DISTRIBUTION OF DISSOLVED NITRATE AND FLUORIDE IN GROUND WATER, HIGHLAND-EAST HIGHLANDS, SAN BERNARDINO COUNTY, CALIFORNIA

U.S. GEOLOGICAL SURVEY Water-Resources Investigations 78-14

Prepared in cooperation with the San Bernardino Valley Municipal Water District

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Lawrence A. Eccles and John M. Klein

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Menlo Park, California 94025

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16. Abstracts
In the Highland-East Highlands area of southern California, concentrations of nitrate in water from many wells exceed the U.S. Environmental Protection Agency's and the California Department of Health's recommended limit for public water supplies. The nitrate standards for public water supplies in the study area are commonly met by blending the high-nitrate water with low-nitrate water before distribution; however, some of the low-nitrate water sources have fluoride concentrations that exceed the optimum level, or in a few cases exceed the maximum level recommended by the California Department of Health. Nitrate-nitrogen concentrations in the study area are generally between 1 and 20 milligrams per liter. In general, nitrate-nitrogen concentrations exceeding 10 milligrams per liter are found in water from wells perforated at depths of less than 500 feet.

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UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Rd.
Menlo Park, Calif. 94025

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CONVERSION FACTORS

For readers who prefer metric units rather than English units, the conversion factors for the terms used herein are listed below.

Multiply English unit	*By*	*To obtain metric unit*
acre	4.047×10^{-1}	hm^2 (square hectometers)
ft (feet)	3.048×10^{-1}	m (meters)
ft/mi (feet per mile)	1.890×10^{-1}	m/km (meters per kilometer)
in/h (inches per hour)	2.540×10	mm/h (millimeters per hour)
mi (miles)	1.609	km (kilometers)

Degrees Fahreheit are converted to degrees Celsius by using the formula: $°C = (°F - 32)/1.8$.

DISTRIBUTION OF DISSOLVED NITRATE AND FLUORIDE

IN GROUND WATER, HIGHLAND-EAST HIGHLANDS

SAN BERNARDINO COUNTY, CALIFORNIA

By Lawrence A. Eccles and John M. Klein

ABSTRACT

In the Highland-East Highlands area of San Bernardino County, Calif., concentrations of nitrate-nitrogen exceeding the U.S. Environmental Protection Agency recommended limit of 10 milligrams per liter occur in water from many wells. Increasing urbanization has placed increasing demands on the ground-water resources for public supplies. The California State Health Department requires that remedial action be taken on those public water sources that exceed the water-quality standards of the U.S. Environmental Protection Agency. One form of action commonly used consists of blending high-nitrate water with low-nitrate water before distribution; however, in the study area some of the low-nitrate water may exceed the California Department of Health's optimum dissolved-fluoride concentration of 0.8 milligram per liter.

In general, nitrate-nitrogen concentrations in water from wells with most perforations at depths less than 500 feet exceed 10 milligrams per liter near the center of the study area and decrease toward the perimeter; however, throughout the study area water from wells with most perforations at depths greater than 500 feet contain less than 5 milligrams per liter dissolved nitrate-nitrogen. Concentrations of dissolved nitrate-nitrogen exceeding 20 milligrams per liter occur in water from four public-supply wells. Wells drilled near areas of recharge, such as the Santa Ana Wash, generally yield water with dissolved nitrate-nitrogen concentrations less than 5 milligrams per liter. Concentrations of fluoride and dissolved solids also are less in wells near recharge areas.

INTRODUCTION

In the Highland-East Highlands area of the San Bernardino Valley in San Bernardino County, Calif. (fig. 1), the principal source of public water supply is ground water. In the past, land was used primarily for citrus groves and other agriculture, and most water supplies were used for irrigation. At present the land-use trend is toward urbanization. Land use in 1976 is shown in figure 2. This trend has caused increased demands on local ground-water resources for public supplies.

The U.S. Environmental Protection Agency (EPA) (1972, p. 73) recommends that the concentration of dissolved nitrate, expressed as elemental nitrogen (nitrate-nitrogen), not exceed 10 mg/L (milligrams per liter) in water used for public supplies. Several public-supply wells in the study area yield water with nitrate-nitrogen concentrations that exceed 10 mg/L, and some other public-supply wells yield water with nitrate-nitrogen concentrations exceeding 20 mg/L. The San Bernardino Valley Municipal Water District reported that the nitrate-nitrogen concentrations in water from several of the wells in the study area increased during 1974-75.

The California Department of Health (1974, p. 4) requires that remedial action be taken whenever the nitrate-nitrogen concentration in public water supplies exceeds the EPA recommended 10-mg/L standard. Remedial action usually consists of discontinuing the use of high-nitrate water sources for the public-supply system, substituting other sources, or blending the high-nitrate water with dilute, low-nitrate water before distribution.

Nitrate-nitrogen concentrations that exceed 10 mg/L in public water supplies in the study area have been partly controlled by blending high-nitrate water with low-nitrate water; however, some of the low-nitrate ground-water sources used for blending have fluoride concentrations exceeding 0.8 mg/L, the optimum concentration recommended for this area by the California Department of Health (1974, p. 148.5). Some of this ground water used for blending contains fluoride concentrations that exceed 1.4 mg/L, the maximum concentration recommended by EPA (1972, p. 66) and the California Department of Health (1974, p. 148.5). Fluoride concentrations in the final blends have not exceeded the EPA or California Department of Health recommended maximum.

In order to determine the severity of the ground-water nitrate problem and the indirectly related fluoride problem in the Highland-East Highlands area, the U.S. Geological Survey and the San Bernardino Valley Municipal Water District (SBVMWD) began a two-phase study in 1976. Phase 1, of which this report is the result, describes the distribution of nitrate and fluoride in water from the saturated zone, with minor emphasis on the distribution of dissolved solids and specific-conductance values. Phase 2 will describe the areal and vertical distribution of nitrate in the unsaturated zone.

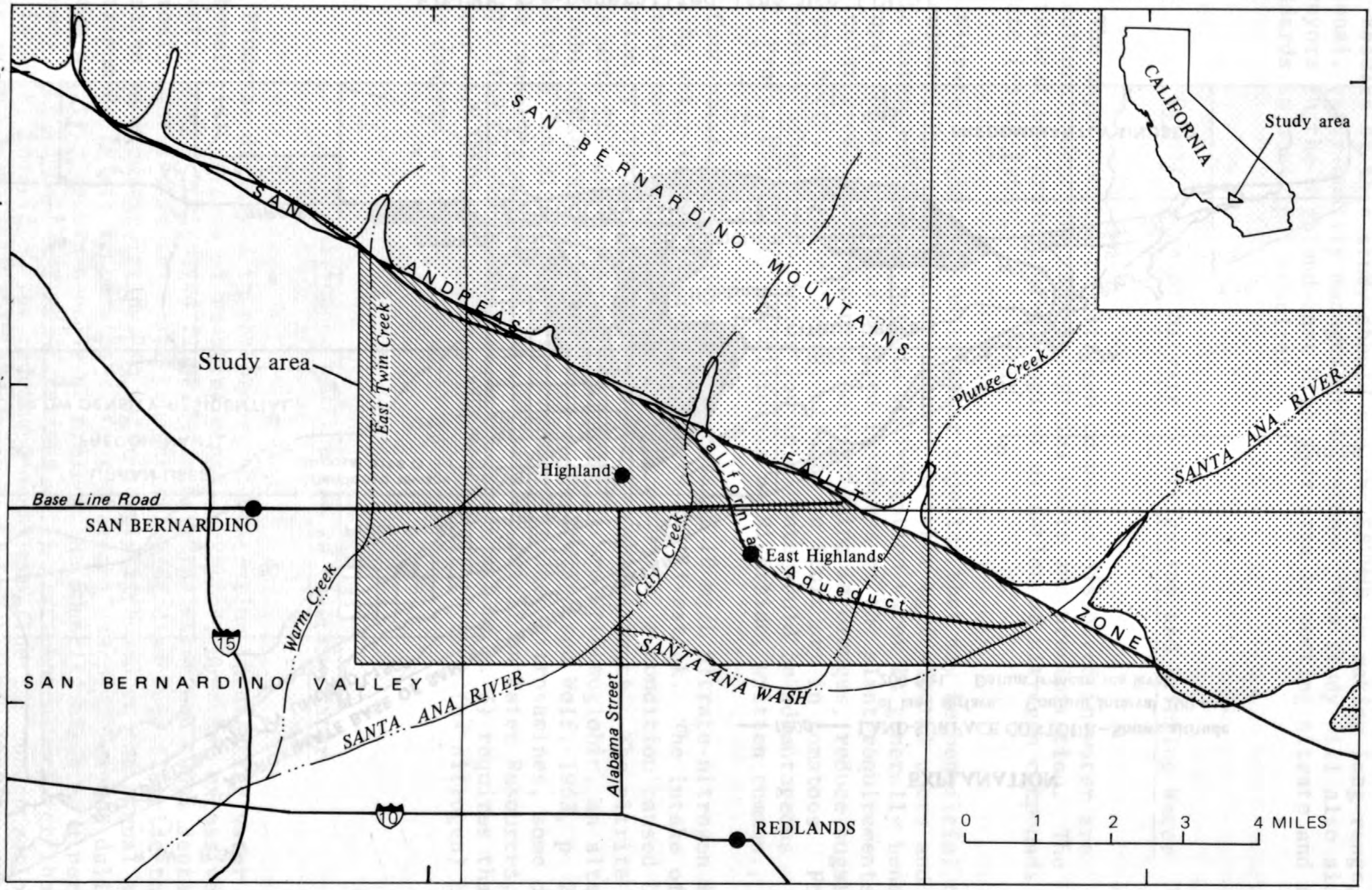


FIGURE 1.--Location of Highland-East Highlands area.

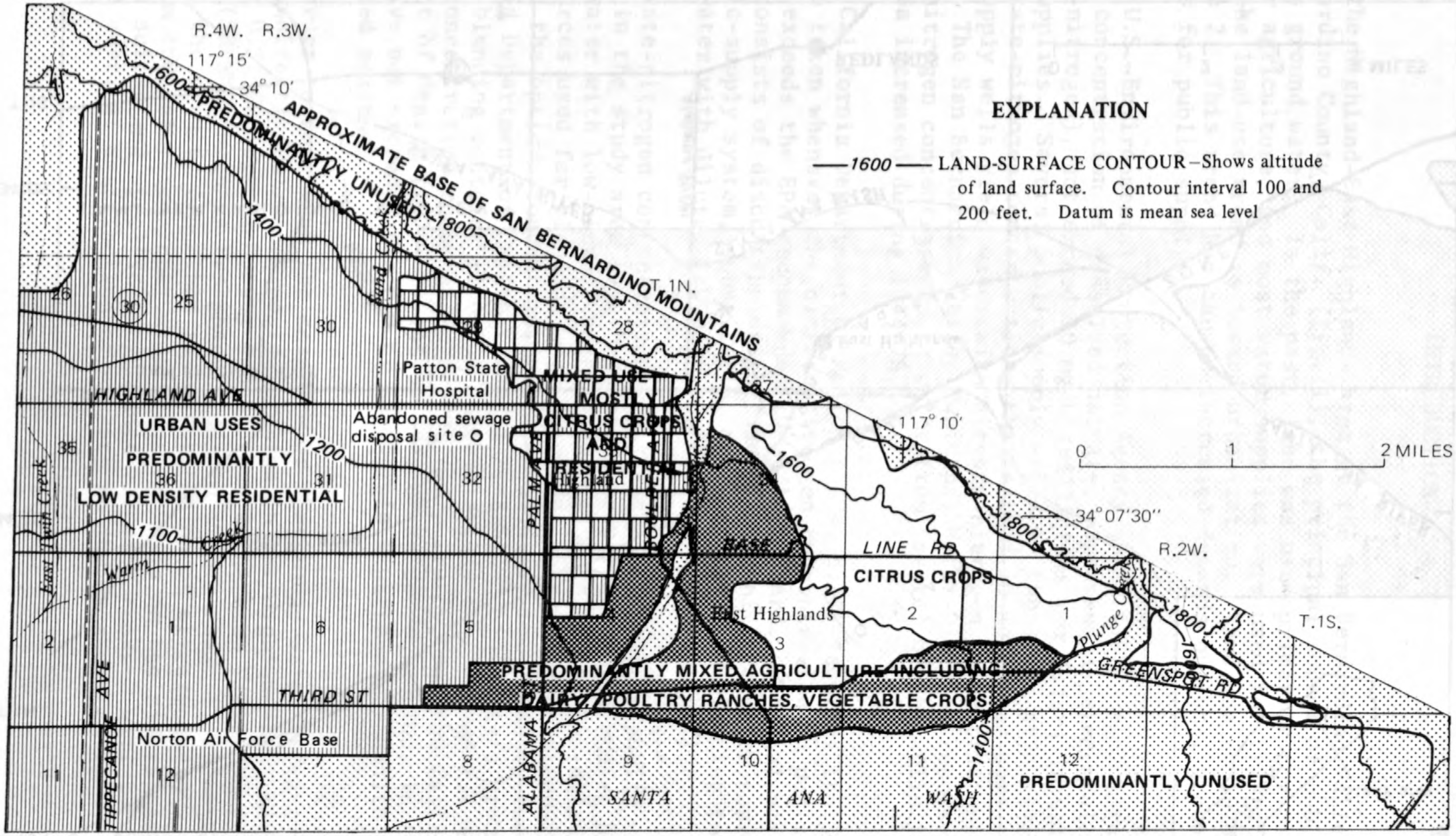


FIGURE 2.--Generalized land use (1976).

Results of this study should aid the SBVMWD in making long-range, regional, water-quality management decisions. The study will also aid water purveyors in the Highland-East Highlands area in meeting nitrate and fluoride standards in municipal supplies.

Significance of Nitrate in Irrigation and Drinking Water

The major sources of nitrogen compounds dissolved in water are agricultural, domestic, and industrial waste and precipitation. The theoretical end product of biological oxidation of nitrogen compounds is nitrate (Feth, 1966).

Nitrate concentrations in water supplies that may be beneficial to some agricultural users may be detrimental to other agricultural users and to public water suppliers. Nitrate in irrigation water is generally beneficial to crops; however, nitrate applied in excess of the plant requirements of a particular growing stage can cause regreening in oranges, reduce sugar content in sugar beets, and have adverse effects on fruit set in tomatoes. For these and perhaps other crops, water low in nitrate would be advantageous (P. F. Pratt, University of California at Riverside, written commun., 1976).

Concentrations of nitrate in excess of 10 mg/L nitrate-nitrogen in drinking water can be harmful to infants and livestock. The intake of nitrate can cause methemoglobinemia, or nitrate cyanosis, a condition caused by the reduction of nitrate to nitrite in the intestinal tract. The nitrite in turn reacts with the hemoglobin of the blood to form methemoglobin, an altered hemoglobin that can no longer carry oxygen (McKee and Wolf, 1963, p. 224). The nitrite can also react with amines to produce nitrosamines, some of which may be cancer-causing agents (Universities Council on Water Resources, 1974, p. 18). The California Department of Health (1974, p. 3) requires that users of water with nitrate concentrations exceeding 10 mg/L (as nitrogen) be warned of the dangers of giving the water to infants.

Significance of Fluoride in Drinking Water

Fluoride dissolved in the proper concentration in drinking water can have the beneficial effects of reducing dental cavities; however, excessive concentrations of dissolved fluoride in drinking water can cause dental fluorosis (mottled teeth). The concentration of dissolved fluoride that is excessive in a particular public water supply is based on the annual average of maximum daily air temperatures for the area of supply, because daily maximum air temperature usually determines the quantity of water a person will consume. The annual average of maximum daily air temperatures for the study area is 80°F; therefore, the recommended maximum fluoride concentration for public water supplies in the study area is 1.4 mg/L (EPA, 1972, p. 66).

Purpose

The purpose of this phase of the study was to determine primarily the distribution of dissolved nitrate and secondarily the distribution of dissolved fluoride in the saturated zone underlying the Highland-East Highlands area. The distribution of dissolved solids, as indicated by specific conductance, was similarly examined to aid in understanding the general water-quality characteristics of the study area, the general direction and rate of ground-water movement, and the areas of dilute native ground water and artificially recharged California Aqueduct water that might be used for blending to meet both nitrate and fluoride health standards.

The study area is in the east end of San Bernardino Valley. The boundaries for the triangular study area are the base of the San Bernardino Mountains, which corresponds to the approximate trace of the San Andreas fault zone, for the north boundary; an east-west line through the Santa Ana Wash for a south boundary; and a north-south line, approximately 1½ mi east of San Bernardino for a west boundary (fig. 1).

The approach to this phase of the study was as follows:

1. Collect data on well locations, well construction, water levels, and water quality.

2. Collect and analyze water samples from selected wells. Analyze some water samples for nitrate only and analyze other water samples for selected dissolved-chemical constituents that aid in evaluating and identifying sources of ground-water degradation and chemical change in the saturated zone.

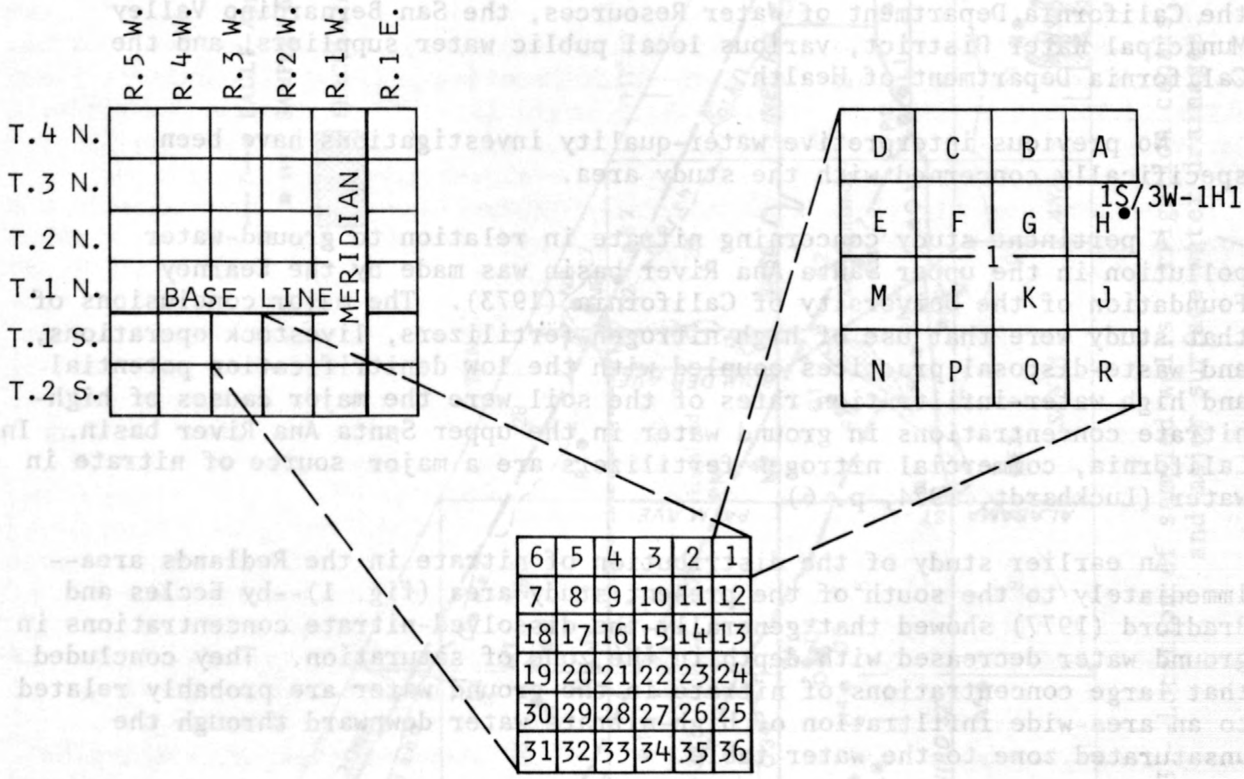
3. Evaluate all data and emphasize the areal and, where possible, the vertical variation in nitrate, fluoride, and specific-conductance values.

Acknowledgments

The authors acknowledge the help from the employees of East San Bernardino County Water District, Southern California Water Co., Patton State Hospital, and Norton Air Force Base in collecting the water samples and well data necessary to carry out this study.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in the well number 1S/3W-1H1, the part of the number preceding the slash indicates the township (T. 1 S.); the number and letter following the slash indicate the range (R. 3 W.); the number following the hyphen indicates the section (sec. 1); the letter following the section number indicates the 40-acre subdivision of the section according to the lettered diagram below. The final digit is a serial number designation for wells in each 40-acre subdivision. Some wells have not been assigned a serial number but are designated by either double zero (00) or nothing following the 40-acre subdivision letter designation.



Previous Hydrologic Investigations

Studies by Burnham and Dutcher (1960) and Dutcher and Garrett (1963) included or were extrapolated into parts of the study area; however, neither of these investigations included a detailed description of the ground-water hydrology and water quality. Moreland (1972) and Schaefer and Warner (1975) evaluated infiltration rates of the stream-channel deposits for City, Plunge, East Twin, and Warm Creeks (fig. 3). In addition, the U.S. Soil Conservation Service, Redlands District, has prepared unpublished maps of various soil types and their infiltration rates. Garrett and Dutcher (1954) compiled much of the historical ground-water basic data.

Surface-water and ground-water quality data for the study area were compiled by Coe and Florian (1957). Recent water-quality data (1957-76), for both ground water and surface water, are on file with the Geological Survey, the California Department of Water Resources, the San Bernardino Valley Municipal Water District, various local public water suppliers, and the California Department of Health.

No previous interpretive water-quality investigations have been specifically concerned with the study area.

A pertinent study concerning nitrate in relation to ground-water pollution in the upper Santa Ana River basin was made by the Kearney Foundation of the University of California (1973). The major conclusions of that study were that use of high-nitrogen fertilizers, livestock operations, and waste-disposal practices coupled with the low denitrification potential and high water-infiltration rates of the soil were the major causes of high-nitrate concentrations in ground water in the upper Santa Ana River basin. In California, commercial nitrogen fertilizers are a major source of nitrate in water (Luckhardt, 1974, p. 6).

An earlier study of the distribution of nitrate in the Redlands area--immediately to the south of the present study area (fig. 1)--by Eccles and Bradford (1977) showed that generally the dissolved-nitrate concentrations in ground water decreased with depth in the zone of saturation. They concluded that large concentrations of nitrate in the ground water are probably related to an area-wide infiltration of high-nitrate water downward through the unsaturated zone to the water table.

A study by Eccles, Klein, and Hardt (1976) further documented the zoning of dissolved nitrate-nitrogen with depth in the Redlands area. Concentrations in excess of 20 mg/L dissolved nitrate occur in the water at the top of the zone of saturation and decrease with depth. A series of aquifer tests (Eccles and others, 1976) showed that dissolved nitrate-nitrogen concentrations increased with time in water pumped from a public-supply well perforated in both upper and lower water-producing zones in the aquifer. A similar test, in an adjacent shallower production well, with perforations only in the top zone of production yielded water high (20 mg/L) in dissolved nitrate-nitrogen and unchanging with time.

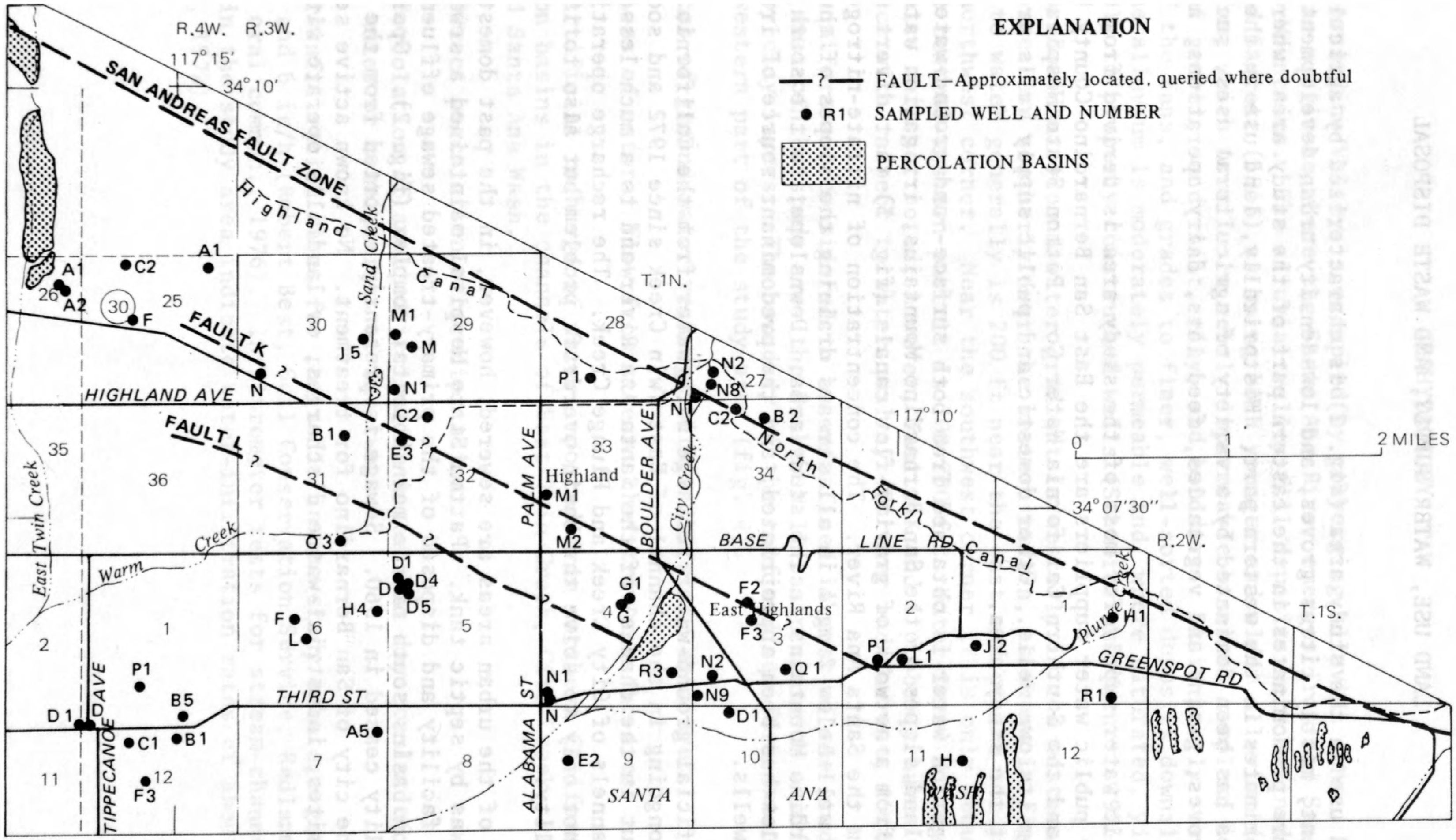


FIGURE 3.--Location of sampled wells, irrigation canals, percolation basins, and major surface-water drainages.

LAND USE, WATER SUPPLY, AND WASTE DISPOSAL

Land use in the study area (fig. 2) is characterized by agricultural development, mostly citrus groves, and low-density urban development. Agriculture predominates in the eastern part of the study area, whereas urban use predominates in the western part. Historically, land use in the entire study area has been dominated by a variety of agricultural uses, such as citrus groves, grains and vegetables, feed lots, dairy operations, and poultry ranches.

Public water supply for most of the study area is derived from wells. The major public water suppliers are the East San Bernardino County Water District and the Southern California Water Co. Patton State Hospital obtains water from its own wells. Other domestic and public supply wells are located throughout the study area.

Irrigation water is obtained from both surface- and ground-water sources. On the upland slopes of the San Bernardino Mountains, irrigation water is obtained from a network of gravity-flow canals (fig. 3) that divert surface water from the Santa Ana River. The concentration of nitrate-nitrogen is generally well below 2 mg/L in all streams draining the slopes of the San Bernardino Mountains in the study area. Downslope, to the south, all surface flow has been appropriated, and the predominant source of irrigation water is wells.

Artificial ground-water recharge with water from the California Aqueduct has been ongoing in the channel of East Twin Creek since 1972 and soon will be carried out in the channel of the Santa Ana River and to a much lesser degree in the channels of City Creek and Plunge Creek. The recharge operations are expected not only to solve the basin overdraft problem but also to improve water quality.

Most of the urban areas are sewered; however, in the past domestic-sewage disposal was by septic tank. Patton State Hospital maintained a sewage-treatment facility and disposed of the primary-treated sewage effluent in percolation basins south of the main hospital complex (fig. 2). Operations in this facility ceased in 1960. Sewage is presently exported from the study area to the city of San Bernardino for treatment. No known active sewage-disposal sites, industrial-waste discharges, or landfills operate within the study area.

GEOHYDROLOGY

San Bernardino Valley is occupied by converging alluvial fans. The largest fans originate where the Santa Ana River emerges from the San Bernardino Mountains. The alluvial valley-fill deposits were defined by Dutcher and Garrett (1963) as being both younger and older alluvium (fig. 4). The alluvium, which overlies a nearly impermeable basement complex, is composed of gravel, sand, silt, clay, and boulders. It is poorly sorted at the top of the fans, and grades to finer, well-sorted deposits downslope. In general the alluvium is moderately permeable and, where saturated, yields water freely to properly constructed wells (Schaefer and Warner, 1975, p. 6).

The predominant ground-water gradient is westerly in the eastern part of the study area and southerly near the western margin, as shown in figure 5. The depth to water generally is 200 ft near the east end of the study area and near the northwest corner. Near the southwest corner it is only about 100 ft, and in the central-western part it is 100-200 ft. Water-level discontinuities due to faults were not noted; however, faults K and L probably have significance with respect to water quality (Dutcher and Garrett, 1963, p. 42).

The aquifers are considered to be unconfined in most of the study area. South and west of the study area the Bunker Hill basin contains aquifers confined by clay layers. The boundary of the confined aquifers extends into the southwestern part of the study area (fig. 4).

Sources of ground-water recharge within the study area are:

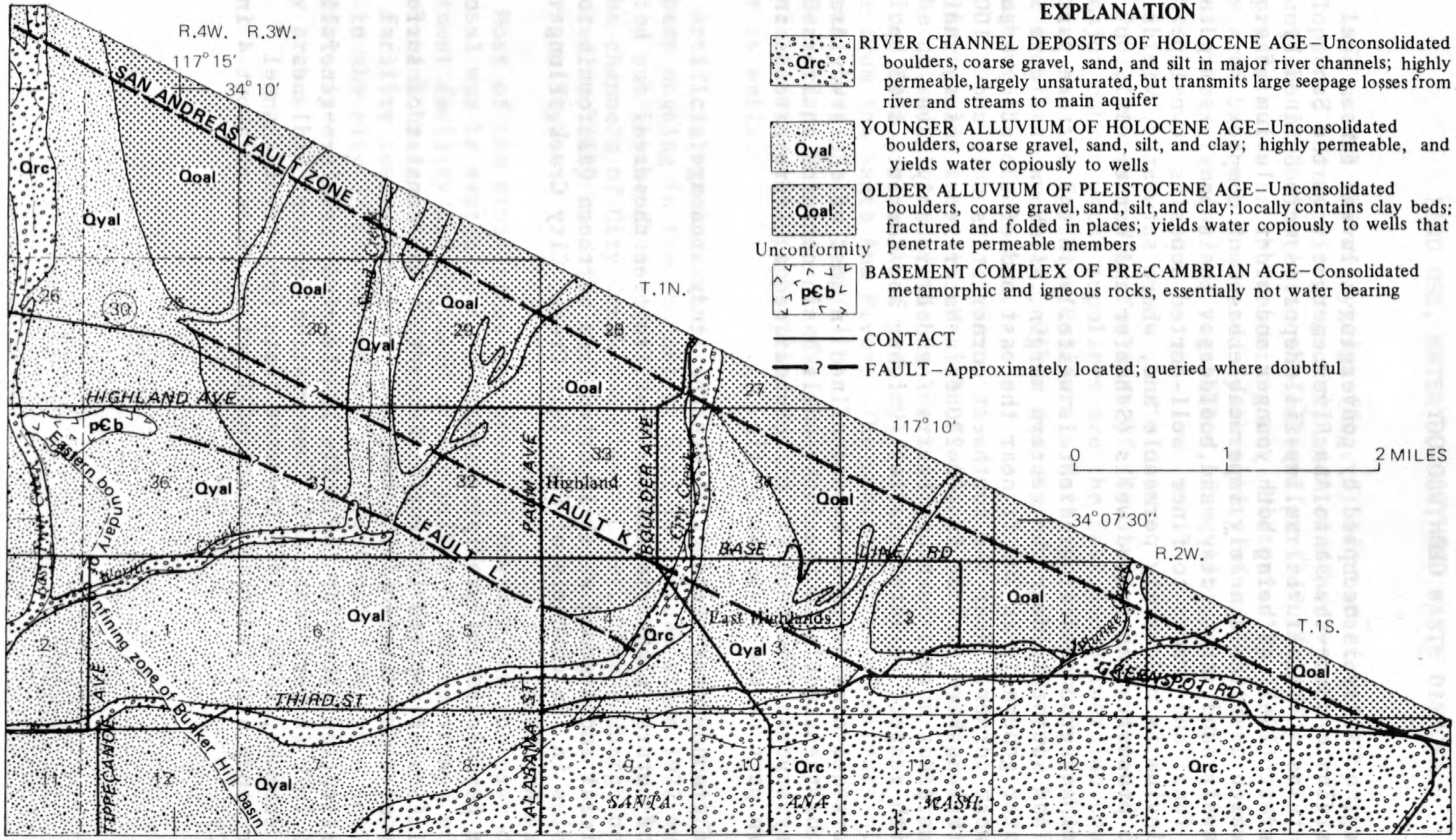
1. Loss of natural flow from streams that traverse the area.

2. Artificial recharge of water imported from northern California to percolation basins in the channels of East Twin Creek, City Creek, Plunge Creek, and Santa Ana Wash.

3. Direct percolation of precipitation.

4. Percolation of applied irrigation water that may consist of surface or ground water or combinations of the two.

Water-infiltration rates for the soils in the study area are generally between 2 and 6 in/h (Robert Best, Soil Conservation Service, Redlands District, oral commun., 1976). Infiltrometer tests for stream-channel deposits in the study area indicate water-infiltration rates of about 4 in/h (Moreland, 1972).



Geology modified from L. C. Dutcher and A. A. Garrett, 1963

FIGURE 4.--Generalized geology.

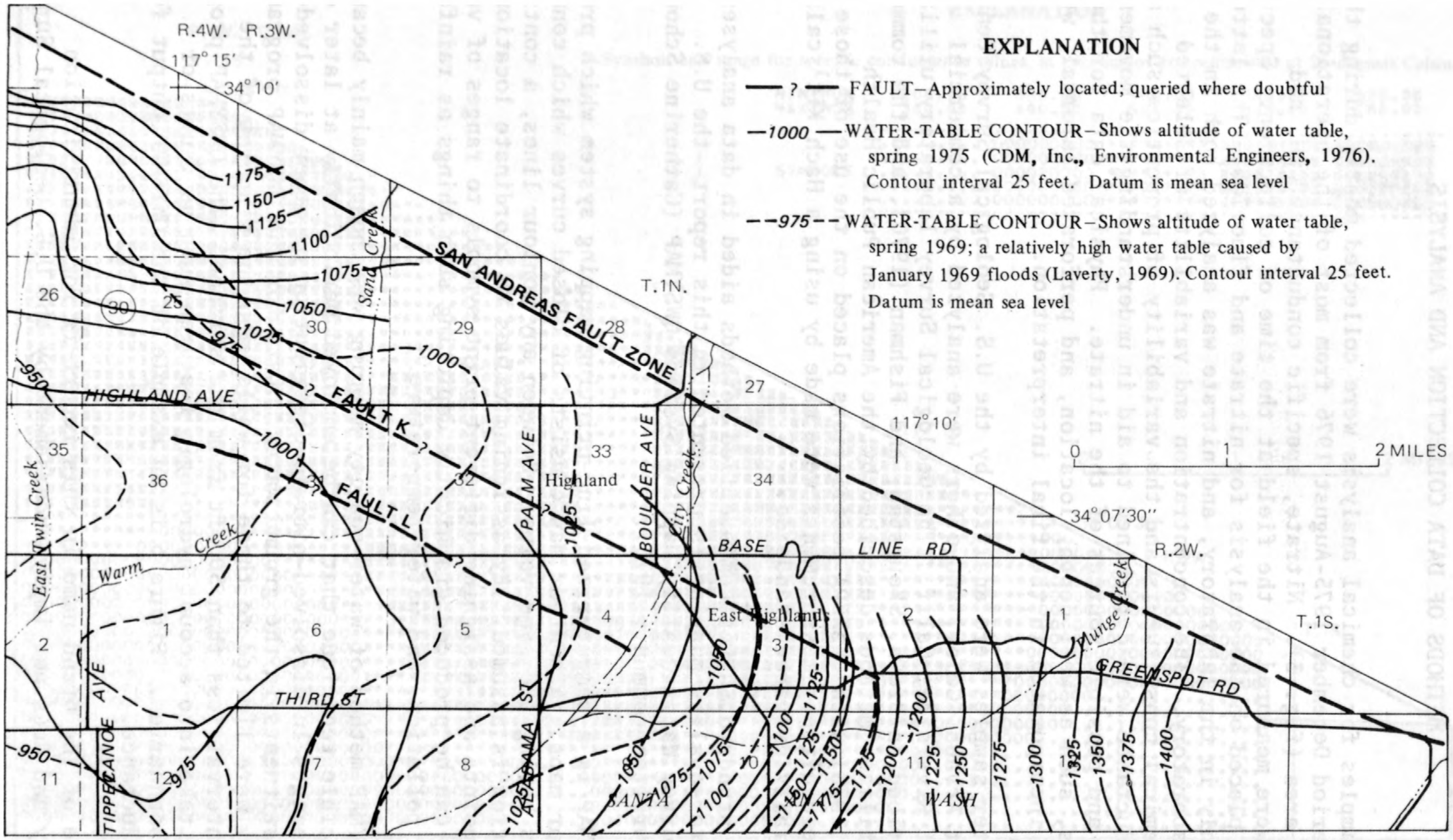


FIGURE 5.--Water-table contours.

METHODS OF DATA COLLECTION AND ANALYSIS

Water samples for chemical analysis were collected mostly during the nine-month period December 1975-August 1976 from most of the operational wells in the study area (fig. 3). Nitrate, specific conductance, pH, and temperature were measured in the field at the time of collection. Special emphasis was placed on the analysis for nitrate and fluoride. The latter was determined only in the laboratory, and nitrate was analyzed both in the field and in the laboratory. The concentration and variability of selected dissolved chemical constituents and the variability of properties such as specific conductance were determined to aid in understanding the movement of ground water and possible sources of the nitrate. Physical data for the sampled wells, such as well depth, location, and perforated interval, were compiled and incorporated in the final interpretation.

Some water samples were analyzed by the U.S. Geological Survey Central Laboratory at Arvada, Colo., and others were analyzed by a commercial laboratory at Riverside, Calif. The Geological Survey laboratory utilizes methods described in Brown, Skougstad, and Fishman (1970), and the commercial laboratory utilizes methods described by the American Public Health Association (1975) with the EPA restrictions placed on the use of those methods. Field nitrate measurements were made by using a Hach Kit[1] calibrated with commercially prepared standards.

Several standard Survey computerized methods aided in data analyses. One method of water-quality mapping is presented in this report--the U.S. Geological Survey Water Quality Mapping Systems QWSYMAP (Catherine Schourek, CACI, Inc., written commun., 1975).

> "QWSYMAP is a computerized line-printing mapping system which produces contour maps. A contour map consists of closed curves which connect points having the same value. Between any contour lines, a continuous variation is assumed. By assigning values to coordinate locations of data points and assigning different print symbols to ranges of values, a map can be produced graphically depicting such things as rainfall, water pollution, and water temperature."

The QWSYMAP method of water-quality mapping was chosen mainly because it is a reproducible technique that can be employed periodically at later dates to monitor changes in dissolved-nitrate distribution or other dissolved-chemical constituents in the ground water. Data for the QWSYMAP program used in this study were limited to those for wells with the midpoint of the perforated interval less than 500 ft from the surface. The QWSYMAP program used did not take into account hydrologic features such as faults or impermeable boundaries. Figure 6 is an example of the QWYSMAP output for specific conductance.

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[1]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

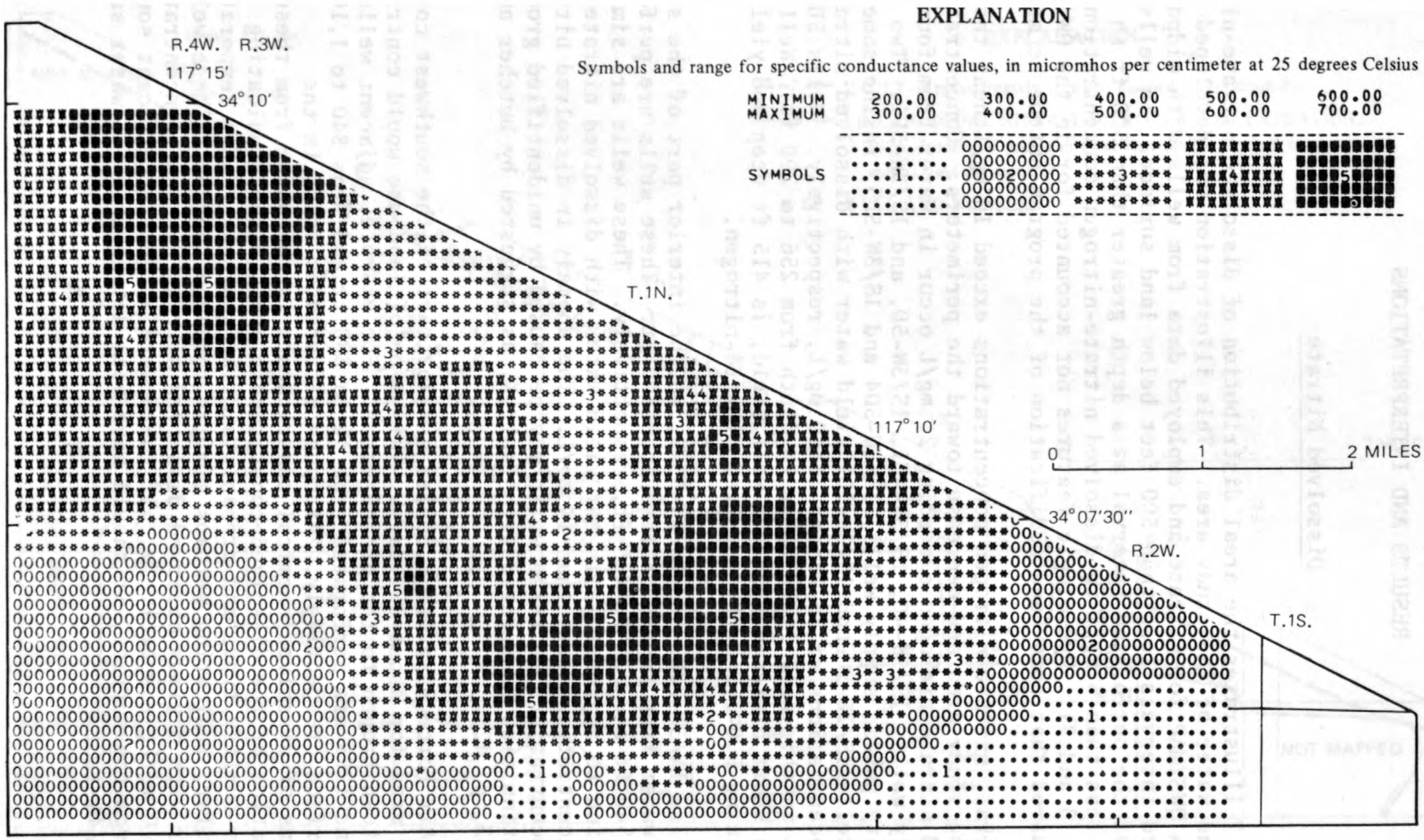

FIGURE 6.--Distribution of specific-conductance values (QWSYMAP output).

RESULTS AND INTERPRETATIONS

Dissolved Nitrate

Figure 7 illustrates the areal distribution of dissolved nitrate-nitrogen in the ground water of the study area. This illustration was developed with the aid of a QWSYMAP for nitrate and employed data from wells with midpoints of perforated intervals less than 500 feet below land surface. In wells with a midpoint of the perforated interval at a depth greater than 500 ft an abrupt decrease to less than 5 mg/L in dissolved nitrate-nitrogen concentrations is noted (figs. 8 and 9). Hydrologic features not accounted for in the QWYSMAP program required that some hand modification of the program output be made.

In general, nitrate-nitrogen concentrations exceed 10 mg/L near the center of the study area and decrease toward the perimeters. Concentrations of dissolved nitrate-nitrogen exceeding 20 mg/L occur in water from four public-supply wells, 1S/3W-4G, 1S/3W-4G1, 1S/3W-5D, and 1S/3W-5D1. Two other large-capacity public supply wells, 1S/3W-5D4 and 1S/3W-5D5, in the same well field with wells 1S/3W-5D and 1S/3W-5D1 yield water with dissolved nitrate-nitrogen concentrations of 16-22 and 16-19 mg/L, respectively. Wells 5D, 5D1, 5D4, and 5D5 in this well field range in depth from 256 to 290 ft. Well 1S/3W-6H4, a short distance from the well field, is 415 ft deep and yields water containing 5.0-7.2 mg/L dissolved nitrate-nitrogen.

Two wells, 1N/3W-32E3 and 1N/3W-33M2, in the interior part of the study area, yield water from depths of less than 500 ft. These wells are perforated from 250 to 540 ft and 135 to 498 ft, respectively. These wells are similar in construction to adjacent wells but yield water with dissolved nitrate-nitrogen concentrations less than 10 mg/L. The anomaly in dissolved nitrate-nitrogen concentrations in these wells may be caused by unidentified ground-water discontinuities associated with fault K, as suggested by Dutcher and Garrett (1963, p. 42).

Norton Air Force Base has occupied a major part of the southwest corner of the study area for about 30 years. This type of land use would contribute little nitrate-nitrogen to the ground water. For example, adjacent wells 1S/4W-12C1 and 12F3 are perforated from 46 to 280 ft and from 840 to 1,100 ft from land surface, respectively. Although differences exist in the concentrations of dissolved chemical constituents in the water from these two wells, the ratios of the dissolved-constituents are similar, indicating similar water-quality types and probably similar sources. Water temperatures are also similar, indicating perhaps similar recharge sources. These wells produce water with maximum observed dissolved nitrate-nitrogen concentrations of 3.8 and 1.0 mg/L, respectively. If there were a local significant source of nitrate from the surface, it should have been detected in the water sample from well 1S/4W-12C1.

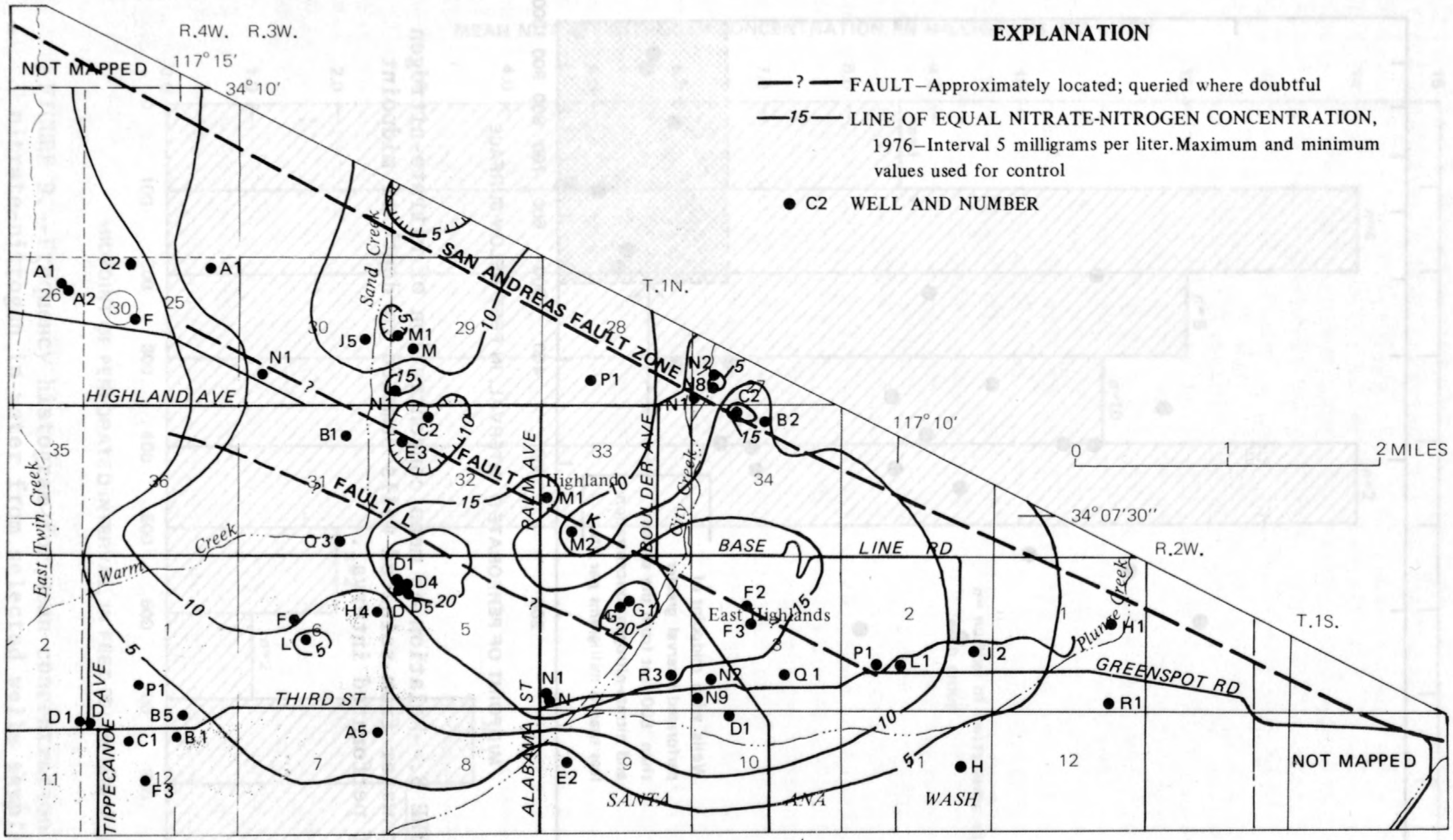

FIGURE 7.--Distribution of dissolved nitrate-nitrogen in ground water, based on QWSYMAP contours of data from wells with midpoint of perforated interval less than 500 feet below land surface.

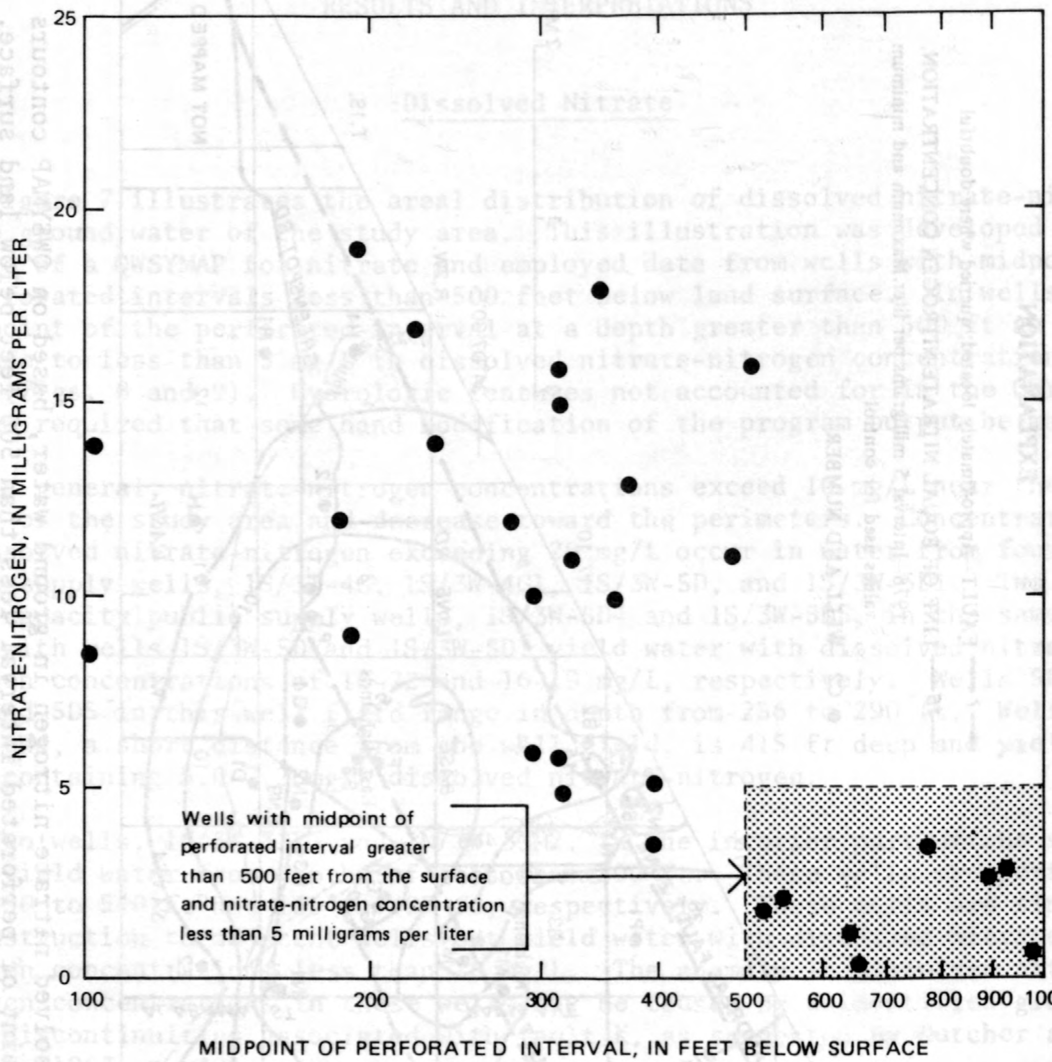

FIGURE 8.--Relation of mean concentration of nitrate-nitrogen in water from selected wells sampled to depth of midpoint of perforated interval.

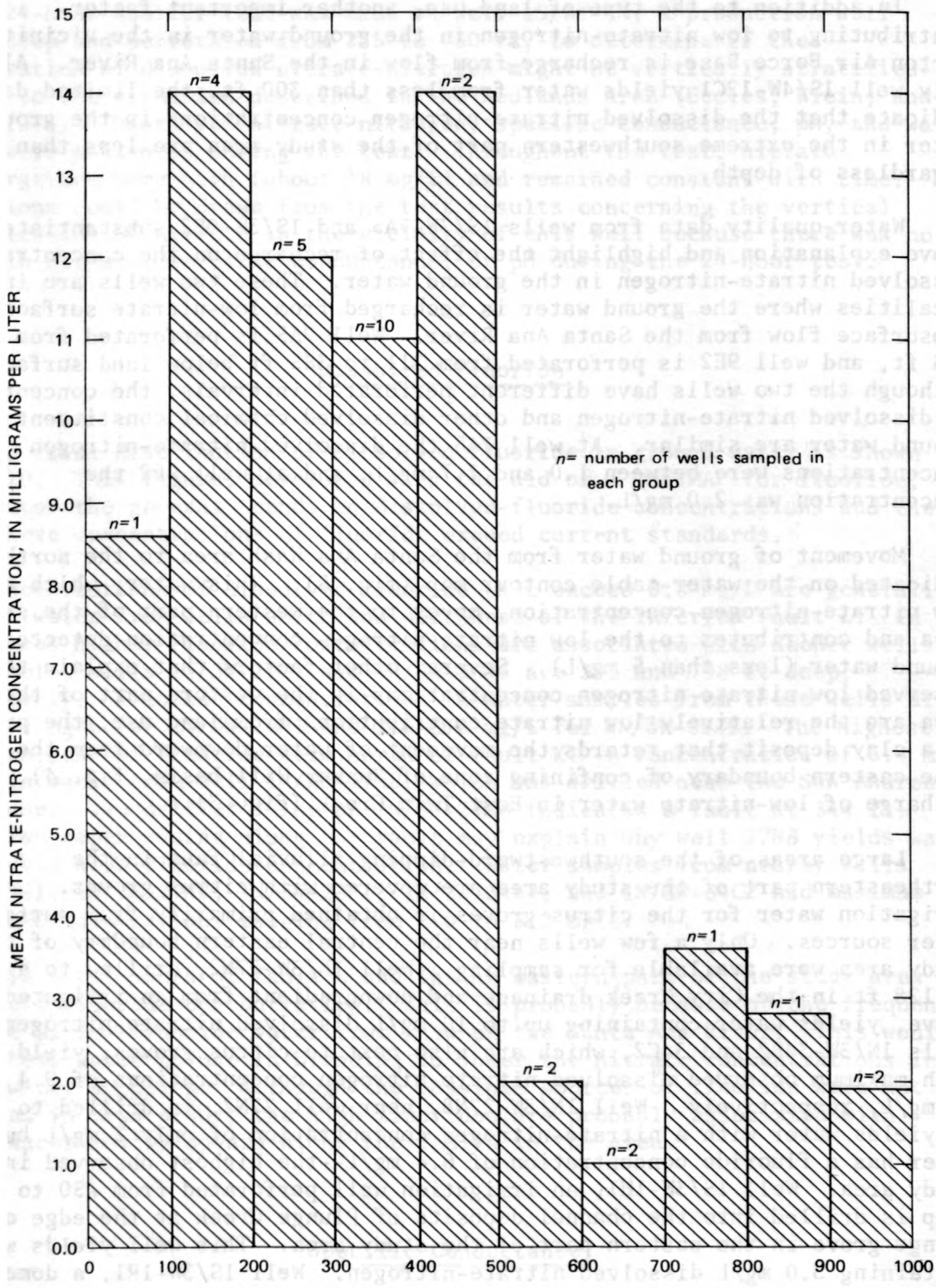

FIGURE 9.--Frequency histogram for mean concentration of nitrate-nitrogen in water from selected wells sampled versus midpoint of perforated interval.

In addition to the type of land use, another important factor contributing to low nitrate-nitrogen in the ground water in the vicinity of Norton Air Force Base is recharge from flow in the Santa Ana River. Although only well 1S/4W-12C1 yields water from less than 300 ft, the limited data indicate that the dissolved nitrate-nitrogen concentrations in the ground water in the extreme southwestern part of the study area are less than 5 mg/L, regardless of depth.

Water-quality data from wells 1S/3W-7A5 and 1S/3W-9E2 substantiate the above explanation and highlight the effect of recharge on the concentration of dissolved nitrate-nitrogen in the ground water. These two wells are in localities where the ground water is recharged from low-nitrate surface and subsurface flow from the Santa Ana River. Well 7A5 is perforated from 544 to 733 ft, and well 9E2 is perforated from 211 to 385 ft below land surface. Although the two wells have different perforated intervals, the concentrations of dissolved nitrate-nitrogen and other dissolved chemical constituents in the ground water are similar. At well 7A5 the dissolved nitrate-nitrogen concentrations were between 1.0 and 1.7 mg/L, and at well 9E2 the concentration was 2.0 mg/L.

Movement of ground water from the Santa Ana Wash area to the northwest is indicated on the water-table contour map (fig. 5). This water, which has a low nitrate-nitrogen concentration, moves to the western part of the study area and contributes to the low nitrate-nitrogen concentration detected in the ground water (less than 5 mg/L). Several other factors that explain the observed low nitrate-nitrogen concentrations in the western part of the study area are the relatively low nitrate contributions from land use, the presence of a clay deposit that retards the movement of water downward from the surface (the eastern boundary of confining zone of Bunker Hill basin, fig. 4), and the recharge of low-nitrate water in East Twin Creek (fig. 3).

Large areas of the southwestward-dipping alluvial fans in the northeastern part of the study area are covered with citrus groves. Irrigation water for the citrus groves is obtained primarily from surface-water sources. Only a few wells near the central eastern boundary of the study area were available for sampling. Well 1N/3W-27N2, drilled to a depth of 128 ft in the City Creek drainage and downgradient from an irrigated citrus grove, yields water containing up to 10 mg/L dissolved nitrate-nitrogen. Wells 1N/3W-34B2 and 34C2, which are also next to citrus groves, yield water with maximum observed dissolved nitrate-nitrogen concentrations of 9.4 and 16 mg/L, respectively. Well 1N/3W-27N8, near well 27N2, is drilled to 340 ft. It yields water with a nitrate-nitrogen concentration of only 2 mg/L but the water has a fluoride concentration of 6.4 mg/L--the highest observed in the study area. Well 1S/3W-1H1, an irrigation well perforated from 250 to 414 ft deep is drilled into the channel deposits of Plunge Creek at the edge of an orange grove in the eastern part of the study area. This well yields water containing 3.0 mg/L dissolved nitrate-nitrogen. Well 1S/3W-1R1, a domestic well of unknown depth drilled into the sand and gravel of the Santa Ana Wash in the southeastern part of the study area, yields water containing a dissolved nitrate-nitrogen concentration between 1.3 and 2.0 mg/L.

A 24-hour aquifer test was made on well 1S/3W-4N, a production well 750 ft deep and perforated from 245 to 750 ft, to determine if the concentration of dissolved nitrate-nitrogen might be vertically stratified--similar to the situation described in the Redlands area (Eccles, Klein, and Hardt, 1976). Dissolved nitrate-nitrogen, specific conductance, pH, and water levels were monitored during the test. Throughout the test, nitrate concentrations were high (about 18 mg/L) and remained constant with time. No conclusions could be drawn from the test results concerning the vertical stratification of nitrate in the vicinity of this well because there was no change in nitrate, specific conductance, or pH during the 24-hour test.

Dissolved Fluoride

The areal distribution of dissolved fluoride in ground water is shown in figure 10. This figure, developed with the aid of a QWSYMAP for fluoride, illustrates the general trends in dissolved-fluoride concentrations and the areas where concentrations of fluoride exceed current standards.

Concentrations of dissolved fluoride that exceed 0.8 mg/L are generally found in water from wells north and northwest of the inferred fault L. In some places higher fluoride concentrations are associated with deeper wells. For example, wells 1N/3W-29M1 and 1N/3W-30J5 are 396 and 798 ft deep, respectively. Fluoride concentrations in water samples from these wells are about 1.4 mg/L for 1N/3W-29M1 and 2.6-3.0 mg/L for 1N/3W-30J5. The highest concentrations of fluoride were north of fault K. A concentration of 6.4 mg/L occurs in water from well 1N/3W-27N8, which was drilled near the San Andreas fault zone. The driller's log on 1N/3W-27N8 indicates a fault at 344 ft. Water from depth rising along the fault may explain why well 27N8 yields water with such a high fluoride concentration. Water samples from nearby wells 1N/3W-27N1, 1N/3W-27N2, 1N/3W-28P1, 1N/3W-34B2, and 1N/3W-34C2 had maximum fluoride concentrations ranging from 1.0 to 3.2 mg/L.

Well water south of fault L and in the eastern part of the study area has the lowest fluoride concentration. This is probably because of the frequent recharge of low-fluoride water from flow of the Santa Ana River. This would be the best water to use in blending to lower the nitrate concentrations in public water supplies. Although the possible sources of fluoride were not addressed in this study, the high fluorides are probably associated with deeper water moving upward along the faults in the area.

Specific Conductance

The water-table contour map (fig. 5) and specific-conductance data were used to help formulate a conceptual model of the movement of ground water in the study area.

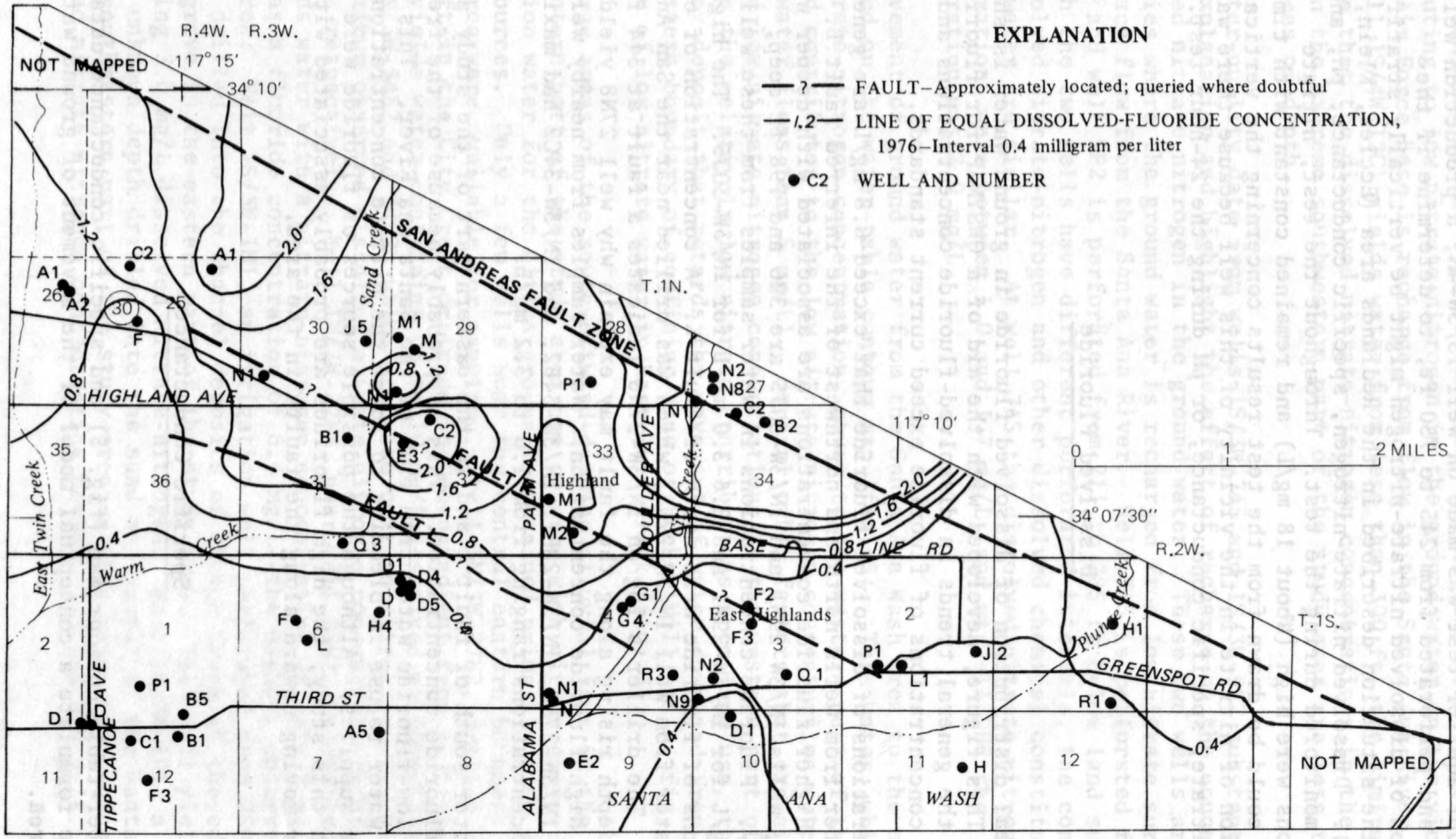

FIGURE 10.--Distribution of dissolved fluoride in ground water, based on QWSYMAP contours.

Figure 11 shows the areal distribution of specific-conductance values for ground water in the study area. Figure 11 was developed from the QWSYMAP output and interpretation of hydrologic data.

Specific conductance of water is a measure of its ability to conduct an electrical current and is a reflection of the concentration of solids dissolved in the water, as indicated for water samples collected during this study (fig. 12).

The distribution of specific-conductance values can be related to land use, hydrologic features, and general ground-water movement. Comparison of figures 5 and 11 shows that as the water-table contours along the trace of the Santa Ana Wash swing slightly to the northwest (contour altitude 1,325 ft through 1,075 ft), specific conductance increases from less than 300 micromhos to more than 600 micromhos. This rapid increase can be related to decreasing permeability of the aquifer and fertilization of citrus and other agricultural land. As water greater than 600 micromhos in turn moves to the west and southwest, it mixes with dilute water in the extreme southwest corner of the study area and a consequent specific-conductance reduction is noted.

Water of lowest specific conductance is pumped from several wells that are completed in the sand and gravel channel deposits of the Santa Ana Wash. Ground-water velocities in the river-channel deposits are higher than those in the other types of deposits; therefore, the residence periods for the dissolution of aquifer materials are shorter. Thus the dissolved chemical constituents (as indicated by specific conductance) for ground water in the river-channel deposits are lower than in the rest of the study area. The major source of recharge to the channel deposits is stormflow in the Santa Ana Wash, which has a low specific conductance. Increases in specific conductance of water near the channel deposits are slight, affected only by the previously discussed mixing with water of higher specific conductance moving downgradient from the north.

Water with the highest specific conductance is generally found in the central and northwestern parts of the study area. In the central part, land use, both present and historical, has been predominantly mixed agriculture and citrus groves. In the northwestern part, present land use is predominantly urban, but historically some of the land was used for citrus crops and mixed agriculture. Fertilizer residues, animal wastes, and septic tank effluents are likely sources of material causing high specific conductance in the ground water in the northwestern part the study area.

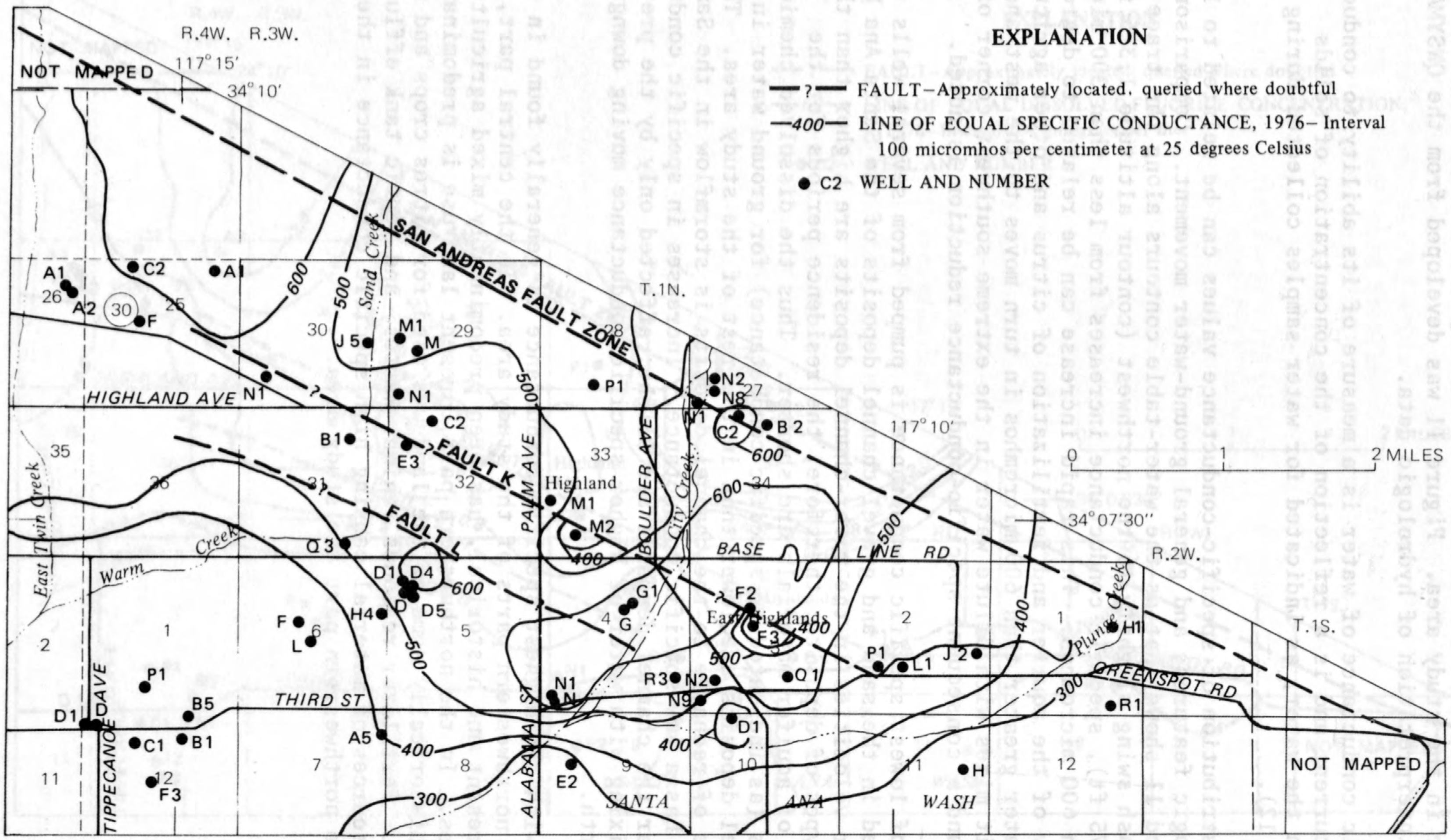

FIGURE 11.--Distribution of specific conductance of ground water, based on QWSYMAP contours.

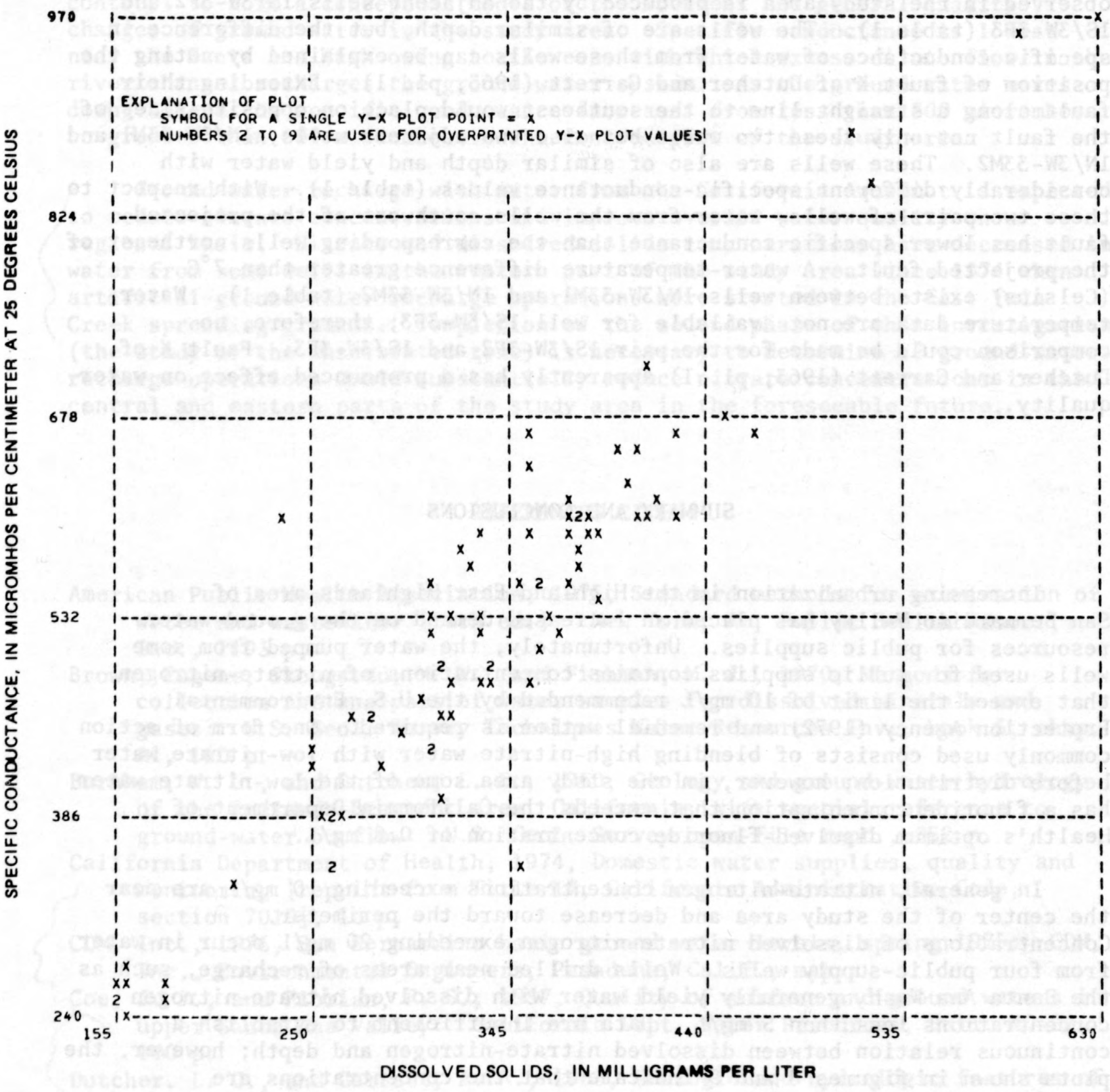

FIGURE 12.--Relation of specific conductance to dissolved solids.

Water with specific-conductance values among the highest and the lowest observed in the study area is produced by the adjacent wells 1S/3W-3F2 and 1S/3W-3F3 (table 1). The wells are of similar depth, but the difference in specific conductance of water from these wells can be explained by noting the position of fault K of Dutcher and Garrett (1963, pl. 1). Extending their fault along a straight line to the southeast would place on opposite sides of the fault not only these two wells but also two adjacent wells, 1N/3W-33M1 and 1N/3W-33M2. These wells are also of similar depth and yield water with considerably different specific-conductance values (table 1). With respect to these two pairs of wells, water from the wells southwest of the projected fault has lower specific conductance than the corresponding wells northeast of the projected fault. A water-temperature difference greater than 7°C (Celsius) exists between wells 1N/3W-33M1 and 1N/3W-33M2 (table 1). Water-temperature data are not available for well 1S/3W-3F3; therefore, no comparison could be made for the pair 1S/3W-3F2 and 1S/3W-3F3. Fault K of Dutcher and Garrett (1963, pl. 1) apparently has a pronounced effect on water quality.

SUMMARY AND CONCLUSIONS

Increasing urbanization in the Highland-East Highlands area of San Bernardino Valley has placed an increased demand on the ground-water resources for public supplies. Unfortunately, the water pumped from some wells used for public supplies contains concentrations of nitrate-nitrogen that exceed the limit of 10 mg/L recommended by the U.S. Environmental Protection Agency (1972) and remedial action is required. One form of action commonly used consists of blending high-nitrate water with low-nitrate water before distribution; however, in the study area some of the low-nitrate water has a fluoride concentration that exceeds the California Department of Health's optimum disolved-fluoride concentration of 0.8 mg/L.

In general, nitrate-nitrogen concentrations exceeding 10 mg/L are near the center of the study area and decrease toward the perimeter. Concentrations of dissolved nitrate-nitrogen exceeding 20 mg/L occur in water from four public-supply wells. Wells drilled near areas of recharge, such as the Santa Ana Wash, generally yield water with dissolved nitrate-nitrogen concentrations less than 5 mg/L. Data are insufficient to establish a continuous relation between dissolved nitrate-nitrogen and depth; however, the plots shown in figures 8 and 9 indicate that the concentrations are substantially less at depths greater than 500 ft.

Concentrations of dissolved fluoride in water from wells show an increase with depth in some places. Shallow wells drilled near faults may intercept water moving up from depth and also yield water with excessive fluoride concentrations. Wells north of Base Line Road drilled to depths greater than 340 ft will generally yield water with concentrations of dissolved fluoride exceeding 1 mg/L. The maximum observed fluoride concentration was 6.4 mg/L. Water from wells to the south near the Santa Ana Wash shows the effects of dilution due to recharge with water having dissolved-fluoride concentrations generally less than 0.4 mg/L.

Specific-conductance data were used in conjuction with the water-table contours to form a conceptual model of the movement and general quality changes of ground water in the study area. Specific conductance is lowest near the Santa Ana Wash owing to the ease with which excess dilute flow in the river channel recharges the ground-water system. As the ground water moves downgradient the specific conductance increases from less than 300 micromhos to greater than 600 micromhos in the central part of the study area.

Ground-water recharge with water from the California Aqueduct is expected to reduce nitrate concentrations and improve overall water quality on a regional basis. Nitrate and dissolved-solids concentrations have decreased in water from some wells in the western part of the study area since 1974 when artificial ground-water recharge operations were started in the East Twin Creek spreading grounds. Completion of the second phase of this investigation (the study of the unsaturated zone) is necessary to determine if ground-water-recharge operations would substantially reduce nitrate concentrations in the central and eastern parts of the study area in the foreseeable future.

REFERENCES CITED

American Public Health Association, 1975, Standard methods for examination of water and wastewater [14th ed.]: New York, Am. Public Health Assoc., Inc., 1193 p.

Brown, Eugene, Skougstad, M. W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geol. Survey Techniques Water-Resources Inv., book 5, chap. A1, 160 p.

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. Geol. Survey open-file rept., 352 p.

California Department of Health, 1974, Domestic water supplies, quality and monitoring [reprint from Title 17, California Administrative Code, section 7019], 16 p.

CDM, Inc., 1976, San Bernardino basin ground water levels, spring 1975: CDM, Inc., Environmental Engineers, Pasadena, Calif., map.

Coe, J. J., and Florian, F. S., 1957, Quality of surface and ground waters in upper Santa Ana Valley: California Dept. Water Resources, Bull. 40-57, 140 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. Geol. Survey Water-Supply Paper 1419, 114 p.

Eccles, L. A., and Bradford, W. L., 1977, Distribution of nitrate in ground water, Redlands, California: Menlo Park, Calif., U.S. Geol. Survey Water-Resources Inv. 76-117, 38 p.

Eccles, L. A., Klein, J. M., and Hardt, W. F., 1976, Abatement of nitrate pollution in a public-supply well by analysis of hydrologic characteristics: Ground Water, v. 14, no. 6, p. 449-454.

Feth, J. H., 1966, Nitrogen compounds in natural water--A review: Water Resources Research, v. 2, no. 1, 18 p.

Garrett, A. A., and Dutcher, L. C., 1954, Appendix, tables of basic data to accompany report on geologic and hydrologic features of the San Bernardino area, California, with special reference to underflow across the San Jacinto fault: U.S. Geol. Survey open-file rept., 170 p.

Kearney Foundation of the University of California, 1973, Nitrates in the upper Santa Ana River basin in relation to ground-water pollution, edited by R. S. Ayers and R. L. Branson: California Exp. Sta. Bull. 861, 59 p.

Laverty, F. B., 1969, San Bernardino basin ground water levels, spring 1969, F. B. Laverty, Consulting Engineer [Pasadena, Calif.], map.

Luckhardt, R. L., 1974, Commercial fertilizer as a source of nitrogen [abs.]: Symposium on nitrogen especially as related to agricultural production and water quality; California Dept. Water Resources, Univ. California, Kearney Foundation, Sacramento, Calif., September 24-25, 1974, p. 6.

McKee, J. E., and Wolf, H. W., eds., 1963, Water quality criteria: California State Water Resources Control Board pub. 3-A, 548 p. (reprint Jan. 1973).

Moreland, J. A., 1972, Artificial recharge in the upper Santa Ana Valley, southern California: U.S. Geol. Survey open-file rept., 51 p.

Schaefer, D. H., and Warner, J. W., 1975, Artificial recharge in the upper Santa Ana River area, San Bernardino County, California: Menlo Park, Calif., U.S. Geol. Survey Water-Resources Inv. 15-75, 27 p.

Universities Council on Water Resources, 1974, Cancer from drinking water, in Update: Lincoln, Nebr., Nebr. Univ., Water Resources Research Inst., issue no. 37, p 18.

U.S. Environmental Protection Agency, Environmental Studies Board, 1972, Water quality criteria, 1972--A report of the Committee on Water Quality Criteria: Washington, Government Printing Office, 594 p.

EXPLANATION FOR TABLE 1

The computer identification of well numbers contains place-holding zeroes and therefore differs in form from the well number as shown in the text. A well number given in the text as 1N/3W-27N1 is shown in the table as 001N003W27N01S. The "S" at the end of the computer listed well number means that the well is referenced to the San Bernardino base line and meridian. Because all wells in the report are referenced to this base line and meridian, the final "S" was omitted from the well number given in the text.

Results of constituents in milligrams per liter (mg/L), except dissolved iron and dissolved boron in micrograms per liter (ug/L), specific conductance in micromhos at 25°C, temperature in degrees Celsius, and pH in units.

E denotes a value that was estimated from comparison with a previous analysis.

Duplicate samples for nitrate analysis were collected in some instances. When no other constituent was to be analyzed, the sample was analyzed in the field at the time of collection.

Code for agency collecting sample, and code for agency analyzing sample: 1028, U.S. Geological Survey; 9801, Babcock Laboratories of Riverside, Calif.

The analysis of each sample is displayed as one line on three consecutive pages.

TABLE 1.--*Chemical analyses of water*

[Table follows on pages 30-42]

WELL NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DEPTH TO TOP OF SAMPLE INTER-VAL (FT)	DEPTH TO BOT-TOM OF SAMPLE INTER-VAL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)
001N003W27N01S	76-08-25	--	--	--	28	80	48	E5.0	45	3.0
	76-08-25	--	--	--	--	--	--	--	--	--
001N003W27N02S	75-09-15	128	--	--	--	--	--	--	--	--
	76-02-09	128	--	--	--	--	--	--	--	--
	76-03-08	128	56	128	23	<10	47	E5.0	35	E2.0
	76-05-20	128	56	128	12	200	55	E5.0	24	E2.0
	76-08-11	128	56	128	31	10	54	14	47	2.1
	76-08-11	128	--	--	--	--	--	--	--	--
	76-08-15	128	56	128	30	30	57	E6.0	46	2.0
	76-08-15	128	--	--	--	--	--	--	--	--
001N003W27N08S	75-09-15	340	--	--	--	--	--	--	--	--
	76-03-08	340	304	340	22	40	9.0	E1.0	100	E6.0
001N003W28P01S	75-12-18	552	396	552	E25	--	51	6.0	32	3.0
	76-08-24	552	396	552	25	--	52	E6.0	34	3.0
	76-08-24	552	--	--	--	--	--	--	--	--
001N003W29M00S	76-04-28	--	--	--	E10	600	57	E6.0	50	E3.0
	76-05-18	--	360	425	--	--	--	--	--	--
	76-05-18	--	--	--	10	100	56	E6.0	45	E3.0
	76-05-18	--	--	--	--	--	--	--	--	--
001N003W29M01S	76-05-18	396	238	396	10	40	32	E3.0	34	E3.0
	76-05-18	396	--	--	--	--	--	--	--	--
001N003W29N01S	76-05-18	382	235	382	10	10	58	E6.0	54	E3.0
	76-05-18	382	--	--	--	--	--	--	--	--
001N003W30J05S	75-12-18	798	485	798	E25	700	23	2.0	100	2.0
	76-08-24	798	485	798	23	20	26	E2.0	94	2.0
	76-08-24	798	--	--	--	--	--	--	--	--
001N003W30N00S	75-12-18	--	--	--	E28	800	40	E4.0	45	E2.0
	76-08-24	--	--	--	28	--	46	E5.0	48	2.0
	76-08-24	--	--	--	--	--	--	--	--	--
001N003W31B01S	76-05-18	381	178	381	12	440	64	E6.0	32	E3.0
	76-05-24	381	--	--	E12	--	59	E6.0	31	E3.0
001N003W31Q00S	76-08-18	--	--	--	20	100	38	E4.0	82	3.0
	76-08-18	--	--	--	--	--	--	--	--	--
001N003W32C02S	76-05-18	--	--	--	10	80	18	E1.0	120	E3.0
001N003W32E03S	76-08-12	540	250	540	20	0	48	8.4	59	2.2
	76-08-12	540	250	540	20	--	60	E8.0	58	3.0
	76-08-12	540	--	--	--	--	--	--	--	--
001N003W33M01S	75-09-15	448	--	--	--	--	--	--	--	--
	76-02-04	448	--	--	--	--	--	--	--	--
	76-03-08	448	182	448	30	30	50	E5.0	58	E3.0

WELL NUMBER	DATE OF SAMPLE	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRATE (N) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)
001N003W27N01S	76-08-25	170	0	66	20	2.2	2.0	310	--	500
	76-08-25	--	--	--	--	--	5.8	--	--	500
001N003W27N02S	75-09-15	--	--	--	--	--	9.0	--	--	--
	76-02-09	--	--	--	--	--	9.0	--	--	--
	76-03-08	170	0	50	18	1.0	6.0	270	--	460
	76-05-20	160	0	42	14	.2	9.0	305	--	440
	76-08-11	190	0	68	24	1.3	10	--	378	550
	76-08-11	--	--	--	--	--	8.8	--	--	--
	76-08-15	160	0	70	23	1.2	E8.5	--	--	580
	76-08-15	--	--	--	--	--	8.5	--	--	565
001N003W27N08S	75-09-15	--	--	--	--	2.9	E2.2	--	--	--
	76-03-08	98	0	100	20	6.4	2.0	315	--	530
001N003W28P01S	75-12-18	160	0	48	10	1.2	10	295	--	450
	76-08-24	160	0	45	14	1.2	14	280	--	460
	76-08-24	--	--	--	--	--	8.5	--	--	470
001N003W29M00S	76-04-28	160	0	74	23	.6	17	390	--	590
	76-05-18	--	--	--	--	--	--	--	--	--
	76-05-18	170	0	68	23	1.1	20	425	--	600
	76-05-18	--	--	--	--	--	--	--	--	620
001N003W29M01S	76-05-18	160	0	35	14	1.4	5.0	265	--	390
	76-05-18	--	--	--	--	--	--	--	--	420
001N003W29N01S	76-05-18	180	0	50	21	.2	16	380	--	570
	76-05-18	--	--	--	--	--	--	--	--	590
001N003W30J05S	75-12-18	130	0	140	27	3.0	.20	380	--	580
	76-08-24	140	0	140	25	2.6	<1.0	355	--	590
	76-08-24	--	--	--	--	--	.60	--	--	610
001N003W30N00S	75-12-18	130	0	57	16	1.4	10	310	--	460
	76-08-24	130	0	57	16	1.5	14	300	--	470
	76-08-24	--	--	--	--	--	11	--	--	490
001N003W31B01S	76-05-18	190	0	35	18	1.4	13	360	--	510
	76-05-24	190	0	34	18	.5	12	310	--	500
001N003W31Q00S	76-08-18	160	0	74	21	.9	18	380	--	600
	76-08-18	--	--	--	--	--	16	--	--	605
001N003W32C02S	76-05-18	110	0	160	39	2.6	4.0	405	--	650
001N003W32E03S	76-08-12	160	0	88	23	1.5	4.9	--	353	560
	76-08-12	160	0	100	25	3.2	5.0	330	--	590
	76-08-12	--	--	--	--	--	5.5	--	--	560
001N003W33M01S	75-09-15	--	--	--	--	--	13	--	--	--
	76-0[illegible]-04	--	--	--	--	--	15	--	--	--
	76-03-08	170	0	64	18	1.0	16	350	--	560

WELL NUMBLR	DATE OF SAMPLE	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED BORON (B) (UG/L)	CODE FOR AGENCY COL-LECTING SAMPLE	CODE FOR AGENCY ANA-LYZING SAMPLE
001N003W27N01S	76-08-25	7.1	20.0	<100	1028	9801
	76-08-25	7.1	20.0	--	1028	1028
001N003W27N02S	75-09-15	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.0	--	--	--	9801
	76-05-20	7.2	17.0	200	1028	9801
	76-08-11	7.0	19.5	--	1028	1028
	76-08-11	--	--	--	1028	1028
	76-08-15	7.3	20.0	200	1028	9801
	76-08-15	7.1	20.0	--	--	9801
001N003W27N08S	75-09-15	--	--	--	--	9801
	76-03-08	7.5	--	--	--	9801
001N003W28P01S	75-12-18	7.7	--	200	--	9801
	76-08-24	7.4	24.5	<100	1028	9801
	76-08-24	7.6	24.5	--	1028	1028
001N003W29M00S	76-04-28	7.4	22.0	--	--	9801
	76-05-18	--	--	--	--	--
	76-05-18	7.6	23.0	100	1028	9801
	76-05-18	7.9	23.0	--	1028	1028
001N003W29M01S	76-05-18	7.4	19.0	400	1028	9801
	76-05-18	7.8	19.0	--	1028	1028
001N003W29N01S	76-05-18	7.4	24.0	100	1028	9801
	76-05-18	7.6	24.0	--	1028	1028
001N003W30J05S	75-12-18	7.8	--	300	--	9801
	76-08-24	7.4	24.0	500	1028	9801
	76-08-24	7.7	24.0	--	1028	1028
001N003W30N00S	75-12-18	7.7	--	400	--	9801
	76-08-24	7.3	23.0	100	1028	9801
	76-08-24	7.6	23.0	--	1028	1028
001N003W31B01S	76-05-18	7.3	--	100	1028	9801
	76-05-24	7.5	22.0	--	--	9801
001N003W31Q00S	76-08-18	7.8	28.0	200	1028	9801
	76-08-18	8.2	28.0	--	1028	1028
001N003W32C02S	76-05-18	7.6	--	300	1028	9801
001N003W32E03S	76-08-12	7.6	36.5	190	1028	1028
	76-08-12	7.7	36.5	<100	1028	9801
	76-08-12	7.6	36.5	--	1028	1028
001N003W33M01S	75-09-15	--	--	--	--	9801
	76-02-04	--	--	--	--	9801
	76-03-08	7.4	>40.0	--	--	9801

WELL NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DEPTH TO TOP OF SAMPLE INTER-VAL (FT)	DEPTH TO BOT-TOM OF SAMPLE INTER-VAL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)
001N003W33M02S	75-09-15	498	--	--	--	--	--	--	--	--
	76-08-15	498	135	498	30	--	32	E3.0	37	3.0
	76-08-15	498	--	--	--	--	--	--	--	--
001N003W34B02S	76-08-11	--	--	--	40	10	47	14	48	2.5
	76-08-11	--	--	--	38	20	55	E13	50	4.0
	76-08-11	--	--	--	--	--	--	--	--	--
	76-08-12	--	--	--	--	--	--	--	--	--
001N003W34C02S	76-05-20	190	33	190	12	10	72	E10	51	E3.0
	76-08-12	190	33	190	31	10	57	13	50	3.6
	76-08-12	190	33	190	30	200	64	E13	50	6.0
001N004W25A01S	75-12-18	546	188	546	E33	200	62	11	62	2.0
	76-08-24	546	188	546	33	100	52	E10	69	1.0
	76-08-24	546	--	--	--	--	--	--	--	--
001N004W25C02S	75-12-18	569	378	569	E33	60	50	9.0	54	3.0
	76-08-24	569	378	569	33	360	48	E9.0	66	3.0
	76-08-24	569	--	--	--	--	--	--	--	--
001N004W25F00S	75-12-18	590	444	590	E30	1600	66	11	16	3.0
	76-08-24	590	444	590	30	60	76	E10	17	3.0
	76-08-24	590	--	--	--	--	--	--	--	--
001N004W26A01S	75-12-18	375	346	375	E30	500	56	5.0	50	3.0
001N004W26A02S	76-08-24	648	428	648	30	20	68	E6.0	31	3.0
	76-08-24	648	--	--	--	--	--	--	--	--
001S003W01H01S	76-05-19	414	250	414	10	40	48	E5.0	24	E2.0
	76-08-19	414	--	--	--	--	--	--	--	--
001S003W01R01S	76-08-10	--	--	--	25	80	28	4.9	12	1.9
	76-08-10	--	--	--	25	110	30	E3.0	13	3.0
001S003W02J02S	76-05-19	230	155	230	12	200	55	E5.0	24	E2.0
001S003W02L01S	76-05-18	--	180	418	10	60	64	E6.0	29	E3.0
	76-08-10	--	180	418	30	10	50	--	23	2.1
	76-08-10	--	180	418	32	100	50	E5.0	24	3.0
001S003W02P01S	76-05-18	--	175	464	10	2400	51	E5.0	24	E2.0
001S003W03F02S	76-08-10	311	130	311	32	10	74	18	40	2.4
	76-08-10	311	130	311	35	--	82	E8.0	28	4.0
001S003W03F03S	76-05-20	--	145	257	10	180	46	E4.0	28	E3.0
001S003W03N02S	76-08-11	225	145	225	29	20	68	10	26	4.0
	76-08-11	225	--	--	30	80	80	E8.0	31	4.0
	76-08-11	225	--	--	--	--	--	--	--	--
001S003W03N09S	76-08-11	--	--	--	31	10	67	12	30	2.8
	76-08-11	--	--	--	E31	180	68	E12	29	E2.8
001S003W03Q01S	76-05-20	292	175	292	10	<100	68	E12	30	E3.0

WELL NUMBER	DATE OF SAMPLE	BICAR- BONATE (HCO3) (MG/L)	CAR- BONATE (CO3) (MG/L)	DIS- SOLVED SULFATE (SO4) (MG/L)	DIS- SOLVED CHLO- RIDE (CL) (MG/L)	DIS- SOLVED FLUO- RIDE (F) (MG/L)	DIS- SOLVED NITRATE (N) (MG/L)	DIS- SOLVED SOLIDS (RESI- DUE AT 180 C) (MG/L)	DIS- SOLVED SOLIDS (SUM OF CONSTI- TUENTS) (MG/L)	SPE- CIFIC CON- DUCT- ANCE (MICRO- MHOS)
001N003W33M02S	75-09-15	--	--	--	--	1.3	5.9	--	--	--
	76-08-15	130	0	34	12	.8	6.0	260	--	390
	76-08-15	--	--	--	--	--	6.7	--	--	370
001N003W34B02S	76-08-11	190	0	55	20	1.3	9.4	--	362	535
	76-08-11	200	0	48	18	3.2	--	320	--	580
	76-08-11	--	--	--	--	--	8.3	--	--	--
	76-08-12	--	--	--	--	--	8.3	--	--	535
001N003W34C02S	76-05-20	190	0	76	27	.1	13	405	--	610
	76-08-12	190	0	63	27	1.7	13	--	397	590
	76-08-12	190	0	66	28	3.2	16	355	--	640
001N004W25A01S	75-12-18	160	0	110	25	1.8	--	465	--	670
	76-08-24	160	0	120	27	2.2	14	450	--	680
	76-08-24	--	--	--	--	--	11	--	--	680
001N004W25C02S	75-12-18	160	0	100	21	1.4	3.4	390	--	550
	76-08-24	170	0	110	23	1.4	3.0	410	--	600
	76-08-24	--	--	--	--	--	4.3	--	--	635
001N004W25F00S	75-12-18	190	0	60	18	.4	1.8	330	--	520
	76-08-24	180	0	65	18	.5	2.0	335	--	490
	76-08-24	--	--	--	--	--	2.3	--	--	495
001N004W26A01S	75-12-18	170	0	96	21	1.0	2.2	370	--	520
001N004W26A02S	76-08-24	190	0	90	23	.6	2.0	385	--	590
	76-08-24	--	--	--	--	--	2.8	--	--	590
001S003W01H01S	76-05-19	170	0	33	23	.5	3.0	260	--	355
	76-08-19	--	--	--	--	--	--	--	--	--
001S003W01R01S	76-08-10	110	0	17	5.3	.4	1.3	--	153	230
	76-08-10	110	0	17	9.0	E.4	2.0	155	--	250
001S003W02J02S	76-05-19	160	0	42	14	.2	9.0	305	--	440
001S003W02L01S	76-05-18	170	0	48	14	.3	12	355	--	480
	76-08-10	160	0	29	13	.3	10	--	280	375
	76-08-10	160	0	31	16	E.3	10	280	--	460
001S003W02P01S	76-05-18	160	0	35	14	.2	10	285	--	425
001S003W03F02S	76-08-10	230	0	71	23	.4	17	--	448	680
	76-08-10	190	0	52	18	E.4	17	325	--	570
001S003W03F03S	76-05-20	170	0	20	14	.4	5.0	255	--	380
001S003W03N02S	76-08-11	190	0	35	17	.3	14	--	344	580
	76-08-11	200	0	46	18	E.3	11	350	--	350
	76-08-11	--	--	--	--	--	E14	--	--	--
001S003W03N09S	76-08-11	210	0	38	19	1.3	10	--	347	530
	76-08-11	190	0	40	18	2.0	E10	305	--	560
001S003W03Q01S	76-05-20	180	0	52	20	.3	14	365	--	530

WELL NUMBER	DATE OF SAMPLE	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED BORON (B) (UG/L)	CODE FOR AGENCY COL-LECTING SAMPLE	CODE FOR AGENCY ANA-LYZING SAMPLE
001N003W33M02S	75-09-15	--	--	--	--	9801
	76-08-15	7.6	33.0	300	--	9801
	76-08-15	7.5	33.0	--	1028	1028
001N003W34B02S	76-08-11	7.4	22.0	90	1028	1028
	76-08-11	7.5	22.0	<100	1028	9801
	76-08-11	--	--	--	--	9801
	76-08-12	7.4	22.0	--	1028	1028
001N003W34C02S	76-05-20	7.3	--	<100	1028	9801
	76-08-12	8.3	--	90	1028	1028
	76-08-12	7.6	--	<100	1028	9801
001N004W25A01S	75-12-18	7.3	--	700	--	9801
	76-08-24	7.1	21.5	500	1028	9801
	76-08-24	7.1	21.5	--	--	--
001N004W25C02S	75-12-18	7.5	--	400	--	9801
	76-08-24	7.4	22.0	500	1028	9801
	76-08-24	7.3	22.0	--	1028	1028
001N004W25F00S	75-12-18	7.9	--	300	--	9801
	76-08-24	7.5	22.0	<100	1028	9801
	76-08-24	7.9	22.0	--	1028	1028
001N004W26A01S	75-12-18	7.6	--	100	--	9801
001N004W26A02S	76-08-24	7.5	21.0	<100	1028	9801
	76-08-24	7.5	21.0	--	1028	1028
001S003W01H01S	76-05-19	7.3	17.0	200	1028	9801
	76-08-19	--	17.0	--	--	--
001S003W01R01S	76-08-10	6.9	21.0	30	1028	1028
	76-08-10	7.4	21.0	0	1028	9801
001S003W02J02S	76-05-19	7.2	17.0	200	1028	9801
001S003W02L01S	76-05-18	7.3	18.0	200	1028	9801
	76-08-10	7.2	19.5	30	1028	1028
	76-08-10	7.6	19.5	<100	1028	9801
001S003W02P01S	76-05-18	7.0	18.0	200	1028	9801
001S003W03F02S	76-08-10	7.3	24.5	30	1028	1028
	76-08-10	7.3	24.5	200	1028	9801
001S003W03F03S	76-05-20	7.7	--	100	1028	9801
001S003W03N02S	76-08-11	7.4	20.0	20	1028	1028
	76-08-11	7.6	20.0	<100	1028	9801
	76-08-11	--	--	--	1028	9801
001S003W03N09S	76-08-11	7.4	21.0	30	1028	1028
	76-08-11	7.6	21.0	--	1028	9801
001S003W03Q01S	76-05-20	7.2	19.0	--	1028	9801

WELL NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DEPTH TO TOP OF SAMPLE INTER- VAL (FT)	DEPTH TO BOT- TOM OF SAMPLE INTER- VAL (FT)	DIS- SOLVED SILICA (SIO2) (MG/L)	DIS- SOLVED IRON (FE) (UG/L)	DIS- SOLVED CAL- CIUM (CA) (MG/L)	DIS- SOLVED MAG- NE- SIUM (MG) (MG/L)	DIS- SOLVED SODIUM (NA) (MG/L)	DIS- SOLVED PO- TAS- SIUM (K) (MG/L)
001S003W03Q01S	76-08-10	292	175	292	32	110	68	12	26	2.6
	76-08-10	292	175	292	35	110	60	E12	42	4.0
	76-08-10	292	--	--	--	--	--	--	--	--
	76-08-10	292	--	--	--	--	--	--	--	--
001S003W04G00S	75-09-15	390	--	--	--	--	--	--	--	--
	75-10-11	390	--	--	--	--	--	--	--	--
	75-10-13	390	--	--	--	--	--	--	--	--
	76-02-09	390	--	--	--	--	--	--	--	--
	76-03-08	390	297	390	22	--	84	E8.0	31	E3.0
001S003W04G01S	75-09-15	--	--	--	--	--	--	--	--	--
	75-10-13	--	--	--	--	--	--	--	--	--
	75-11-10	--	--	--	--	--	--	--	--	--
	76-02-09	--	--	--	--	--	--	--	--	--
	76-03-08	--	--	E600	27	150	88	E8.0	34	E3.0
	76-08-15	--	--	--	25	120	74	E7.0	34	2.0
	76-08-15	--	--	--	--	--	--	--	--	--
001S003W04N00S	75-10-17	750	245	750	E25	10	59	E6.0	20	E4.0
	75-11-11	750	245	750	E25	<10	62	E6.0	24	E4.0
	75-12-09	750	245	750	E25	50	60	E6.0	24	E4.0
	75-12-18	750	--	--	--	--	--	--	--	--
	76-01-11	750	245	750	25	60	67	E6.0	27	E4.0
	76-04-06	750	245	750	E25	--	90	E6.0	24	E4.0
	76-08-24	750	245	750	28	140	76	E6.0	24	E4.0
	76-08-24	750	245	750	--	--	--	--	--	--
001S003W04N01S	76-03-08	245	110	245	15	240	62	E6.0	16	E2.0
	76-03-08	245	110	245	20	50	94	E9.0	20	E2.0
001S003W04R03S	76-04-13	245	155	245	E20	--	80	E4.0	29	E3.0
	76-08-10	245	155	245	E20	--	20	E2.0	34	E3.0
001S003W05D00S	75-09-15	--	--	--	--	--	--	--	--	--
	75-10-13	--	--	--	--	--	--	--	--	--
	75-11-10	--	--	--	--	--	--	--	--	--
	76-02-09	--	--	--	--	--	--	--	--	--
	76-03-08	--	--	--	25	60	25	E3.0	27	E3.0
	76-08-15	--	--	--	30	40	23	E6.0	28	E3.0
	76-08-15	--	--	--	--	--	--	--	--	--
001S003W05D01S	75-09-15	290	--	--	--	--	--	--	--	--
	75-10-13	290	--	--	--	--	--	--	--	--
	75-11-10	290	--	--	--	--	--	--	--	--
	76-02-09	290	--	--	--	--	--	--	--	--
	76-03-08	290	--	--	27	130	84	E8.0	29	E4.0

WELL NUMBER	DATE OF SAMPLE	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)
001S003W03Q01S	76-08-10	180	0	52	20	.3	15	--	371	550
	76-08-10	180	0	65	23	E.3	E15	410	--	--
	76-08-10	--	--	--	--	--	E13	--	--	--
	76-08-10	--	--	--	--	--	13	--	--	--
001S003W04G00S	75-09-15	--	--	--	--	.3	16	--	--	--
	75-10-11	--	--	--	--	--	13	--	--	--
	75-10-13	--	--	--	--	--	20	--	--	--
	76-02-09	--	--	--	--	--	21	--	--	--
	76-03-08	200	0	63	21	.2	22	395	--	650
001S003W04G01S	75-09-15	--	--	--	--	.4	16	--	--	--
	75-10-13	--	--	--	--	--	20	--	--	--
	75-11-10	--	--	--	--	--	20	--	--	--
	76-02-09	--	--	--	--	--	22	--	--	--
	76-03-08	200	0	66	21	.2	23	425	--	660
	76-08-15	190	0	64	20	.4	19	235	--	610
	76-08-15	--	--	--	--	--	19	--	--	585
001S003W04N00S	75-10-17	160	0	36	18	.1	11	--	--	450
	75-11-11	180	0	32	14	.2	16	335	--	500
	75-12-09	160	0	34	18	.3	18	335	--	480
	75-12-18	--	--	--	--	--	11	--	--	--
	76-01-11	170	0	43	20	.4	16	305	--	520
	76-04-06	210	0	62	23	.2	18	355	--	660
	76-08-24	170	0	48	25	.2	E19	375	--	560
	76-08-24	--	--	--	--	--	19	--	--	570
001S003W04N01S	76-03-08	170	0	40	16	.3	4.0	250	--	420
	76-03-08	250	0	63	18	.2	8.0	375	--	620
001S003W04R03S	76-04-13	200	0	50	18	.4	15	390	--	590
	76-08-10	200	0	49	20	.3	15	375	--	590
001S003W05D00S	75-09-15	--	--	--	--	.3	20	--	--	--
	75-10-13	--	--	--	--	--	16	--	--	--
	75-11-10	--	--	--	--	--	22	--	--	--
	76-02-09	--	--	--	--	--	17	--	--	--
	76-03-08	150	0	67	25	.2	23	380	--	610
	76-08-15	160	0	70	23	.2	23	415	--	620
	76-08-15	--	--	--	--	--	19	--	--	575
001S003W05D01S	75-09-15	--	--	--	--	.4	19	--	--	--
	75-10-13	--	--	--	--	--	20	--	--	--
	75-11-10	--	--	--	--	--	22	--	--	--
	76-02-09	--	--	--	--	--	15	--	--	--
	76-03-08	160	0	65	28	.2	20	375	--	610

WELL NUMBER	DATE OF SAMPLE	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED BORON (B) (UG/L)	CODE FOR AGENCY COL-LECTING SAMPLE	CODE FOR AGENCY ANA-LYZING SAMPLE
001S003W03Q01S	76-08-10	7.2	18.5	390	1028	1028
	76-08-10	7.5	18.5	<100	1028	9801
	76-08-10	--	--	--	1028	9801
	76-08-10	--	--	--	1028	1028
001S003W04G00S	75-09-15	--	--	--	--	9801
	75-10-11	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.1	--	--	1028	9801
001S003W04G01S	75-09-15	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	75-11-10	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.2	--	--	1028	9801
	76-08-15	7.5	25.0	100	1028	9801
	76-08-15	7.6	25.0	--	1028	9801
001S003W04N00S	75-10-17	7.5	23.0	--	--	9801
	75-11-11	7.3	22.0	--	--	9801
	75-12-09	7.4	20.0	--	--	9801
	75-12-18	--	--	--	--	9801
	76-01-11	7.5	19.0	--	--	9801
	76-04-06	7.1	20.0	--	1028	9801
	76-08-24	7.2	--	400	1028	9801
	76-08-24	7.2	20.0	--	1028	1028
001S003W04N01S	76-03-08	7.5	--	--	1028	9801
	76-03-08	7.4	--	--	1028	9801
001S003W04R03S	76-04-13	7.4	--	--	1028	9801
	76-08-10	7.3	--	--	1028	9801
001S003W05D00S	75-09-15	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	75-11-10	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.1	--	--	--	9801
	76-08-15	7.4	24.0	200	1028	9801
	76-08-15	7.0	24.0	--	1028	1028
001S003W05D01S	75-09-15	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	75-11-10	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.1	--	--	--	9801

WELL NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DEPTH TO TOP OF SAMPLE INTER-VAL (FT)	DEPTH TO BOT-TOM OF SAMPLE INTER-VAL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)
001S003W05D01S	76-12-25	290	--	--	--	--	--	--	--	--
001S003W05D04S	75-09-15	256	--	--	--	--	--	--	--	--
	75-10-13	256	--	--	--	--	--	--	--	--
	75-11-10	256	--	--	--	--	--	--	--	--
	76-02-09	256	--	--	--	--	--	--	--	--
	76-03-08	256	130	256	30	20	78	E8.0	31	E3.0
	76-08-15	256	130	256	30	20	76	E6.0	31	4.0
	76-08-15	256	--	--	--	--	--	--	--	--
001S003W05D05S	75-09-15	--	--	--	--	--	--	--	--	--
	75-10-13	--	--	--	--	--	--	--	--	--
	75-11-10	--	--	--	--	--	--	--	--	--
	76-02-09	--	--	--	--	--	--	--	--	--
	76-03-08	--	--	--	27	20	70	E6.0	25	E3.0
	76-08-15	--	--	--	30	<10	55	E6.0	26	3.0
001S003W06F00S	76-06-00	--	--	--	--	--	--	--	--	--
001S003W06H04S	75-12-18	415	173	415	E25	500	50	6.0	22	3.0
	76-08-24	415	173	415	30	--	57	E6.0	27	4.0
	76-08-24	415	--	--	--	--	--	--	--	--
001S003W06L00S	76-08-18	--	326	460	20	40	36	E6.0	16	2.0
	76-08-18	--	326	460	--	--	--	--	--	--
001S003W07A05S	76-08-17	733	544	733	20	40	30	E3.0	14	2.0
	76-08-17	733	--	--	--	--	--	--	--	--
001S003W09E02S	74-10-03	385	--	--	--	--	--	--	--	--
	75-12-30	385	211	385	E20	13	32	E3.0	12	E1.0
001S003W10D01S	75-11-11	460	250	460	E20	<10	46	E4.0	21	E2.0
	75-12-09	460	250	460	E20	200	42	E4.0	23	E2.0
001S003W11H00S	74-04-25	--	<100	E400	E20	--	30	E3.0	16	E2.0
001S004W01P01S	76-08-18	952	E850	952	15	100	72	E7.0	29	3.0
001S004W12B01S	76-08-17	818	700	818	20	20	30	E3.0	16	2.0
	76-08-17	818	--	--	--	--	--	--	--	--
001S004W12B05S	75-12-18	1052	704	1052	E20	80	30	2.0	15	3.0
	76-08-17	1052	704	1052	--	<10	30	E2.0	15	3.0
	76-08-17	1052	--	--	--	--	--	--	--	--
	76-08-24	1052	704	1052	20	20	31	E2.0	16	3.0
001S004W12C01S	76-08-17	280	46	280	20	140	53	E5.0	26	2.0
	76-08-17	280	--	--	--	--	--	--	--	--
001S004W12D00S	76-08-18	--	--	--	20	40	37	E3.0	25	3.0
	76-08-18	--	--	--	--	--	--	--	--	--
001S004W12D01S	76-08-18	--	--	<972	25	200	130	E10	57	4.0
	76-08-18	--	--	--	--	--	--	--	--	--

WELL NUMBER	DATE OF SAMPLE	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)
001S003W05D01S	76-12-25	--	--	--	--	--	E25	--	--	--
001S003W05D04S	75-09-15	--	--	--	--	.3	18	--	--	--
	75-10-13	--	--	--	--	--	20	--	--	--
	75-11-10	--	--	--	--	--	22	--	--	--
	76-02-09	--	--	--	--	--	18	--	--	--
	76-03-08	170	0	65	23	.2	20	385	--	610
	76-08-15	180	0	74	21	.2	18	400	--	630
	76-08-15	--	--	--	--	--	18	--	--	600
001S003W05D05S	75-09-15	--	--	--	--	.3	16	--	--	--
	75-10-13	--	--	--	--	--	16	--	--	--
	75-11-10	--	--	--	--	--	19	--	--	--
	76-02-09	--	--	--	--	--	18	--	--	--
	76-03-08	150	0	55	18	.2	17	330	--	530
	76-08-15	130	0	50	16	.2	16	330	--	480
001S003W06F00S	76-06-00	--	--	--	--	--	13	--	--	--
001S003W06H04S	75-12-18	130	0	55	14	.2	5.9	310	--	400
	76-08-24	130	0	72	20	.3	5.0	315	--	460
	76-08-24	--	--	--	--	--	7.2	--	--	480
001S003W06L00S	76-08-18	120	0	21	120	.3	2.5	200	--	320
	76-08-18	--	--	--	--	--	4.7	--	--	305
001S003W07A05S	76-08-17	120	0	16	5.0	.5	1.0	155	--	250
	76-08-17	--	--	--	--	--	1.7	--	--	240
001S003W09E02S	74-10-03	--	--	--	--	--	--	--	--	280
	75-12-30	120	0	16	7.0	.4	2.0	--	190	250
001S003W10D01S	75-11-11	150	0	19	9.0	.3	11	260	--	380
	75-12-09	150	0	17	11	.5	9.0	260	--	350
001S003W11H00S	74-04-25	64	0	17	7.0	.4	1.6	175	--	225
001S004W01P01S	76-08-18	140	0	110	25	.4	3.0	360	--	560
001S004W12B01S	76-08-17	110	0	11	9.0	.5	4.0	155	--	260
	76-08-17	--	--	--	--	--	3.2	--	--	240
001S004W12B05S	75-12-18	110	0	10	9.0	.4	3.2	180	--	250
	76-08-17	120	0	12	9.0	.4	3.0	160	--	260
	76-08-17	--	--	--	--	--	3.0	--	--	240
	76-08-24	110	0	12	9.0	.4	2.0	160	--	240
001S004W12C01S	76-08-17	150	0	52	18	.4	2.0	250	--	--
	76-08-17	--	--	--	--	--	3.8	--	--	370
001S004W12D00S	76-08-18	120	0	32	12	.5	2.0	210	--	340
	76-08-18	--	--	--	--	--	2.8	--	--	300
001S004W12D01S	76-08-18	230	0	260	130	.6	1.0	630	--	970
	76-08-18	--	--	--	--	--	1.4	--	--	1060

WELL NUMBER	DATE OF SAMPLE	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED BORON (B) (UG/L)	CODE FOR AGENCY COL-LECTING SAMPLE	CODE FOR AGENCY ANA-LYZING SAMPLE
001S003W05D01S	76-12-25	--	--	--	--	--
001S003W05D04S	75-09-15	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	75-11-10	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.2	--	--	--	9801
	76-08-15	7.4	28.0	100	1028	9801
	76-08-15	7.3	28.0	--	1028	1028
001S003W05D05S	75-09-15	--	--	--	--	9801
	75-10-13	--	--	--	--	9801
	75-11-10	--	--	--	--	9801
	76-02-09	--	--	--	--	9801
	76-03-08	7.2	--	--	--	9801
	76-08-15	7.4	23.0	100	1028	9801
001S003W06F00S	76-06-00	--	--	--	--	9801
001S003W06H04S	75-12-18	7.5	--	--	--	9801
	76-08-24	7.1	25.0	<20	1028	9801
	76-08-24	7.3	25.0	--	1028	1028
001S003W06L00S	76-08-18	7.5	19.0	200	1028	9801
	76-08-18	7.6	19.0	--	1028	1028
001S003W07A05S	76-08-17	7.7	18.5	<20	1028	9801
	76-08-17	--	18.5	--	1028	1028
001S003W09E02S	74-10-03	7.8	20.0	--	--	--
	75-12-30	7.6	17.0	--	--	9801
001S003W10D01S	75-11-11	7.4	22.0	200	--	9801
	75-12-09	7.5	18.0	--	--	9801
001S003W11H00S	74-04-25	7.3	--	--	--	9801
001S004W01P01S	76-08-18	7.7	--	<100	1028	9801
001S004W12B01S	76-08-17	7.9	18.0	<100	1028	9801
	76-08-17	8.0	--	--	1028	1028
001S004W12B05S	75-12-18	7.8	--	<10	--	9801
	76-08-17	7.5	18.5	100	1028	9801
	76-08-17	8.0	--	--	1028	1028
	76-08-24	7.5	--	<100	1028	9801
001S004W12C01S	76-08-17	7.6	20.0	<100	1028	9801
	76-08-17	7.7	20.0	--	1028	1028
001S004W12D00S	76-08-18	7.7	20.0	10	1028	9801
	76-08-18	8.0	20.0	--	1028	1028
001S004W12D01S	76-08-18	7.6	22.0	100	1028	9801
	76-08-18	7.5	22.0	--	1028	1028

WELL NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DEPTH TO TOP OF SAMPLE INTER-VAL (FT)	DEPTH TO BOT-TOM OF SAMPLE INTER-VAL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)
001S004W12F03S	76-08-17	1100	840	1100	20	20	22	E2.0	35	3.0
	76-08-17	1100	--	--	--	--	--	--	--	--

WELL NUMBER	DATE OF SAMPLE	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRATE (N) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)
001S004W12F03S	76-08-17	120	0	22	9.0	.5	1.0	160	--	280
	76-08-17	--	--	--	--	--	.60	--	--	260

WELL NUMBER	DATE OF SAMPLE	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED BORON (B) (UG/L)	CODE FOR AGENCY COL-LECTING SAMPLE	CODE FOR AGENCY ANA-LYZING SAMPLE
001S004W12F03S	76-08-17	7.7	21.5	<10	1028	9801
	76-08-17	8.0	21.5	--	1028	1028

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