	--
105	Y-01.E2	01N/03W-32C02	227.0	1979
106	Y-01.E2	01N/03W-33C01	411.5	1976
107	Y-01.E2	01N/04W-36K07	125.5	1979
108	Y-01.E2	01N/03W-33M01,02	204.0	1979
109	U-05.E3	01S/08W-06A01,03	98.8	1979
110	U-05.E3	01S/08W-06H01	145.9	1974
111	U-05.E3	01S/08W-06L01	135.2	1979
112	U-05.E3	01S/08W-06J02,03	61.2	1979
113	U-05.E2	01S/09W-12F01	97.4	1977
114	U-05.E2	01S/09W-12H01	--	--
115	U-05.E2	01S/08W-07F01	--	--
116	U-05.E2	01S/08W-07G01,02	--	--
117	U-05.E2	01S/09W-12L01	98.5	1977
118	U-05.E2	01S/09W-12J01	--	--
119	U-05.E2	01S/09W-11R02,01	12.5	1978
120	U-05.E2	01S/09W-12N01,03	29.1	1979
121	U-05.E2	01S/09W-13A01	114.0	1975
122	U-05.E2	01S/08W-18J02	--	--
123	U-05.E2	01S/08W-19A03,01	96.0	1975
124	U-05.E1	01S/09W-23R01	137.0	1975
125	U-05.E1	01S/09W-24Q02	178.3	1978
126	U-05.E1	01S/08W-19N01	210.8	1977
127	U-05.E1	01S/09W-26A02	--	--
128	U-05.E1	01S/09W-25B01	163.8	1975
129	U-05.E1	01S/09W-26H01	--	--
130	U-05.E1	01S/09W-25E01,02	--	--

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
131	U-05.E1	01S/09W-25F01	168.1	1979
132	U-05.E1	01S/09W-25G01	169.0	1979
133	Y-01.B1	01S/08W-30K01	--	--
134	Y-01.B1	01S/08W-31J01	--	--
135	Y-01.B1	01S/08W-31Q01	120.5	1979
136	U-05.E3	01N/08W-32P08	--	--
137	U-05.E3	01N/08W-33N02	73.7	1979
138	U-05.E3	01N/08W-33P01	139.2	1975
139	U-05.E3	01N/08W-33Q02,03	135.0	1978
140	Y-01.B1	01N/08W-35Q01	67.7	1978
141	Y-01.B1	01N/08W-35R01	142.0	1978
142	Y-01.B4	01N/07W-32R03,02	19.0	1978
143	Y-01.B4	01N/07W-33N03,01	126.0	1973
144	U-05.E3	01S/08W-05D01,02,04	141.1	1978
145	U-05.E3	01S/08W-05B01	--	--
146	U-05.E3	01S/08W-05A02	4.5	1978
147	U-05.E3	01S/08W-04D01	18.5	1978
148	Y-01.B3	01S/08W-03A01	69.9	1978
149	Y-01.B3	01S/08W-02D02,01	26.9	1978
150	Y-01.B1	01S/08W-02B01	43.5	1978
	Y-01.B3	01S/08W-02B02		
151	Y-01.B1	01S/08W-01D02,01,03	99.0	1978
152	U-05.E3	01S/08W-05E02	140.7	1978
153	Y-01.B3	01S/08W-03F02,01,03	78.5	1978
154	Y-01.B3	01S/08W-03G04,02	35.1	1978
155	Y-01.B3	01S/08W-02F01	43.0	1978
156	Y-01.B4	01S/07W-04E02,03	50.8	1974
157	U-05.E3	01S/08W-04M01	--	--
158	U-05.E3	01S/08W-04L01	--	--
159	Y-01.B3	01S/08W-04K01	96.7	1978
160	Y-01.B3	01S/08W-03L02	61.7	1975
161	Y-01.B3	01S/08W-03J01	14.5	1978
162	Y-01.B1	01S/08W-02M03	46.1	1978
163	U-05.E2	01S/08W-08B03	171.8	1975
164	Y-01.B2	01S/08W-09D01	--	--
165	Y-01.B1	01S/08W-10B01	--	--
166	Y-01.B2	01S/08W-08H01	--	--
167	Y-01.B2	01S/08W-09E01	--	--
168	Y-01.B2	01S/08W-09G03	Flow	1978,1979
169	Y-01.B2	01S/08W-09H03	74.2	1976
170	Y-01.B2	01S/08W-09M01	--	--
171	Y-01.B2	01S/08W-09L01	--	--
172	Y-01.B1	01S/08W-12K01	630.0	1975
173	Y-01.B1	01S/08W-12J01	--	--
174	Y-01.B2	01S/08W-09P01	281.6	1979
175	Y-01.B1	01S/08W-10N01,07,12	--	--
176	Y-01.B1	01S/08W-11R01	576.0	1976
177	Y-01.B1	01S/08W-12P01	587.6	1974
178	Y-01.B1	01S/07W-08N01	589.4	1973
179	Y-01.B2	01S/08W-16B01	--	--
180	Y-01.B1	01S/08W-14D01	626.0	1979
181	Y-01.B1	01S/08W-14A02,03	549.1	1973
182	Y-01.B2	01S/08W-16F01	228.5	1973
183	Y-01.B1	01S/08W-15H01	537.0	1973
184	Y-01.B1	01S/07W-18E01	546.5	1975
185	Y-01.B1	01S/07W-18G01	531.0	1978
186	Y-01.B1	01S/07W-17E01	550.0	1979
187	Y-01.B2	01S/08W-17K03,01,02	214.9	1976
188	Y-01.B1	01S/08W-15J01	521.5	1979
189	Y-01.B1	01S/07W-17J01	496.7	1973,1974
190	Y-01.B2	01S/08W-17P02,04	156.8	1973
191	Y-01.B1	01S/08W-15P02	--	--
192	Y-01.B1	01S/08W-15Q02	459.2	1979
193	Y-01.B1	01S/08W-14N01	442.0	1979
194	Y-01.B1	01S/08W-13P01	494.0	1975
195	Y-01.B2	01S/08W-20B02	--	--
196	Y-01.B1	01S/08W-23A03	470.8	1973
197	Y-01.B1	01S/07W-19D01,02	383.0	1976

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
198	Y-01.B1	01S/07W-20A01	449.8	1978
199	Y-01.B1	01S/07W-21D01	454.3	1974,1975
200	Y-01.B1	01S/08W-24E01	435.1	1973
201	Y-01.B1	01S/08W-22M01	--	--
202	Y-01.B1	01S/08W-23N01	405.0	1973
203	Y-01.B1	01S/08W-26B01	396.0	1973
204	Y-01.B1	01S/07W-29A01	340.0	1974
205	Y-01.B1	01S/08W-29F02	308.1	1974
206	Y-01.B1	01S/08W-29H02	265.8	1973
207	Y-01.B1	01S/08W-28E01,02	--	--
208	Y-01.B1	01S/08W-28F02	--	--
209	Y-01.B1	01S/08W-28G01,02	--	--
210	Y-01.B1	01S/08W-27H01	365.6	1973
211	Y-01.B1	01S/08W-28M01,02,03	--	--
212	Y-01.B1	01S/08W-28L01	--	--
213	Y-01.B1	01S/07W-28M02	323.0	1978
214	Y-01.B1	01S/08W-28N01,02	--	--
215	Y-01.B1	01S/08W-25Q02	321.0	1975
216	Y-01.B1	01S/07W-30Q01	315.0	1975
217	Y-01.B1	01S/07W-30R01	335.9	1975
218	Y-01.B1	01S/08W-33D01	--	--
219	Y-01.B1	01S/08W-33C01	--	--
220	Y-01.B1	01S/08W-34A01	332.0	1979
221	Y-01.B1	01S/08W-35C04,01,02	294.2	1978
222	Y-01.B1	01S/08W-32G01	--	--
223	Y-01.B1	01S/08W-33E03	--	--
224	Y-01.B1	01S/08W-33L06	273.3	1974
225	Y-01.B1	01S/08W-35J01,02	285.0	1978
226	Y-01.B1	01S/08W-32P05	251.3	1974
227	Y-01.B1	02S/08W-05G01	230.0	1974
228	Y-01.B1	02S/08W-05M01	19.1	1974
229	Y-01.B1	02S/08W-04P01	202.6	1974
230	Y-01.B1	02S/08W-12F01	170.1	1973
231	Y-01.B1	02S/08W-11M01	134.0	1975
232	Y-01.B1	02S/08W-11L01	159.2	1973
233	Y-01.B4	01N/07W-33P01	135.0	1974
234	Y-01.B4	01N/07W-33R02	129.9	1973
235	Y-01.B4	01S/07W-04B02,01,03	78.8	1974
236	Y-01.B4	01S/07W-04A01	188.1	1974
237	Y-01.B1	01S/07W-14D01	411.5	1974
238	Y-01.B1	01S/06W-16A01	397.6	1975
239	Y-01.B1	01S/07W-14E01	406.0	1975
240	Y-01.B1	01S/07W-14G01	411.0	1974
241	Y-01.B1	01S/06W-16G01	378.6	1974
242	Y-01.B1	01S/07W-14L01	393.0	1976
243	Y-01.B1	01S/06W-16L01	340.0	1974,1975,1976
244	Y-01.B1	01S/07W-13R01	363.6	1973
245	Y-01.B1	01S/07W-21C01	421.0	1978
246	Y-01.B1	01S/07W-22B01	--	--
247	Y-01.B1	01S/07W-27D01	324.0	1975
248	Y-01.B1	01S/07W-28R02	290.0	1978
249	Y-01.B1	01S/07W-34A01	248.0	1975
250	Y-01.B1	02S/06W-05B01,02	197.0	1973
251	Y-01.B1	02S/06W-06N02	186.2	1974
252	Y-01.B1	02S/06W-08D03	163.3	1974
253	Y-01.B1	02S/06W-10M03,02,04	137.8	1975
254	Y-01.B1	02S/06W-18A01	--	--
255	Y-01.B1	02S/06W-16D02	104.1	1979
256	Y-01.B1	02S/06W-16B02	116.5	1974
257	Y-01.D4	01S/05W-05A03,02	253.4	1975
258	Y-01.D4	01S/05W-04D01,02	362.2	1974
259	Y-01.D4	01S/05W-02C01	355.0	1978
260	Y-01.B1	01S/05W-06J01	543.6	1977
261	Y-01.B1	01S/06W-11B01	476.9	1975
262	Y-01.B1	01S/06W-11N01	423.8	1973,1974
263	Y-01.B1	01S/06W-12P01	448.0	1979
264	Y-01.B1	01S/05W-07N01	431.0	1979
265	Y-01.B1	01S/05W-07R01	465.5	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
266	Y-01.B1	01S/05W-16C01	416.6	1973
267	Y-01.B1	01S/05W-15G01	335.0	1975
268	Y-01.B1	01S/06W-23D01	305.9	1975
269	Y-01.B1	01S/05W-19D01	--	--
270	Y-01.B1	01S/05W-19A01	395.9	1975
271	Y-01.B1	01S/05W-22E01	284.6	1974
272	Y-01.B1	01S/05W-19J01	350.5	1975
273	Y-01.B1	01S/05W-22M01	260.0	1978,1979
274	Y-01.B1	01S/06W-25C01	310.0	1973,1975
275	Y-01.B1	01S/05W-29A01	285.0	1975
276	Y-01.B1	01S/06W-27L01	242.0	1974
277	Y-01.B1	01S/05W-30L01	300.3	1973
278	Y-01.B1	01S/06W-36D01	233.1	1977
279	Y-01.B7	01S/05W-33A02,01	182.4	1979
280	Y-01.B7	01S/05W-34D01	132.9	1978
281	Y-01.B7	01S/05W-34B02	163.0	1978
282	Y-01.B7	01S/05W-33F01	94.8	1979
283	Y-01.B7	01S/05W-35G02	87.5	1974
284	Y-01.B7	01S/05W-33L01	82.0	1979
285	Y-01.B7	01S/05W-34M01	125.1	1979
286	Y-01.B7	01S/05W-34L02	132.0	1979
287	Y-01.B7	01S/05W-34J01	118.7	1979
288	Y-01.B7	02S/05W-03A01	127.0	1978
289	Y-01.B7	02S/05W-02C01	102.9	1979
290	Y-01.B7	02S/05W-03G02	71.5	1979
291	Y-01.B7	02S/05W-02E01	--	--
292	Y-01.B7	02S/05W-02F02,01	80.7	1979
293	Y-01.B7	02S/05W-02M06	--	--
294	Y-01.B7	02S/05W-02L01,02,05	78.6	1979
295	Y-01.B1	02S/06W-01Q01	20.2	1978
296	Y-01.B1	02S/05W-07F01	31.7	1978
297	Y-01.B1	02S/05W-08G01,04	150.1	1975
298	Y-01.B7	02S/05W-10G07,01	45.9	1978
299	Y-01.B1	02S/06W-11K03	21.4	1975
300	Y-01.B1	02S/06W-11J02	18.2	1978
301	Y-01.B1	02S/06W-12M03	16.8	1978
302	Y-01.B1	02S/06W-12L01	46.8	1973,1974
303	Y-01.B1	02S/05W-07M01	16.1	1976
304	Y-01.B1	02S/05W-08K02	150.5	1975
305	Y-01.B7	02S/05W-10L05	76.3	1978
306	Y-01.B1	02S/06W-11Q01	21.8	1978
307	Y-01.B1	02S/05W-07R03	9.5	1978
308	Y-01.B7	02S/05W-10P01	73.3	1978
309	Y-01.B7	02S/05W-10Q04	34.0	1978
310	Y-01.B1	02S/06W-14C02	28.7	1973
311	Y-01.B1	02S/06W-13C06,07	19.9	1979
312	Y-01.B1	02S/06W-13B04,06	20.7	1973,1974
313	Y-01.B1	02S/05W-18C02	39.9	1978
314	Y-01.B7	02S/05W-17A01,02	63.0	1977
315	Y-01.B7	02S/05W-15B06	7.5	1979
316	Y-01.B7	02S/05W-14D01	6.4	1978
317	Y-01.E9	01N/05W-36R01	35.5	1978
318	Y-01.E2	01N/04W-32N01	128.2	1975
319	Y-01.E2	01S/04W-05C03	129.6	1979
320	Y-01.E2	01S/04W-03D01	90.5	1979
321	Y-01.E2	01S/04W-02A03,05	77.4	1979
322	Y-01.E2	01S/04W-06H01	129.0	1975
323	Y-01.E2	01S/04W-05E05	105.7	1979
324	Y-01.E2	01S/04W-04E03	--	--
325	Y-01.E2	01S/04W-01E01,02	54.5	1979
326	Y-01.D4	01S/05W-02K01	296.0	1979
327	Y-01.E2	01S/04W-06J01	149.5	1977
328	Y-01.E2	01S/04W-03J05	53.4	1978
329	Y-01.E2	01S/04W-02M01	62.6	1979
330	Y-01.E2	01S/04W-02L07	56.3	1979
331	Y-01.E2	01S/04W-02K02,01,03,08	45.1	1979
332	Y-01.E2	01S/04W-03Q01	48.5	1979
333	Y-01.E2	01S/04W-02N01	17.6	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
334	Y-01.E2	01S/04W-02P06,02,03,05	39.1	1979
335	Y-01.E2	01S/04W-02Q03,04,05,06, 08,09	48.2	1979
336	Y-01.D4	01S/04W-07C01	185.9	1974
337	Y-01.E2	01S/04W-08C01	70.5	1978
338	Y-01.E2	01S/04W-08A01	88.0	1979
339	Y-01.E2	01S/04W-09B01,03	66.8	1979
340	Y-01.E2	01S/04W-11D02,03	34.4	1979
341	Y-01.E2	01S/04W-08F07,01,02,08, 10	85.0	1979
342	Y-01.E2	01S/04W-08G01	205.0	1976
343	Y-01.E2	01S/04W-09E02	84.0	1979
344	Y-01.E2	01S/04W-10F01	38.4	1979
345	Y-01.E2	01S/04W-11H01	38.7	1979
346	Y-01.D4	01S/05W-12L01	245.8	1974
347	Y-01.E2	01S/04W-09J01	38.6	1979
348	Y-01.D4	01S/05W-12N01	236.3	1975
349	Y-01.E2	01S/04W-08Q01,03	83.0	1979
350	Y-01.E2	01S/04W-08R05,01,04	85.5	1979
351	Y-01.E2	01S/04W-09N06,01	59.3	1979
352	Y-01.E2	01S/04W-09P01	63.8	1979
353	Y-01.E2	01S/04W-10N06	3.7	1977
354	Y-01.E2	01S/04W-11Q01	--	--
355	Y-01.D4	01S/04W-18B01	230.0	1979
356	Y-01.D4	01S/04W-18E01	--	--
357	Y-01.D4	01S/04W-18F01	196.0	1975
358	Y-01.D4	01S/04W-18G01	196.0	1975
359	Y-01.E2	01S/04W-15F05	--	--
360	Y-01.E2	01S/04W-14H03	76.8	1979
361	Y-01.E2	01S/04W-13F02	75.1	1979
362	Y-01.D4	01S/04W-17M01	180.3	1979
363	Y-01.E2	01S/04W-16J09	16.0	1974
364	Y-01.E2	01S/04W-15M02	--	--
365	Y-01.E2	01S/04W-15L03	28.5	1974
366	Y-01.E2	01S/04W-13M02	53.6	1979
367	Y-01.E2	01S/04W-13L02	69.4	1979
368	Y-01.E2	01S/04W-16R04	--	--
369	Y-01.E2	01S/04W-15N05	--	--
370	Y-01.E2	01S/04W-14P06,02	44.5	1979
371	Y-01.E2	01S/04W-13N01,02	72.1	1979
372	Y-01.E2	01S/04W-13P03	66.5	1979
373	Y-01.E2	01S/04W-21B05	12.7	1978
374	Y-01.E2	01S/04W-21A01	--	--
375	Y-01.E2	01S/04W-22D01,02	--	--
376	Y-01.E2	01S/04W-22C02	23.6	1979
377	Y-01.E2	01S/04W-22B07,01,03,05	27.5	1979
378	Y-01.E2	01S/04W-23C02,03	40.3	1979
379	Y-01.E2	01S/04W-23A01,02,05	50.2	1979
380	Y-01.B7	01S/05W-24E01	212.7	1979
381	Y-01.E2	01S/04W-22E05	21.7	1978
382	Y-01.E2	01S/04W-22G16,14,17,18, 19	24.0	1979
383	Y-01.E2	01S/04W-22H02,01,03,04	11.1	1979
384	Y-01.E2	01S/04W-23G03,01	52.4	1979
385	Y-01.E2	01S/04W-23H01	69.4	1979
386	Y-01.D4	01S/04W-21L01	58.3	1973
387	Y-01.D4	01S/04W-21K11,01,06,09, 10	29.8	1978
388	Y-01.D4	01S/04W-21J04,01,05,06	27.8	1978
389	Y-01.E2	01S/04W-22M06	20.8	1979
390	Y-01.E2	01S/04W-22L05,08,09,12, 15	9.2	1979
391	Y-01.E2	01S/04W-23K03,01,02	49.5	1979
392	Y-01.B7	01S/05W-23Q01	170.7	1979
393	Y-01.D4	01S/04W-21N01	71.0	1974
394	Y-01.D4	01S/04W-21Q03	50.9	1979
395	Y-01.E2	01S/04W-22P05	21.2	1979
396	Y-01.E2	01S/04W-23Q01	50.3	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
397	Y-01.B7	01S/05W-25B02	136.1	1979
398	Y-01.B7	01S/05W-25A03,02	133.7	1979
399	Y-01.B7	01S/04W-30D06	127.4	1974
400	Y-01.D4	01S/04W-28D01	30.0	1979
401	Y-01.D4	01S/04W-28C01	51.3	1973
402	Y-01.D4	01S/04W-28A05	50.6	1974
403	Y-01.E2	01S/04W-27A10,07,08,09, 11,13,19	13.7	1978
404	Y-01.B7	01S/04W-29H01,02	25.7	1979
405	Y-01.D4	01S/04W-28E01	15.2	1979
406	Y-01.D4	01S/04W-28G01	50.5	1979
407	Y-01.E2	01S/04W-27H01	22.1	1979
408	Y-01.B7	01S/05W-25L02	84.8	1979
409	Y-01.B7	01S/04W-30L02	15.0	1973
410	Y-01.B7	01S/04W-28M01	28.1	1979
411	Y-01.B7	01S/04W-28L02,01	36.8	1979
412	Y-01.D4	01S/04W-28K02,01	33.1	1979
413	Y-01.D4	01S/04W-27L01	81.9	1974
414	Y-01.E2	01S/04W-26J01	89.5	1979
415	Y-01.B7	01S/05W-25R04	18.3	1979
416	Y-01.B7	01S/04W-30P01	12.0	1979
417	Y-01.B7	01S/04W-29Q01,03,04	13.1	1979
418	Y-01.B1	01S/04W-29R01	24.6	1978,1979
419	Y-01.B7	01S/04W-28N05	25.4	1979
420	Y-01.B7	01S/04W-28R01	96.9	1978
421	Y-01.B7	01S/05W-36C11	36.6	1979
422	Y-01.B7	01S/04W-31D02	42.8	1979
423	Y-01.B7	01S/04W-32B01,02	19.9	1979
424	Y-01.B7	01S/04W-33B05,03	40.0	1978
425	Y-01.D5	01S/04W-34B01	--	--
426	Y-01.B7	01S/05W-35G02	52.1	1978
427	Y-01.B7	01S/04W-32E11,07,10	18.7	1978
428	Y-01.B7	01S/04W-32G04	19.2	1978
429	Y-01.B7	01S/04W-31J01	61.7	1978
430	Y-01.B7	01S/04W-32M01,03	35.8	1979
431	Y-01.B7	01S/04W-32Q02	134.6	1979
432	Y-01.D5	01S/04W-34Q01	46.0	1973
433	Y-01.B7	02S/04W-06A03	--	--
434	Y-01.B7	02S/04W-05C01	102.8	1979
435	Y-01.B7	02S/04W-05F01	115.4	1979
436	Y-01.B7	02S/05W-01J01,02	6.5	1979
437	Y-01.B7	02S/04W-06K02	57.0	1979
438	Y-01.B7	02S/05W-02Q07	11.1	1978
439	Y-01.B7	02S/05W-02R03,01,02	9.0	1974
440	Y-01.B7	02S/04W-06R06,01,05	83.4	1979
441	Y-01.B7	02S/04W-05N01	88.8	1979
442	Y-01.B7	02S/05W-11A01	8.7	1978
443	Y-01.B7	02S/05W-12A01	17.8	1979
444	Y-01.B7	02S/04W-08D04	115.0	1974,1975
445	Y-01.B7	02S/04W-08E01	127.2	1979
446	Y-01.B7	02S/05W-11K02	8.5	1978,1979
447	Y-01.B7	02S/05W-12K02	17.8	1979
448	Y-01.B7	02S/05W-12J01	41.2	1974
449	Y-01.B7	02S/04W-07L01	63.0	1979
450	Y-01.B7	02S/04W-08M02,01	130.1	1979
451	Y-01.B7	02S/05W-12P01	15.9	1978
452	Y-01.B7	02S/04W-07N03	64.0	1979
453	Y-01.D5	02S/04W-12P02	34.8	1979
454	Y-01.E2	01N/04W-36Q01	99.3	1979
455	Y-01.E2	01N/03W-33R02	170.9	1978
456	Y-01.E2	01S/04W-01B04	98.0	1979
457	Y-01.E2	01S/04W-01A06	88.3	1979
458	Y-01.E2	01S/03W-05D04 and 06, 01,05	122.0	1979
459	Y-01.E2	01S/03W-03D03	190.9	1974
460	Y-01.E2	01S/04W-01G01	83.2	1979
461	Y-01.E2	01S/04W-01H01	74.4	1979
462	Y-01.E2	01S/03W-06H04,03	148.0	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
463	Y-01.E2	01S/03W-04G02	170.0	1979
464	Y-01.E2	01S/03W-01H01	--	--
465	Y-01.E2	01S/04W-01K04	83.6	1979
466	Y-01.E2	01S/03W-06K01	125.0	1979
467	Y-01.E2	01S/03W-02J01	27.1	1979
468	Y-01.E2	01S/02W-06M01	--	--
469	Y-01.E2	01S/03W-04N01,03	138.5	1979
470	Y-01.E2	01S/03W-03N07	159.6	1979
471	Y-01.E2	01S/03W-02P02	--	--
472	Y-01.E2	01S/04W-12B06,05	82.8	1979
473	Y-01.E2	01S/03W-09D01	147.2	1979
474	Y-01.E2	01S/03W-10D01	125.0	1973
475	Y-01.E2	01S/02W-07B01	--	--
476	Y-01.E2	01S/03W-09E02	135.1	1979
477	Y-01.E2	01S/03W-11H01	--	--
478	Y-01.E2	01S/03W-12J01	--	--
479	Y-01.E2	01S/02W-07K01	--	--
480	Y-01.E2	01S/03W-17C03	112.2	1979
481	Y-01.E2	01S/04W-13G03,02	53.1	1979
482	Y-01.E2	01S/03W-17H03	--	--
483	Y-01.E2	01S/03W-16F01	--	--
484	Y-01.E2	01S/03W-15F01	61.2	1979
485	Y-01.E2	01S/03W-16J01	--	--
486	Y-01.E2	01S/03W-15M03	--	--
487	Y-01.E3	01S/03W-13P01	175.2	1978
488	Y-01.E2	01S/03W-22A02	149.3	1979
489	Y-01.E2	01S/03W-23A03	--	--
490	Y-01.E3	01S/03W-24C01	169.7	1979
491	Y-01.E4	01S/02W-19D01	180.0	1979
492	Y-01.E2	01S/03W-19G02	122.2	1979
493	Y-01.E2	01S/03W-20F01	--	--
494	Y-01.E2	01S/03W-21E02	--	--
495	Y-01.E2	01S/03W-21H07,01,06	128.3	1979
496	Y-01.E2	01S/04W-24K01	88.2	1979
497	Y-01.E2	01S/03W-24K01	116.0	1974
498	Y-01.E4	01S/02W-19K01	49.9	1978
499	Y-01.E2	01S/03W-20P01	--	--
500	Y-01.E3	01S/03W-26C01	170.0	1979
501	Y-01.E4	01S/02W-30C01	80.3	1979
502	Y-01.E2	01S/04W-25G01	108.0	1975
503	Y-01.E2	01S/03W-28E02	132.8	1973
504	Y-01.E2	01S/03W-28H01	134.9	1979
505	Y-01.E2	01S/03W-27E02	134.9	1979
506	Y-01.E2	01S/03W-28K01	123.9	1979
507	Y-01.E2	01S/03W-32D01	--	--
508	Y-01.E2	01S/03W-33C01	136.5	1976
509	Y-01.E5	01S/03W-35G13,07,08,09, 11	72.0	1979
510	Y-01.E5	01S/03W-35H02,03,04	81.9	1974
511	Y-01.E3	02S/03W-05A02	99.9	1979
512	Y-01.E6	02S/03W-01D01	183.5	1979
513	Y-01.F2	02S/03W-10B01	67.6	1979
514	Y-01.D5	02S/03W-18D02	37.0	1974
515	Y-01.E7	01S/02W-08C01	18.9	1978
	Y-01.E2	01S/02W-08C02		
516	Y-01.E8	01S/02W-09Q01	151.6	1977
517	Y-01.E7	01S/02W-13A01	6.0	1978
518	Y-01.E4	01S/02W-18R01	65.7	1979
519	Y-01.E4	01S/02W-21D01	11.5	1979
520	Y-01.E8	01S/02W-21B02	12.0	1978
521	Y-01.E8	01S/02W-22C02	15.0	1978
522	Y-01.E8	01S/02W-21E01	14.7	1979
523	Y-01.E1	01S/02W-19J01	172.0	1979
524	Y-01.E8	01S/02W-21M01	9.6	1979
525	Y-01.F5	01S/01W-30E01	282.0	1979
526	Y-01.F5	01S/01W-30G01	187.0	1975
527	Y-01.E5	01S/02W-29M01	202.8	1979
528	Y-01.F5	01S/02W-25M02	179.0	1979

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
529	Y-01.F5	01S/02W-25K02	234.0	1979
530	Y-01.F6	01S/02W-25R02	291.4	1974
531	Y-01.F6	01S/02W-36C04	304.4	1973
532	Y-01.F7	01S/01W-32C01	21.0	1979
533	Y-01.F7	01S/01W-32A01	19.0	1974
534	Y-01.F6	01S/02W-36F01	290.0	1974
535	Y-01.F1	01S/02W-34N02	250.0	1979
536	Y-01.F6	01S/02W-36N01	221.6	1973
537	Y-01.F6	01S/02W-36R01	329.0	1973
538	Y-01.F4	02S/02W-02D02	278.0	1977
539	Y-01.F6	02S/02W-01F01	215.0	1973
540	Y-01.F4	02S/02W-03L01	148.1	1979
541	Y-01.F4	02S/02W-02M02	261.0	1979
542	Y-01.F4	02S/02W-02N01	228.0	1979
543	Y-01.F4	02S/02W-10C01	169.3	1979
544	Y-01.F4	02S/02W-11D02	187.0	1979
545	Y-01.F7	02S/02W-11B02,01	240.0	1979
546	Y-01.F7	02S/02W-11A01	280.0	1979
547	Y-01.F7	02S/01W-08C01	--	--
548	Y-01.F1	02S/01W-08E01	56.0	1979
549	Y-01.F4	02S/02W-10K01	--	--
550	Y-01.F1	02S/02W-15A03	--	--
551	Y-01.F7	02S/02W-14B01	274.0	1975
552	Y-01.B1	02S/08W-26J02	--	--
553	Y-01.B1	02S/08W-35C02	--	--
554	Y-01.B1	02S/07W-32H01	68.8	1973
555	Y-01.B1	02S/08W-35J01,02	--	--
556	Y-01.B1	03S/07W-06H02	11.1	1973
557	Y-01.B1	03S/07W-08L01	42.3	1975,1976
558	Y-01.B5	03S/07W-21M02,01	- 0.9	1974
559	Y-01.B5	03S/07W-21N01	1.1	1979
560	Y-01.B1	02S/06W-21D03	105.1	1974
561	Y-01.B1	02S/06W-21E01	89.6	1975
562	Y-01.B1	02S/07W-27A02	--	--
563	Y-01.B1	02S/06W-27D04	19.1	1979
564	Y-01.B1	02S/06W-28E01	12.8	1973
565	Y-01.B1	02S/07W-25M01	50.8	1974
566	Y-01.B1	02S/07W-27R01	49.2	1975
567	Y-01.B1	02S/06W-30R03	25.2	1973
568	Y-01.B1	02S/07W-35C02	45.0	1974
569	Y-01.B1	02S/07W-36D01	41.5	1974
570	Y-01.B1	02S/07W-36A07	53.0	1975
571	Y-01.B1	02S/06W-31D01	50.1	1974
572	Y-01.B1	02S/06W-31C01	25.4	1974
573	Y-01.B1	02S/07W-34H01	32.1	1974
574	Y-01.B1	02S/07W-36E01	35.2	1974
575	Y-01.B1	02S/07W-36H02	28.0	1979
576	Y-01.B1	02S/06W-33E02,01	30.0	1978
577	Y-01.B1	02S/07W-34J01	27.6	1974
578	Y-01.B1	02S/07W-36M02	50.6	1974
579	Y-01.B1	02S/07W-36L01	10.1	1973
580	Y-01.B1	02S/07W-34R01	36.0	1973
581	Y-01.B1	03S/07W-03J01	39.9	1978
582	Y-01.B5	03S/06W-06K02	36.2	1978
583	Y-01.B1	03S/07W-03N01	32.9	1978
584	Y-01.B1	03S/07W-10D01	31.1	1974
585	Y-01.B1	03S/07W-11E01	45.0	1975
586	Y-01.B1	03S/07W-09J01	8.0	1975
587	Y-01.B5	03S/07W-11L03	49.9	1979
588	Y-01.B5	03S/07W-14J02	21.4	1979
589	Y-01.B5	03S/07W-21C03	--	--
590	Y-01.B5	03S/07W-23C03	16.1	1974
591	Y-01.B5	03S/07W-21G01	0.2	1979
592	Y-01.B5	03S/07W-22L01	9.9	1974
593	Y-01.B5	03S/07W-22J02	7.4	1974
594	Y-01.B5	03S/07W-23M02	21.9	1974
595	Y-01.B5	03S/07W-23L01	31.8	1974
596	Y-01.B5	03S/07W-24L01	41.0	1975

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
597	Y-01.B5	03S/07W-24Q03,04,05	17.0	1979
598	Y-01.B5	03S/07W-26C01	36.2	1978
599	Y-01.B5	03S/07W-25D01	131.0	1975
600	Y-01.B5	03S/06W-28A02	20.6	1979
601	Y-01.B5	03S/07W-28F01	58.1	1978
602	Y-01.B5	03S/07W-27F01	135.9	1979
603	Y-01.B5	03S/07W-27G01	124.8	1978
604	Y-01.B5	03S/07W-27H01	130.5	1974
605	Y-01.B5	03S/07W-26G01	95.0	1978
606	Y-01.B5	03S/07W-25E01	67.0	1976
607	Y-01.B5	03S/07W-25H01	55.6	1974
608	Y-01.B5	03S/06W-28H01	--	--
609	Y-01.B5	03S/07W-26K01	135.0	1978
610	Y-01.B5	03S/07W-25M01,02	67.5	1978
611	Y-01.B5	03S/07W-25J01	68.6	1979
612	Y-01.B5	03S/06W-28M01,02	22.7	1979
613	Y-01.B5	03S/06W-28L03,04	27.7	1978
614	Y-01.B5	03S/06W-29Q04	18.8	1978
615	Y-01.B1	02S/06W-14G02	18.3	1979
616	Y-01.B1	02S/06W-14H02	14.4	1979
617	Y-01.B1	02S/06W-13F02,01,03,05	12.1	1979
618	Y-01.B1	02S/06W-13G03	23.8	1979
619	Y-01.B7	02S/05W-16G04	12.7	1978
620	Y-01.B7	02S/05W-15F06	14.0	1979
621	Y-01.B1	02S/06W-14L01	7.0	1979
622	Y-01.B1	02S/06W-13M03,02	15.8	1979
623	Y-01.B7	02S/05W-17L01	45.7	1978
624	Y-01.B7	02S/05W-17K01	59.1	1979
625	Y-01.B7	02S/05W-15M01	11.8	1979
626	Y-01.B7	02S/05W-16P01	3.3	1978
627	Y-01.B7	02S/05W-16R01	6.3	1978
628	Y-01.B1	02S/06W-23A01	41.3	1973
629	Y-01.B7	02S/05W-20A02	8.5	1979
630	Y-01.B7	02S/05W-21A01	1.6	1979
631	Y-01.B7	02S/05W-22D01	2.6	1979
632	Y-01.B1	02S/06W-22G01	36.2	1979
633	Y-01.B1	02S/06W-23G01,04	25.5	1979
634	Y-01.B1	02S/05W-20H05	4.8	1976
635	Y-01.B7	02S/05W-21E01	5.3	1973
636	Y-01.B7	02S/05W-20K01,03	22.8	1974
637	Y-01.B7	02S/05W-20J03,02	1.8	1978
638	Y-01.B1	02S/05W-19Q01	45.5	1973
639	Y-01.B7	02S/05W-22R01,02	23.4	1979
640	Y-01.B1	02S/06W-27A01	16.0	1979
641	Y-01.B1	02S/06W-26D01,02	34.7	1979
642	Y-01.B1	02S/06W-25C01	2.6	1979
643	Y-01.B7	02S/05W-29D02	17.0	1975
644	Y-01.B7	02S/05W-28A01	10.4	1979
645	Y-01.B7	02S/05W-29E02,06	3.2	1978
646	Y-01.B7	02S/05W-26E02	45.2	1979
647	Y-01.B7	02S/05W-26F01	37.3	1979
648	Y-01.B7	02S/05W-26M01	39.0	1979
649	Y-01.B7	02S/05W-32B01	48.0	1979
650	Y-01.B7	02S/05W-32A01	49.8	1979
651	Y-01.B7	02S/05W-32K01	38.4	1974
652	Y-01.B6	02S/06W-36R01	7.1	1973,1974
653	Y-01.B6	03S/05W-05B01	18.4	1978
654	Y-01.B6	03S/06W-03L01	13.6	1974
655	Y-01.B6	03S/05W-05M03	5.7	1979
656	Y-01.B6	03S/05W-06Q03,02,04,05	5.2	1976
657	Y-01.B6	03S/05W-08B02	39.3	1979
658	Y-01.B6	03S/05W-09A01	114.7	1978
659	Y-01.B6	03S/06W-10G01	11.9	1973
660	Y-01.B6	03S/05W-08E02	25.7	1979
661	Y-01.B6	03S/05W-09E01	84.1	1979
662	Y-01.B6	03S/05W-07J01	--	--
663	Y-01.B6	03S/05W-09M01	85.7	1978
664	Y-01.B6	03S/06W-13B01,02	41.9	1973

TABLE 3.--Well identification numbers and data showing minimum depth to ground water, 1973-1979--Continued

Map location No.	Areal designation	State well No.[1]	Minimum depth to ground water(ft)[2]	Year measured
665	Y-01.B6	03S/06W-13A01	34.9	1975
666	Y-01.B6	03S/06W-13E05	33.2	1973
667	Y-01.B6	03S/05W-17G01	--	--
668	Y-01.B6	03S/05W-14E01	8.2	1978
669	Y-01.B6	03S/06W-13M03	33.3	1973
670	Y-01.B6	03S/05W-17K02	42.0	1978
671	Y-01.B6	03S/06W-14Q01	45.2	1973
672	Y-01.B6	03S/06W-13N01 and 02	15.4	1978,1979
673	Y-01.B6	03S/05W-17Q01	52.4	1973
674	Y-01.B6	03S/06W-23H01	35.1	1978
675	Y-01.B6	03S/06W-24G01	8.4	1974
676	Y-01.B6	03S/05W-19E03,04	1.7	1979
677	Y-01.B6	03S/06W-22L03	--	--
678	Y-01.B6	03S/06W-22K01	--	--
679	Y-01.B6	03S/06W-24Q01	4.7	1974
680	Y-01.B6	03S/05W-19P02,01,03	1.0	1978
681	Y-01.B7	02S/04W-18E01	89.3	1979
682	Y-01.B7	02S/05W-13Q02	88.5	1979
683	Y-01.B7	02S/05W-24D01	89.6	1979
684	Y-01.B7	02S/04W-19A01	176.1	1979
685	Y-01.B7	02S/05W-23F01	66.9	1979
686	Y-01.B7	02S/05W-14G01	13.6	1974
687	Y-01.B7	02S/04W-19E01	124.4	1979
688	Y-01.B7	02S/05W-23J01	87.1	1979
689	Y-01.B7	02S/04W-19J02	198.4	1978
690	Y-01.B7	02S/05W-23Q01	74.9	1979
691	Y-01.B7	02S/05W-23R01	93.3	1978
692	Y-01.B7	02S/04W-19N02	142.5	1979
693	Y-01.B7	02S/04W-19P01	182.7	1974
694	Y-01.B7	02S/05W-25A01	158.0	1979
695	Y-01.B7	02S/04W-29M01	59.1	1978
696	Y-01.B7	02S/05W-36A01	60.0	1978
697	Y-01.F3	02S/02W-14J02	183.5	1977
698	Y-01.F7	02S/02W-14R01	132.0	1977

[1] All wells occur in the San Bernardino Base and Meridian (S).
[2] A dash indicates well locations not having an acceptable value for minimum depth to ground water.