# Shallow Ground Water in the Whitney Area, Southeastern Las Vegas Valley, Clark County, Nevada

## Part I. Description of Chemical Quality, 1986-87

By David H. Emme and David E. Prudic

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# CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to metric (International System) units by using the following factors:

| *Multiply* | *By* | *To obtain* |
|---|---|---|
| Acre | 0.4047 | Square hectometer ($hm^2$) |
| Foot (ft) | 0.3048 | Meter (m) |
| Inch (in.) | 25.40 | Millimeter (mm) |
| Mile (mi) | 1.609 | Kilometer (km) |
| Square mile ($mi^2$) | 2.590 | Square kilometer ($km^2$) |

For temperature, degree Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)] + 32.

# SEA LEVEL

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which is derived from a general adjustment of the first-order leveling networks of both the United States and Canada (formerly called "Sea-Level Datum of 1929").

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## ABSTRACT

A prototype ground-water detention basin was proposed by the U.S. Bureau of Reclamation to reduce the quantity of dissolved solids entering Las Vegas Wash from ground-water seepage, as part of an overall plan to reduce salinity in the lower Colorado River. This report describes ground-water quality in the area of the prototype detention basin prior to its construction and the processes that may control the chemical quality of the ground water.

The prototype detention basin is adjacent to Las Vegas Wash about 7 miles southeast of Las Vegas, Nevada, and is an area of about 1 square mile just downstream from two wastewater treatment facilities. The surficial sediments beneath the prototype basin are primarily flood-plain deposits that are dominated by silt near land surface, silty sand between depths of 10 and 25 feet, and silt and clay below about 25 feet. Ground-water flow is generally southeastward, paralleling the course of Las Vegas Wash. The water table at the proposed basin site is generally 1 to 10 feet below land surface, and it fluctuates seasonally in response to changing rates of evapotranspiration.

Water samples were collected four times, at most, during a 16-month period from about 65 wells ranging in depth from 5 to 45 feet. Dissolved-solids concentrations in the shallow ground water differ throughout the study area; measured values range from about 2,000 milligrams per liter, in an area affected by seepage of treated effluent, urban runoff, and storm runoff, to about 28,000 milligrams per liter along the western edge of the study area.

Geochemical interpretation of water-quality analyses suggests that the concentrations and distribution of major ions in the ground water are controlled by: (1) seepage of treated effluent, including land disposal of sludge; (2) seepage of urban runoff entering the area; (3) dissolution of minerals as ground water moves through sediments in Las Vegas Valley, including those of the study area; and (4) evapotranspiration, which tends to concentrate solutes near the water table.

# INTRODUCTION

The dissolved-solids concentration of water in the Colorado River is increasing as a result of increasing water use for irrigation and municipal supplies in the basin. The river supplies water to more than 14 million people and is used to irrigate about 1 million acres of farmland in the mostly arid southwestern United States (U.S. Bureau of Reclamation, 1982, p. 35-36). Any increase in the quantity of dissolved solids in the river water adversely affects both the people and the irrigated crops. In 1974, the Colorado River Basin Salinity Control Act, Title II (public law 92-320), authorized the U.S. Bureau of Reclamation to construct salinity-control structures in four areas along the Colorado River. Las Vegas Wash, Nev., was one of the four areas. One of the proposed salinity-control efforts in Las Vegas Wash was the construction of 14 shallow ground-water detention basins along the channel of the wash (U.S. Bureau of Reclamation, 1985, figure 1). The basins would include a dike raised above land surface and a slurry wall excavated to the top of a hydraulically confining clay thought to underlie the shallow alluvial deposits.

The intent of the detention basins was to reduce the quantity of saline ground water entering Las Vegas Wash (U.S. Bureau of Reclamation, 1985, p. 4-6). Because of uncertainties regarding the effectiveness of the detention basins, the Bureau of Reclamation proposed construction of one prototype basin (basin D-14). Ground-water flow and water quality were to be monitored both before and after construction of the basin to determine if it produced the expected reduction in ground-water seepage to the channel of Las Vegas Wash and reduced the quantity of dissolved solids entering the wash (U.S. Bureau of Reclamation, 1985). In March 1986 and prior to construction of the detention basin, the U.S. Geological Survey, in cooperation with the U.S. Bureau of Reclamation, began a study to define ground-water flow and water quality in the vicinity of the proposed detention basin.

Construction of the dike began in September 1986, and was mostly completed by the end of October 1986. Construction of the slurry wall was initially scheduled for the fall of 1987 but in January 1987, the project was cancelled as a result of policy changes within the Bureau of Reclamation

The location of the prototype detention basin is near the town of East Las Vegas, about 7 miles southeast of Las Vegas (figure 1). The area is a rectangular parcel of land approximately 1 $mi^2$ in area located downstream from three wastewater treatment plants (figure 1B). The area is referred to herein as the Whitney study area because the Bureau of Reclamation project is called the Whitney Verification Program, named after the small community of Whitney that is now part of East Las Vegas.

## Purpose and Scope

The purposes of this report are to describe (1) the areal, vertical, and seasonal variations of ground-water quality in the vicinity of the D-14 prototype detention basin for the period April 1986 through June 1987 and prior to construction of the proposed slurry wall, and (2) the processes and factors that may control the chemistry of ground water. The scope of the study included: (1) drilling numerous test holes and installing observation wells, principally by the Bureau of Reclamation; (2) collecting lithologic data (thickness, grain-size distribution, and mineral composition of the alluvial deposits); (3) routinely measuring ground-water levels in the observation wells; (4) estimating hydraulic properties from field and laboratory tests; and (5) routinely collecting water samples from observation wells for chemical analyses.

Results of the chemical analyses of water samples are depicted on maps and graphs and listed in tables presented in this report. The processes and factors that may influence or control the chemistry of ground water are evaluated herein.

## Previous Work

Previous investigations of the quality of shallow ground water in Las Vegas Valley include work by Dinger (1977), Kaufmann (1978), and Dettinger (1987). Through detailed mapping of surficial sediments, Dinger established carbonate and sulfate lithofacies (rock units defined on the basis of mineralogic composition and other physical characteristics) in the valley. Sulfate-dominated sediments occupy the eastern part of the valley, including the Whitney study area. Kaufmann (1978, p. 87) described a sulfate hydrochemical facies for ground water that roughly correlated with the lithofacies of Dinger. Comparing the quality of shallow ground water to that of water from deeper aquifers, Kaufmann (p. 57) notes the prevalent effect of sewage effluent and irrigation return flow on the quality at shallow depths. Deeper ground water was found to be of better chemical quality and virtually unaffected by recharge of sewage effluent. According to Kaufmann (p. 37), degradation of deeper aquifers is a concern where the vertical hydraulic gradient is downward.

In a study of nutrient input to Las Vegas Wash, Schmidt and Hess (1980, p. 21) discuss the possibility of surface flow from the wash recharging the shallow ground water at times in the vicinity of the Whitney study area. They also describe the potential for reduction of nutrient concentrations in sewage effluent through uptake by marsh vegetation in the vicinity of the wash. A detailed discussion of the existence, extent, and mechanisms for nutrient and toxin stripping in Las Vegas Wash is presented by Roline and Sartoris (1984). Their report deals primarily with surface water in the channel of Las Vegas Wash and how toxin and nutrient loads change as a result of changing environments along the course of the wash.

## Monitoring Well Design and Numbering Systems

The U.S. Bureau of Reclamation drilled seven wells in the Whitney study area during May 1984 to obtain preliminary information on ground water along Las Vegas Wash. These wells were drilled to depths of 11 to 39 feet using a 6-inch diameter, solid-stem power auger or a 3-inch hand auger. The wells were completed with 2-inch polyvinylchloride (PVC) pipe. The bottom 10 to 11 feet of each well was generally machine-slotted and the space between the wall of the hole and the pipe was backfilled with sediments brought up during the drilling process. The wells were designated by the Bureau as "PG," followed by three numerals (figure 2).

The Bureau of Reclamation constructed 39 more wells between September and October 1985 as part of their Whitney Verification Program. These wells are aligned along the Nevada State-plane coordinate system at 1,000-foot intervals to form a grid of wells throughout most of the study area (figure 2). The wells were drilled to depths of 5 to 45 feet using a 6-inch diameter, solid-stem power auger, and each well was completed with 2-inch PVC pipe. Most of the PVC pipe for these wells was machine-slotted from the bottom of the hole to land surface. The space between the hole and the pipe was filled with pea gravel except in the 2-foot interval below land surface, which was filled with a cement grout. These wells are designated "WG," followed by three numerals (figure 2).

The numbering sequence of the "WG" well sites follows a column-and-row system for the 1,000-foot grid when the first number in the designation is a zero. The second number designates the column, numbered sequentially from west to east, and the third number designates the row, numbered sequentially from south to north (figure 2). Five wells have the number 1 following "WG"; these wells are aligned along the Tropicana floodway (figure 2).

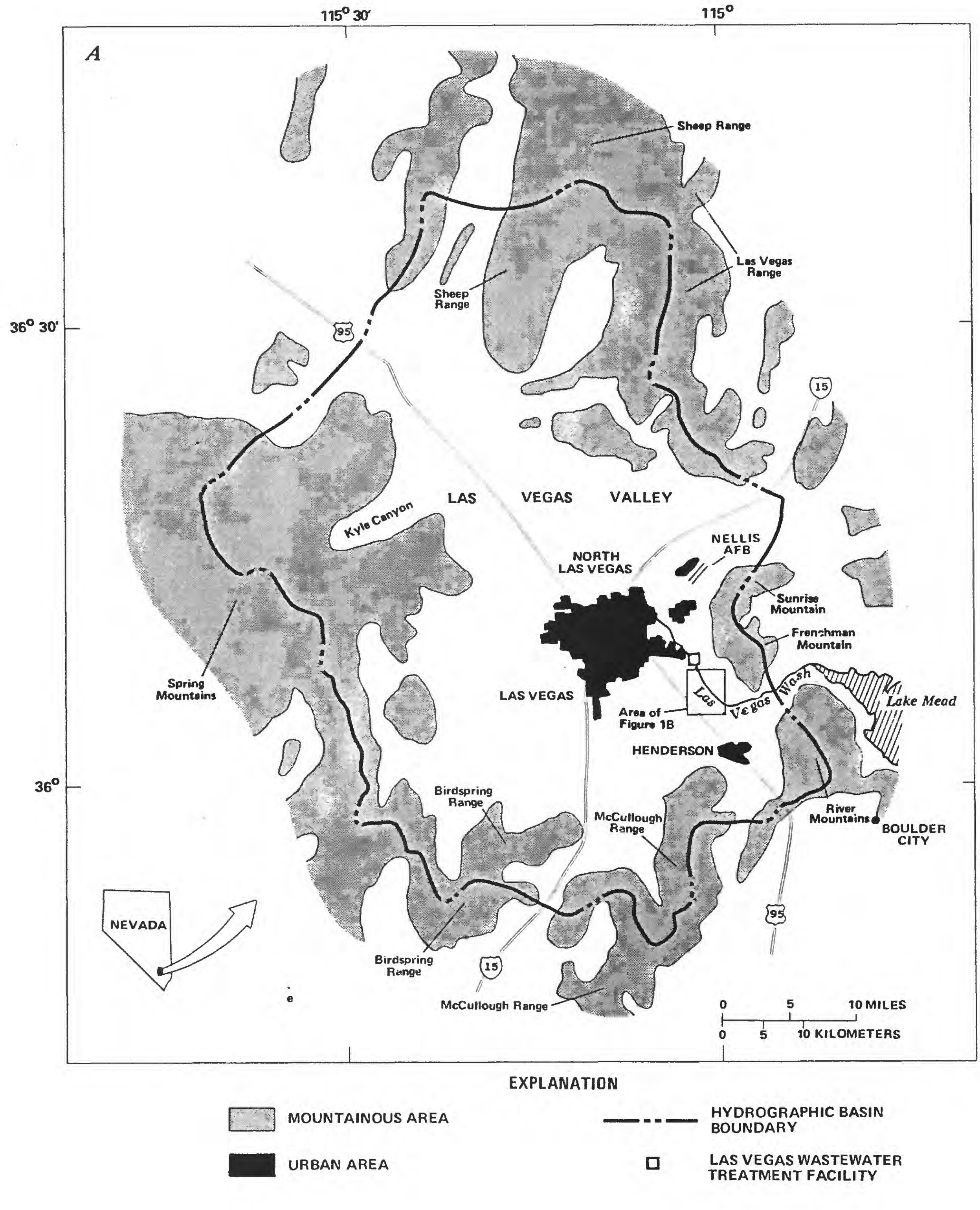
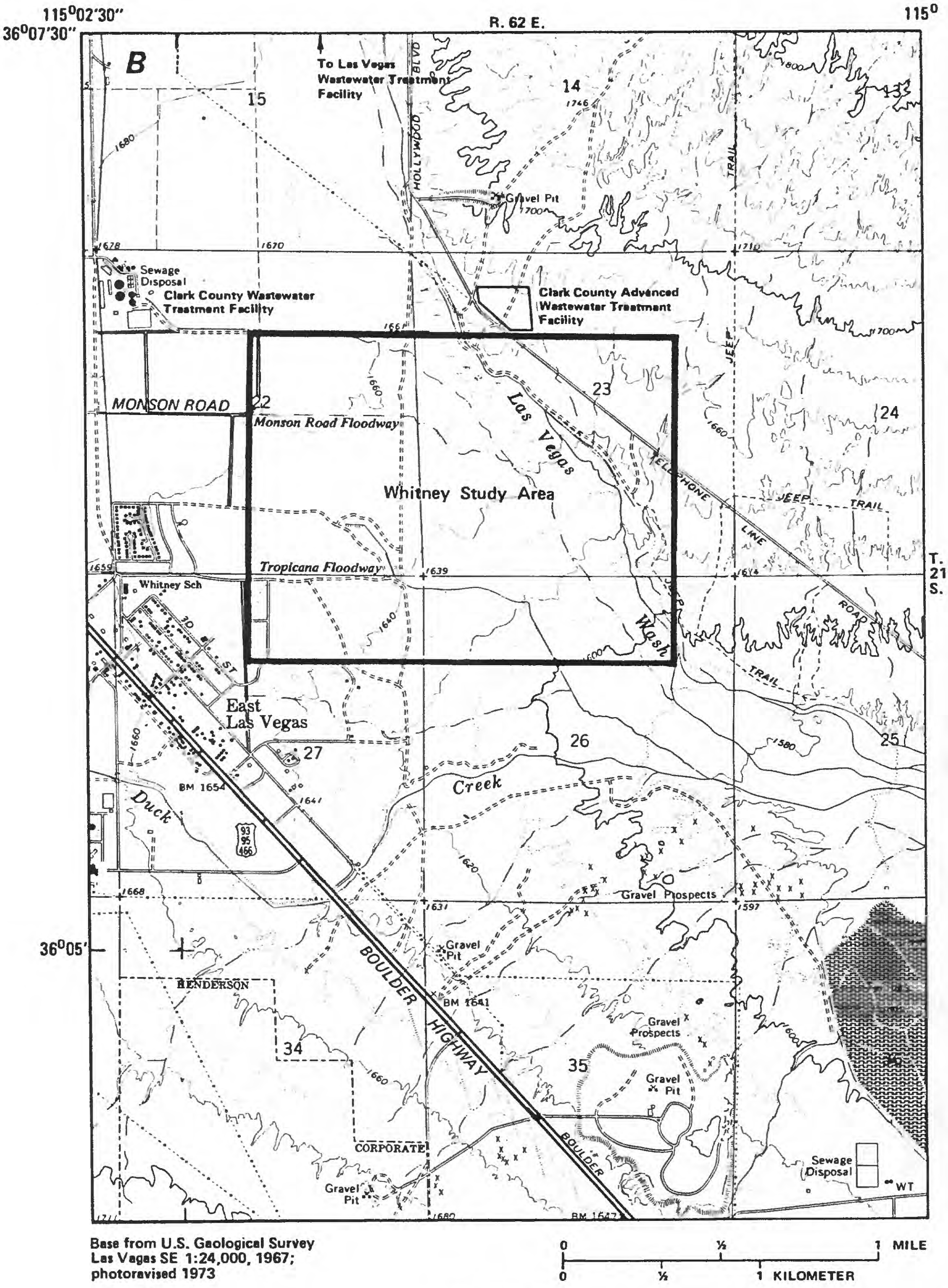


FIGURE 1.--Location and general features of *(A)* Las Vegas Valley (modified from Dettinger, 1987, figure 1) and *(B)* the Whitney study area.

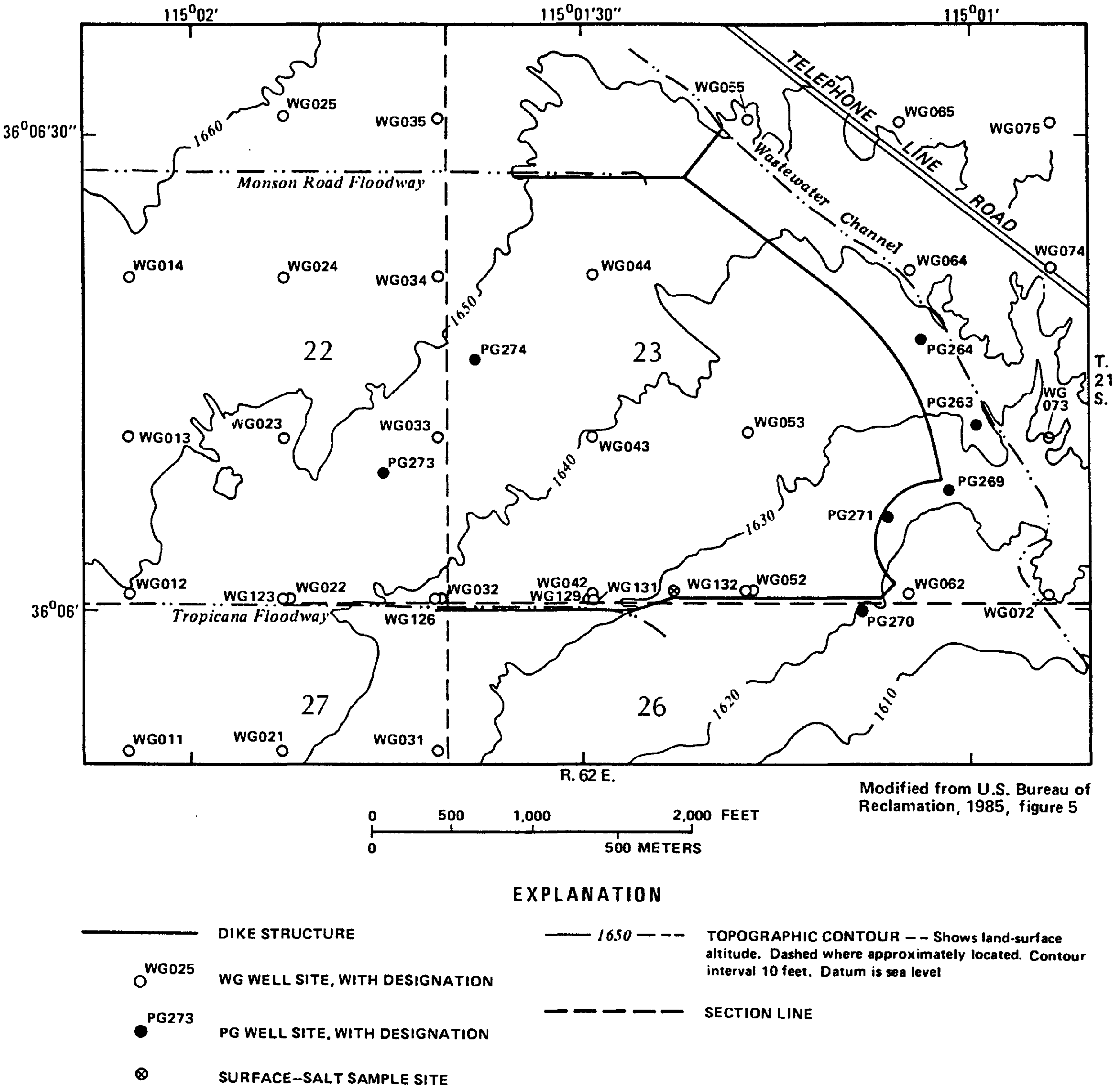


Base from U.S. Geological Survey Las Vegas SE 1:24,000, 1967; photorevised 1973

**EXPLANATION**

| | |
|---|---|
| —*1580*— | TOPOGRAPHIC CONTOUR – – Shows land-surface altitude. Contour interval 20 feet, with dotted supplementary 10-foot contours. Datum is sea level |

FIGURE 1.--Continued.



Modified from U.S. Bureau of Reclamation, 1985, figure 5

FIGURE 2.--Location of sampled wells.

At sites WG035, WG044, and WG053, as many as five wells were drilled to different depths during September and October 1985; these are referred to as cluster wells. Only the bottom 5 feet of PVC pipe at each cluster well is machine slotted; pea gravel was used to fill the space between the wall of the drill hole and the pipe. Designations at these cluster sites include the letters A-E to identify individual wells. The letter A is used to identify the shallowest well, B the next deepest well, and so on. For example, WG035A is the shallowest well at site WG035, and WG035E is the deepest.

Several wells were drilled by the Bureau of Reclamation using a rotary drill rig during October 1986. The purpose of the drilling was to: (1) add new wells at selected sites; (2) replace wells that had been destroyed; (3) replace the cluster wells at sites WG035, WG044, and WG053 because pea gravel that had been used to backfill around the pipe provided an avenue for vertical movement of water; or (4) add new wells near some existing wells that were slotted from the pipe bottom to land surface or above. The new wells that replaced destroyed or cluster site wells are designated with an N. Thus, WG044EN is the deepest new well drilled at site WG044. Wells drilled next to those slotted along the entire length of the pipe are designated with a B. For example, WG043B, with slotted pipe at only the bottom 2 feet, was drilled next to well WG043, which is slotted throughout its length.

The drilling technique used by the U.S. Bureau of Reclamation in October 1986 was considerably different from that used previously. A hole was made by pushing a 4-inch diameter tube into the ground. The tube generally was pushed 5 feet downward and then removed to collect sediment samples from it. The hole was deepened to the desired depth by alternately pushing and removing the tube. Generally, only small amounts of sediment collapsed into the hole as it was drilled, even below the zone that was saturated with water.

Each well was completed using 2-inch PVC pipe with 2 feet of machine-slotted PVC (0.001-inch slots) at the bottom. Silica sand (20 to 40 mesh) was used to fill the space between the wall of the hole and the slotted PVC and for 1 to 2 feet above the slotted pipe. Bentonite pellets were then used to fill at least 5 feet of the space around the pipe, and the remainder was backfilled with sediments brought up during the drilling process. Each well was covered with a capped 3-foot-long, 4-inch-diameter steel pipe set into a cement grout for protection.

Wells at site WG062 were constructed in February 1986 by the U.S. Geological Survey using both a 4-inch, solid-stem power auger and 3- to 4-inch hand augers because the area was too marshy for a large drill rig. The wells were completed in a manner similar to those drilled by the Bureau during October 1986.

Available information for each well (depth of hole, depth to water, drilling method, casing type and diameter, slotted interval, land-surface altitude) was entered into the Geological Survey's WATSTORE data base. Each well having information stored in WATSTORE is identified by the standard Geological Survey site-identification number, a local (Nevada) identification number, and a Bureau of Reclamation designation (referred to as an "owner number" in the data base). These identification numbers and other well data are listed in table 9 at the end of this report.

## Acknowledgments

The U.S. Bureau of Reclamation, Boulder City, Nev., funded the project and provided information regarding the drilling and design of test holes drilled prior to this study. Especially helpful in providing previously collected data were D. Art Tuma, Joseph Kahl, Jr., and David J. Sobek. Christian Carlsen and Roberta C. Lunnis, (U.S. Geological Survey, Las Vegas, Nev.), were responsible for the collection of field data.

## HYDROLOGY AND HYDROGEOLOGY OF THE WHITNEY STUDY AREA

Las Vegas Wash is a broad, low-lying area that drains Las Vegas Valley (figure 1). Sewage effluent from treatment plants upstream from the study area is the primary source of surface water entering the study area (figure 1B). Prior to the excavation of a wastewater channel in 1983 (figure 2), most of the treated effluent flowed in small channels choked with marshland vegetation. Urban runoff and ground-water seepage, including percolation from irrigation of lawns and golf courses, contribute to flow in the wash. Two floodways that convey storm runoff away from urban areas enter the study area from the west (figure 2). The Monson Road floodway parallels Monson Road, enters the study area from the west, and ends about one-half mile beyond (east of) the end of Monson Road. Flow from the end of the floodway meanders through marshlands on its way to the channel of Las Vegas Wash. The Tropicana floodway parallels Tropicana Avenue and also discharges urban runoff and ground-water seepage into the study area.

The surficial deposits are composed of Quaternary alluvial-fan and flood-plain sediments. North of Las Vegas Wash, the deposits are primarily alluvial-fan sediments derived from Frenchman Mountain (figure 1), and are a heterogeneous mixture of sand, gravel, silt, and clay. Flood-plain deposits are dominant elsewhere in the study area. These deposits generally are silts and clays at land surface; in the marshy areas, they include considerable organic matter from decaying plant materials. The deposits become coarser between depths of 10 and 25 feet, and generally consist of sand and silt with some gravel. Below about 25 feet, the deposits are predominately silts and clays. Thickness of the surficial deposits is not precisely known.

The Muddy Creek Formation of late Tertiary age, consisting primarily of clay and silt, is thought to underlie the surficial deposits, but it has not as yet been absolutely identified in the study area. A reddish silty clay, which could be the Muddy Creek Formation, was encountered in a test hole at a depth of about 30 feet at site WG062 (D.E. Prudic, U.S. Geological Survey, written communication, 1987). The lateral extent of the clay found in test hole WG062 is uncertain; however, a pronounced increase in the resistance to drilling was noted at depths between 20 and 30 feet in several test holes (U.S. Bureau of Reclamation, Boulder City, Nev., written communication, 1986). The depth at which the resistance to drilling increased was interpreted by the U.S. Bureau of Reclamation as the top of the Muddy Creek Formation, which was assumed to be a resistant clay.

The coarser sediments in the surficial deposits constitute the principal near-surface aquifer in the study area. The general direction of ground-water flow in this shallow upper unit is from northwest to southeast, approximately paralleling the course of Las Vegas Wash (figure 3). The water table is generally 1 to 10 feet below land surface, except where the land surface rises up the fan toward Frenchman Mountains. In this area, which lies north of the wastewater channel, the depth to water may be more than 20 feet.

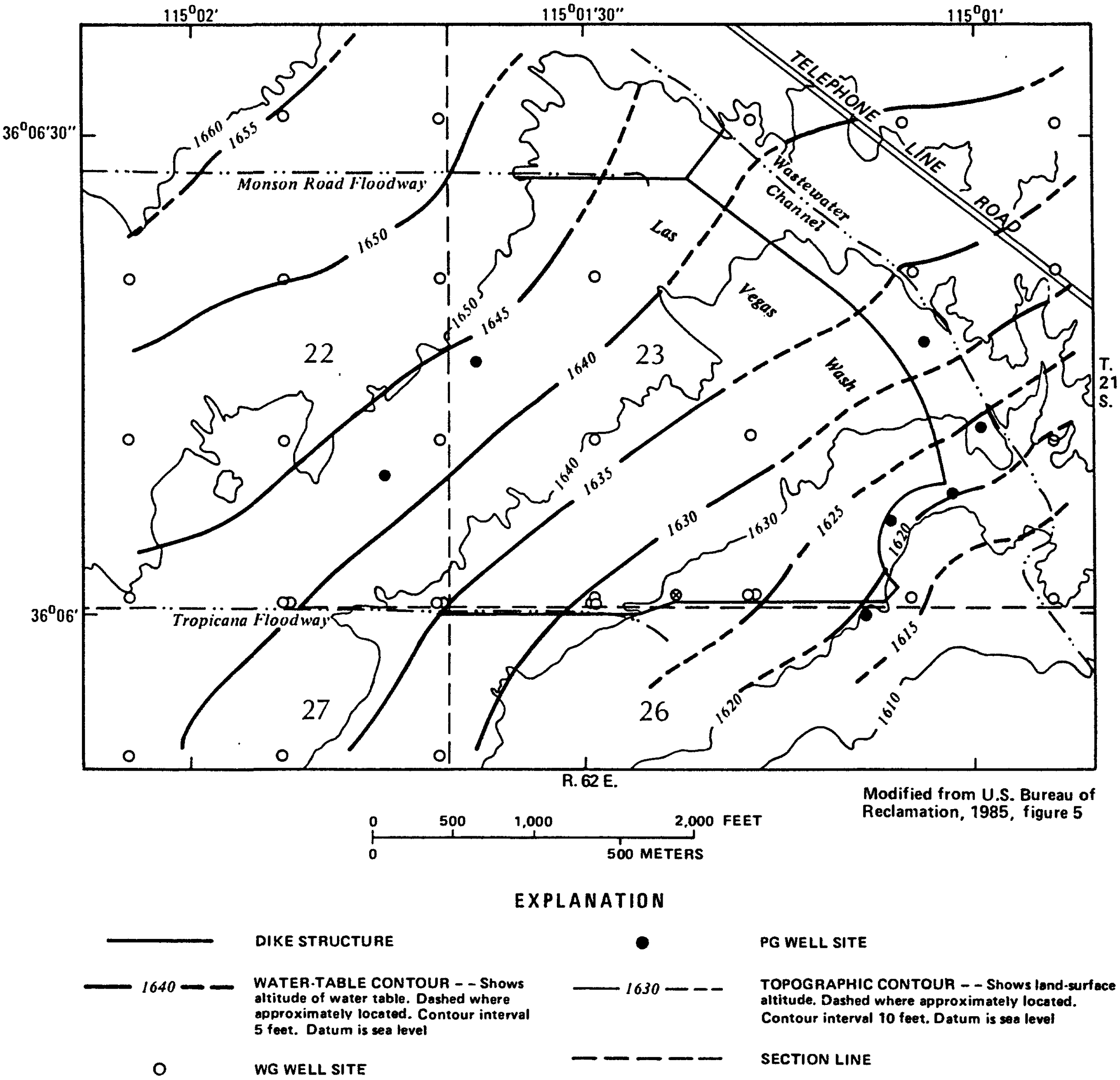


FIGURE 3.--Water-table altitude, March 1986 (modified from T.J. Burbey, U.S. Geological Survey, written communication, 1987).

Several sediment samples collected during test drilling in October 1986 and February 1987 were analyzed by x-ray diffraction to identify the types of minerals present in the sediments. Results of the analyses are shown in table 1. In general, the deposits consist primarily of quartz, calcite, and dolomite, and the predominant clay minerals are smectite and illite. Seven samples contained 1 to 15 percent gypsum. One sample of the reddish silty clay that may be from the Muddy Creek Formation was collected from test hole WG062. It consists mostly of dolomite, calcite, and quartz, but contains no detectable gypsum. Results of analyses of surface salt collected near a pit midway between sites WG042 and WG052 (location of sample is shown in figure 2) are also included in table 1.

TABLE 1.--*Bulk x-ray diffraction analyses of 10 sediment samples collected during the drilling of wells in October 1986 and February 1987. Well locations are shown in figure 2.*

[Mineral abundances are reported as percent by weight, except as follows: M, major constituent; m, minor; tr, trace; ?, tentative identification; nd, not detected; <, less than. Analyzed by University of Utah Research Institute, Earth Science Laboratory.]

| Mineral | Surface salts[1] | U.S. Bureau of Reclamation well designation and sample depth, in feet | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | WG044A 3-6 | WG044A 9-12 | WG053A 0-3 | WG053A 26-29 | WG062 6.4-7 | WG062 12-12.6 | WG062 21.5-22.5 | WG062 32-33 | WG071 2.5-3 |
| Quartz | 7 | 17 | 13 | 40 | 32 | 25 | 15 | 47 | 13 | 21 |
| Potassium feldspar | 1 | 5 | 7 | 8 | 6 | 5 | 3 | 3 | 5 | 6 |
| Plagioclase | 3 | 6 | 9 | 11 | 5 | 8 | 4 | 3 | 5 | 6 |
| Calcite | 4 | 3 | 43 | 10 | 19 | 22 | 24 | 22 | 21 | 24 |
| Dolomite | 8 | 18 | 13 | 15 | 19 | 18 | 11 | 13 | 40 | 18 |
| Gypsum | 9 | 15 | nd | 4 | 4 | 1 | nd | 1 | nd | 1 |
| Halite | 15 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Bloedite[2] | M | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Hydromagnesite[2] | m | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Nesquehonite | nd | m? | nd | nd | nd | nd | nd | nd | nd | m |
| Siderite | nd | 3 | nd | nd | nd | nd | nd | nd | nd | nd |
| Amphibole | nd | 1 | 1 | nd | nd | 1 | nd | nd | nd | 2 |
| Smectite | 1 | 11 | 7 | 7 | 7 | 9 | 6 | 4 | 7 | 11 |
| Illite | 1 | 5 | 5 | 5 | 6 | 5 | 5 | 3 | 7 | 7 |
| Kaolinite | tr | 2 | 1 | tr | 1 | 1 | tr | nd | 1 | 2 |
| Palygorskite | 2 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Sepiolite | tr | nd | 1 | tr | 1 | 1 | tr | nd | 1 | nd |
| Other | <48 | 14 | nd | nd | nd | 3 | 32 | 5 | nd | 2 |

[1] Sample of surface salts was collected in October 1986 near a pit about midway between sites WG042 and WG052. Sample-site location is shown in figure 2.

[2] No standards available.

# GROUND-WATER SAMPLING AND ANALYSES

## Sampling Procedures

Each monitoring well was purged of at least three well volumes before sampling to obtain water representative of the aquifer. Samples were obtained by using a surge pump or a 1-3/4-inch Teflon[1] bailer, depending on the depth of the well and the length of the water-level recovery period. Both the surge pump and bailer were thoroughly rinsed with deionized water between wells to reduce the potential of contamination.

Once a sufficient quantity of water had been removed from a well, a water sample was collected. At least three 250-mL (milliliter) polyethylene sample bottles were used. One was filled with unfiltered and untreated water. A second was filled with water filtered through a pre-rinsed 0.45-micrometer pore-size filter but was untreated. A third bottle, for cation analysis, was filled with filtered water that was acidified with nitric acid to a pH of about 1.5 (Wood, 1976, p. 7). At selected wells, filtered water was added to an opaque, 250-mL polyethylene bottle and treated with a mercuric chloride tablet (a tablet contains about 10 milligrams mercuric ion as mercuric chloride in a 150 milligram sodium chloride base), then chilled immediately in ice (to about 4 °C) and kept chilled until it was analyzed for nutrients. Water temperature, pH, specific conductance, and alkalinity were determined on-site at the time of sample collection.

Ground-water samples for dissolved constituents were collected from 41 wells between April 28 and May 3, 1986, and from 36 wells during September 22-28, 1986 (table 10). A few of the wells were destroyed by vandals between the sampling dates. In October 1986, 17 water samples were collected from new wells drilled at the cluster-well sites WG035, WG044, and WG053. Ground-water samples also were collected from 49 wells during January 12-18, 1987, and from 43 wells during June 1-4, 1987 (table 10). Supplemental field measurements of water temperature, specific conductance, and dissolved oxygen were made at selected wells in April 1987.

## Analyses of Water Quality

Water samples for analysis of major dissolved constituents were delivered to the U.S. Bureau of Reclamation Soils Laboratory in nearby Boulder City, Nev. Analytical results from the Bureau of Reclamation Soils Laboratory are stored in their computer data base at Boulder City, Nev. The analytical results are given in table 10 at the end of this report.

A few duplicate samples were sent to the U.S. Geological Survey laboratory in Arvada, Colo. Water samples for nutrient analysis were also sent to the same Geological Survey laboratory. The analytical methods used by the U.S. Geological Survey laboratory for the analyses of inorganic substances and nutrients in water are discussed by Fishman and Friedman (1985). Analyses of water samples done by the U.S. Geological Survey laboratory are stored in the Survey's WATSTORE data base. Results are given in table 2.

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[1] The use of trade or product names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

TABLE 2.--*Comparison of analytical results from U.S. Geological Survey and U.S. Bureau of Reclamation laboratories for dissolved constituents in ground-water samples collected during the period from April 1986 through January 1987*

[All values are in milligrams per liter rounded to two significant figures; --, not determined. Well locations are shown in figure 2]

| U.S. Bureau of Reclamation well designation | Sample date | Analyzing agency[1] | Dissolved solids[2] | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Sulfate ($SO_4$) | Chloride (Cl) | Silica (Si) |
|---|---|---|---|---|---|---|---|---|---|---|
| WG013 | 01-13-87 | USGS | 10,300 | 610 | 480 | 1,800 | 250 | 3,700 | 3,000 | 74 |
| | | USBR | 10,500 | 720 | 510 | 1,700 | 260 | 3,600 | 3,000 | 73 |
| WG014 | 04-29-86 | USGS | 21,800 | 370 | 1,600 | 3,200 | 660 | 9,700 | 3,600 | 51 |
| | | USBR | 21,800 | 440 | 1,600 | 3,300 | 820 | 9,700 | 3,700 | 53 |
| WG014 | 01-13-87 | USGS | [a]19,900 | 450 | 1,800 | 4,400 | 830 | 13,000 | 4,900 | 52 |
| | | USBR | 27,500 | 560 | 2,000 | 4,100 | 910 | 12,000 | 4,500 | 42 |
| WG022 | 04-29-86 | USGS | 5,350 | 670 | 270 | 500 | 50 | 2,800 | 910 | -- |
| | | USBR | 5,280 | 720 | 250 | 440 | 54 | 2,300 | 820 | 74 |
| WG025 | 05-01-86 | USGS | 7,640 | 480 | 420 | 830 | 78 | 4,100 | 1,100 | 78 |
| | | USBR | 6,760 | 490 | 420 | 800 | 94 | 3,300 | 910 | 75 |
| WG035CN | 01-17-87 | USGS | 5,950 | 380 | 420 | 660 | 42 | 3,400 | 330 | 86 |
| | | USBR | 6,240 | 460 | 440 | 630 | 46 | 3,100 | 530 | 52 |
| WG044B | 04-30-86 | USGS | 7,490 | 500 | 510 | 780 | 85 | 4,000 | 760 | 100 |
| | | USBR | 7,260 | 500 | 510 | 770 | 98 | 3,700 | 710 | 92 |
| WG052 | 05-03-86 | USGS | 8,550 | 510 | 640 | 900 | 73 | 4,700 | 980 | 82 |
| | | USBR | 8,620 | 550 | 660 | 910 | 85 | 4,300 | 1,000 | 75 |
| WG055 | 05-01-86 | USGS | 3,670 | 550 | 130 | 280 | 28 | 2,000 | 310 | 97 |
| | | USBR | 3,430 | 480 | 160 | 230 | 30 | 1,800 | 270 | 88 |
| WG064 | 05-01-86 | USGS | 3,240 | 560 | 80 | 200 | 23 | 1,800 | 240 | -- |
| | | USBR | 3,160 | 610 | 110 | 190 | 24 | 1,700 | 250 | 77 |
| WG072 | 05-02-86 | USGS | 4,690 | 590 | 210 | 450 | 41 | 2,400 | 700 | -- |
| | | USBR | 4,720 | 620 | 230 | 430 | 45 | 2,200 | 630 | 112 |
| WG075 | 05-02-86 | USGS | 7,520 | 570 | 470 | 960 | 76 | 4,000 | 820 | -- |
| | | USBR | 7,440 | 590 | 490 | 900 | 87 | 3,600 | 990 | 27 |
| WG131 | 01-14-87 | USGS | 7,500 | 570 | 470 | 850 | 57 | 4,000 | 870 | 83 |
| | | USBR | 7,520 | 630 | 510 | 830 | 69 | 3,600 | 1,000 | 70 |
| PG273 | 01-14-87 | USGS | 5,650 | 500 | 280 | 680 | 37 | 3,000 | 680 | 75 |
| | | USBR | 5,680 | 540 | 280 | 680 | 39 | 2,700 | 630 | 70 |

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[1] USGS, U.S. Geological Survey laboratory, Arvada, Colo.; USBR, U.S. Bureau of Reclamation Soils Laboratory, Boulder City, Nev.

[2] Dissolved solids determined from residue at 180 degrees Celsius.

[a] Dissolved solids as the sum of constituents is 26,000 milligrams per liter.

## Quality Assurance

Since 1983, the Bureau of Reclamation Soils Laboratory in Boulder City, Nev., has participated in the Geological Survey standard-reference water sample (SRWS) program for quality-assurance purposes of concern to both agencies (Janzer, 1985). The U.S. Geological Survey laboratory also participates in the SRWS program, as well as a quality-assurance program sponsored by the U.S. Environmental Protection Agency. A description of the quality assurance program implemented for the U.S. Geological Survey laboratory is discussed by Friedman and Erdman (1982).

Statistics that summarize each semi-annual SRWS testing indicate that most analyses made by the Bureau of Reclamation Soils Laboratory were acceptable. As an added check during the study, a few samples collected in April and May 1986 and January 1987 were split and sent to both laboratories. The results are given in table 2. The analyses from both laboratories are generally within acceptable limits (±5 percent). However, results from the Geological Survey laboratory were slightly lower for potassium and calcium and generally higher for sodium and sulfate than results from the Bureau of Reclamation laboratory. The sample-to-sample consistency of these differences suggests a slight bias in the analyses between the two laboratories.

Results from the SRWS testing program indicate that nitrate concentrations determined by the Bureau of Reclamation Soils Laboratory were periodically unacceptable. In recognition of this problem, the Bureau of Reclamation requested that nutrients in water from selected wells be analyzed by the U.S. Geological Survey. Although the primary purpose of the nutrient analyses was to determine the concentrations of the various forms of nitrogen, the analyses also allowed a comparison between nitrate concentrations determined by the Bureau of Reclamation Soils Laboratory and those determined from the Geological Survey laboratory. These results are given in table 3.

The Bureau of Reclamation Soils Laboratory analyzed only the combined oxidized forms of nitrogen (nitrate plus nitrite) and reported the concentrations as nitrate (David Hemphill, U.S. Bureau of Reclamation, oral communication, 1988). Analyses by the Geological Survey laboratory include the organic and ammonium forms of nitrogen, which, along with nitrate and nitrite, are reported as nitrogen. Analyses by the Bureau of Reclamation are recalculated from nitrate to nitrogen in table 3 for comparison with the Geological Survey data. In general, the analyses by the two laboratories are nearly the same when concentrations exceed 3 milligrams per liter as nitrogen (mg/L as N) but the Bureau of Reclamation results are slightly higher at concentrations less than 3 mg/L (table 3). Only 6 of the 28 analysis pairs differ by more than a factor of 2 and one pair differs by a factor of 10 (water sampled from well WG072 on January 18, 1987).

Differences in the concentrations of nitrate plus nitrite shown in table 3 may, in part, be related to the amount of ammonium in the samples and to differences in the sampling procedures. Sampling procedures for nutrient analyses were described in the section "Sampling Procedures." Briefly, filtered water was poured into an opaque polyethylene bottle; mercuric chloride was then added as a preservative, and the samples chilled to about 4 °C. The samples were kept chilled until analyzed. These procedures, which are standard for nutrient analyses by the U.S. Geological Survey, are done to reduce the possibility of changes in nutrient concentrations between the time of sample collection and analyses.

TABLE 3.--*Comparison of analytical results from U.S. Geological Survey and U.S. Bureau of Reclamation laboratories for dissolved nitrogen concentrations in ground-water samples collected during the period from April 1986 through January 1987*

[All values are in milligrams per liter as nitrogen; --, not determined. Well locations are shown in figure 2]

| U.S. Bureau of Reclamation well designation | Sample date | Analytical results by U.S. Geological Survey[1] | | | | | | Analytical results by U.S. Bureau of Reclamation[2] |
|---|---|---|---|---|---|---|---|---|
| | | Total nitrogen | Ammonium ($NH_4$) | Organic nitrogen | Nitrate ($NO_3$) | Nitrite ($NO_2$) | Nitrate plus nitrite | Nitrate plus nitrite |
| WG014 | 04-29-86 | 3.3 | 0.53 | 2.3 | -- | -- | 0.33 | 1.0 |
| | 09-23-86 | 1.1 | .51 | .00 | 0.55 | 0.08 | .63 | 1.4 |
| | 01-13-87 | 1.7 | .52 | 1.0 | .21 | .01 | .22 | .9 |
| WG022 | 04-29-86 | 7.9 | .35 | .15 | -- | -- | 7.4 | 6.8 |
| | 09-23-86 | 9.3 | .30 | 1.2 | 7.8 | .01 | 7.8 | 7.5 |
| | 01-13-87 | 8.5 | .27 | 1.4 | 6.8 | .05 | 6.8 | 6.6 |
| WG025 | 05-01-86 | 12 | .20 | .30 | 11 | -- | 11 | 10 |
| | 09-25-86 | 12 | .23 | .87 | 11 | .03 | 11 | 10 |
| | 01-17-87 | 12 | .20 | 1.0 | 11 | .04 | 11 | 11 |
| WGC42 | 01-16-87 | 7.9 | .20 | 1.4 | 6.3 | <.01 | 6.3 | 5.9 |
| WG044B | 04-30-86 | 2.8 | .22 | .18 | -- | -- | 2.4 | 2.5 |
| | 09-25-86 | 3.4 | .22 | .58 | 2.6 | <.01 | 2.6 | 2.7 |
| WG044BN | 01-13-87 | 3.8 | .20 | .90 | 2.7 | <.01 | 2.7 | 2.7 |
| WG052 | 05-03-86 | -- | -- | -- | -- | -- | 2.8 | 3.2 |
| | 09-23-86 | 5.2 | .29 | .41 | 4.4 | .11 | 4.5 | 4.5 |
| WG055 | 05-01-86 | 2.2 | 1.1 | .00 | -- | -- | 1.1 | 1.4 |
| | 09-25-86 | 6.0 | 2.2 | .30 | 3.5 | .03 | 3.5 | 4.1 |
| | 01-17-87 | 10 | .27 | 2.0 | 7.6 | .18 | 7.8 | 7.0 |
| WG064 | 05-01-86 | 18 | 6.5 | 1.7 | -- | -- | 10 | 11 |
| | 01-17-87 | 9.7 | 2.9 | .80 | 6.0 | .02 | 6.0 | 6.5 |
| WG072 | 05-02-86 | 3.6 | 2.8 | .20 | -- | -- | .78 | 3.8 |
| | 09-27-86 | 5.7 | 3.6 | .80 | 1.3 | <.01 | 1.3 | 1.6 |
| | 01-18-87 | 4.3 | 3.8 | .10 | .41 | .01 | .42 | 6.5 |
| WG075 | 05-02-86 | 46 | .23 | .37 | -- | -- | 45 | 48 |
| | 09-27-86 | 26 | .24 | .36 | 25 | <.01 | 25 | 23 |
| | 01-17-86 | 29 | .22 | 2.5 | 26 | <.01 | 26 | 23 |
| PG263 | 09-24-86 | 5.2 | 4.4 | 0 | .8 | .01 | .8 | 2.2 |
| PG271 | 01-16-87 | .8 | .18 | .52 | .1 | <.01 | .1 | .16 |

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[1] Analyses by U.S. Geological Survey were done on ground-water samples that were filtered using a 0.45-micrometer filter and stored in 250-milliliter opaque polyethylene bottles. The samples were treated with 10 milligrams of mercuric ion as mercuric chloride in a 250-milligram sodium-chloride base and kept chilled to about 4 °C.

[2] Analyses by U.S. Bureau of Reclamation Soils Laboratory were done on ground-water samples that were filtered using a 0.45-micrometer filter and stored in 250-milliliter translucent polyethylene bottles. The samples were neither treated nor chilled.

Water samples sent to the U.S. Bureau of Reclamation Soils Laboratory were collected by pouring filtered water into a translucent polyethylene bottle. The samples were not chilled but were delivered to the laboratory once the samples from all wells were collected. No special treatment was given to the samples at the laboratory, and they were stored at room temperature until analyzed. These procedures may allow for changes in the concentrations of nutrients. In samples where oxygen is abundant, some or all of the ammonium could be converted into nitrate or nitrite prior to analyses. In samples where oxygen is depleted, both nitrate and nitrite may be converted into ammonium or nitrogen gas. Thus, the nitrate-plus-nitrite concentrations determined by the Bureau of Reclamation could range from values that are less than those determined by the Geological Survey laboratory to the amount of total nitrogen in table 3. Interpretation of nitrate-plus-nitrite values determined by the Bureau of Reclamation must, therefore, be viewed in the context of these analytical procedures.

Even though efforts were made to reduce errors in the sampling of ground water and in the analyses, and quality-control procedures are routinely done by both laboratories, concentrations reported as representative of ground-water quality at a specific well must be interpreted with caution.

## GROUND-WATER QUALITY

### Chemical Character

The quality of ground water in the Whitney study area is controlled (1) by the quality of recharge to the area, either from local sources or from sources that originate outside the study area, and (2) by the physical, chemical, and biological processes in the shallow subsurface within the area. Ground water in the study area is primarily from three sources: lateral ground-water inflow from areas to the west and northwest; seepage and lateral ground-water inflow of sewage effluent adjacent to the wastewater channel and upstream from the study area; and surface-water inflow from the Monson Road floodway (figure 1). Seepage from surface flow mixes with shallow ground water in the eastern one-third of the study area. Surface flow from the Tropicana floodway (figure 1) normally does not seep into the ground in the western half of the study area because adjacent ground-water levels normally are higher than the water in the floodway.

Occasionally, floods may result in seepage of surface water into the shallow ground-water body, which in turn may influence the quality of the ground water. However, only one flood of short duration occurred between April 1986 and June 1987. Its effect could not be separated from the normal flow in the Monson Road floodway and the surface flow of treated effluent. Thus, the effect floods may have on ground-water quality in the study area is uncertain, and is not discussed herein.

The primary processes within the Whitney study area that influence or control the quality of ground water include: (1) mixing of water from sewage effluent and urban and storm runoff with ground water; (2) application of sludge from the nearby wastewater treatment facilities onto the ground in the study area; (3) dissolution of minerals as water flows through the subsurface sediments; and (4) concentration of dissolved constituents in ground water near land surface due to evapotranspiration. The effect of the sludge on dissolved nitrate and nitrite concentrations in ground water is described in a separate section.

The Whitney study area represents the distal end of a much larger ground-water flow system. The average chemical composition of ground-water samples collected from wells in the Whitney study area is compared with potential sources of recharge in table 4. Results of the tabulation suggest that shallow ground water in Las Vegas Valley has a generally higher dissolved-solids concentration than deeper ground water, and that shallow ground water sampled in the Whitney study area is generally more concentrated than shallow ground water sampled elsewhere on the valley floor.

Dissolved anions in the ground water within the Whitney study area are dominated by sulfate. An apparent evolutionary trend in dominant anions from bicarbonate in waters sampled from possible source areas to sulfate in the study area can be interpreted from the relations shown in figure 4 and the analyses listed in table 4. No particularly dominant cation is discernible, although water from possible source areas to the west generally contains a lower proportion of sodium than does ground water in the Whitney study area.

TABLE 4.--*Average chemical composition of (1) shallow ground water in the study area and (2) potential ground-water sources*

[Milligrams per liter; --, not determined]

| Source | Dissolved solids | Calcium | Magnesium | Sodium | Potassium | Bicarbonate | Sulfate | Chloride | Nitrate |
|---|---|---|---|---|---|---|---|---|---|
| Whitney area[1] | 6,587 | 539 | 415 | 737 | 83 | 282 | 3,158 | 800 | 30 |
| Ground water elsewhere below floor of Las Vegas Valley | | | | | | | | | |
| Shallow[2] | 2,824 | 303 | 212 | 262 | 34 | 242 | 1,569 | 311 | 13 |
| Intermediate[3] | 640 | 89 | 55 | [a]35 | (a) | 120 | 267 | 45 | 3.2 |
| Deep[4] | 295 | 40 | 35 | 12 | 2 | 237 | 47 | 9 | 2.3 |
| Spring Mountains[5] | 266 | 64 | 23 | 2.3 | .6 | 303 | 12 | 2.2 | -- |
| Colorado River[6] | 737 | 85 | 28 | 92 | 13 | 128 | 310 | 88 | -- |

[1] Average of 53 samples collected during September 1986 for this study.

[2] Average of 35 samples collected from depths less than 100 feet (Dinger, 1977, p. 48).

[3] Average of 250 samples collected from depths of 101 to 300 feet (Dinger, 1977, p. 48).

[4] Average of 3 samples collected from a depth greater than 300 feet (Dinger, 1977, p. 48).

[5] Average of 4 spring samples (U.S. Geological Survey, data in WATSTORE data base).

[6] Average of 4 samples of Colorado River water imported into Las Vegas Valley (Dinger, 1977, p. 48).

[a] Values reported as sodium plus potassium, expressed as sodium.

## EXPLANATION

- SHALLOW GROUND WATER IN STUDY AREA -- Samples collected during September 1986

2• POTENTIAL SOURCES -- See table 4 for water-chemistry data

1 Average for 35 samples of shallow ground water (well depths less than 100 feet; Dinger, 1977, p. 48)
2 Average for 250 samples of intermediate ground water (well depths range from 101 to 300 feet; Dinger, 1977, p. 48)
3 Average for 3 samples of deep ground water (well depths greater than 300 feet; Dinger, 1977, p. 48)
4 Average for 4 samples collected from springs in the Spring Mountains west of Las Vegas (U.S. Geological Survey, data in WATSTORE data base)
5 Average for 4 samples of Colorado River water imported to Las Vegas Valley (Dinger, 1977, p. 48)

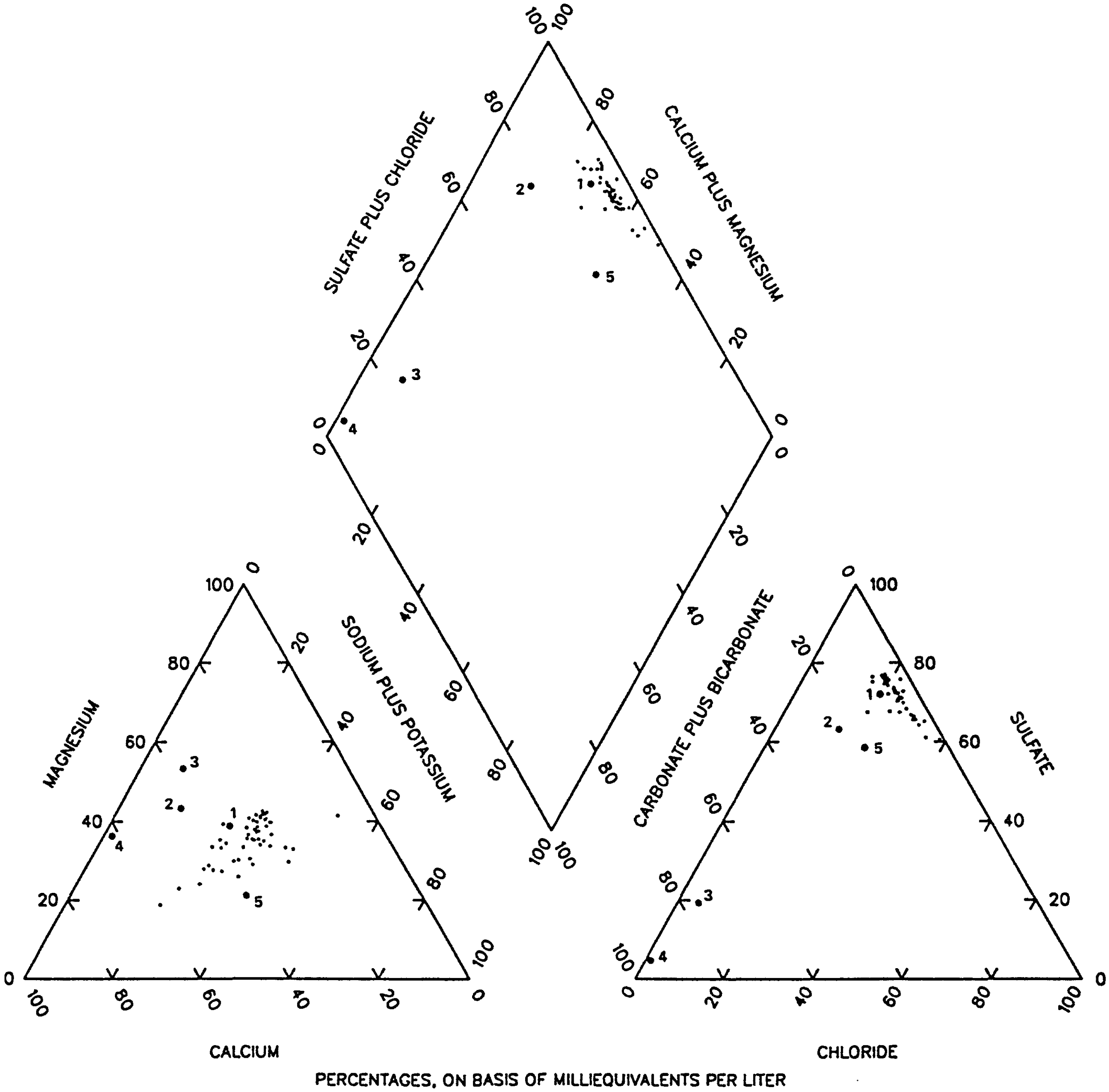

FIGURE 4.--Chemical character of (1) shallow ground water in the study area and (2) potential sources of the ground water.

A summary of water quality from samples collected during the study is given in table 5. Results of analyses summarized in table 5 are given in table 10. Table 5 includes one to four samples for each well in the study area and, thus, the statistics represent variations in space and time. Most major constituents range in concentration over more than an order of magnitude except for calcium, bicarbonate, and silica. For all samples, dissolved-solids concentrations range from 1,840 to 27,500 mg/L and have a median of 6,140 mg/L (mean, 6,550 mg/L). The highest dissolved-solids concentrations in sampled water are from two wells at site WG014; they range from 18,600 to 27,500 mg/L (table 10). Removing these analyses from the statistics results in lower maximum concentrations for most major constituents and slightly lower mean concentrations, but the median concentrations are not greatly affected (table 5).

Sulfate is the dominant anion in all ground-water samples, accounting for nearly half of the mean dissolved-solids concentration. The dominant cations are sodium, calcium, and magnesium.

TABLE 5.--*Statistical summary of data on ground-water quality*

[Temperature, pH, and specific conductance were determined at time of sample collection. Laboratory analyses of dissolved solids and constituents determined by U.S. Bureau of Reclamation Soils Laboratory, Boulder City, Nev. Milligrams per liter, except as indicated]

| Constituent or property | Number of analyses | Mean | Median | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| | | | All data | | | |
| Temperature[1] | 189 | 18.7 | 19.0 | 2.9 | 9.0 | 24.5 |
| pH | 191 | 7.2 | 7.2 | .15 | 6.9 | 7.9 |
| Specific conductance[2] | 191 | 7,100 | 6,500 | 3,300 | 2,500 | 26,000 |
| Dissolved solids[3] | 192 | 6,550 | 6,140 | 3,310 | 1,840 | 27,500 |
| Calcium | 192 | 540 | 540 | 85 | 190 | 750 |
| Magnesium | 192 | 410 | 400 | 260 | 93 | 2,000 |
| Sodium | 192 | 730 | 650 | 560 | 190 | 4,100 |
| Potassium | 192 | 82 | 57 | 115 | 15 | 910 |
| Bicarbonate | 192 | 280 | 280 | 77 | 120 | 570 |
| Sulfate | 192 | 3,100 | 3,000 | 1,400 | 800 | 12,000 |
| Chloride | 192 | 800 | 660 | 690 | 140 | 4,900 |
| Silica | 192 | 74 | 75 | 16 | 21 | 120 |
| | | | Excluding site WG014 (anomalously high dissolved solids) | | | |
| Temperature[1] | 183 | 19.0 | 19.0 | 2.9 | 9.0 | 24.5 |
| pH | 185 | 7.2 | 7.2 | .16 | 6.9 | 7.9 |
| Specific conductance[2] | 185 | 6,500 | 6,500 | 1,400 | 2,500 | 12,000 |
| Dissolved solids[3] | 186 | 6,020 | 6,110 | 1,350 | 1,840 | 10,500 |
| Calcium | 186 | 540 | 540 | 86 | 190 | 750 |
| Magnesium | 186 | 370 | 400 | 120 | 93 | 700 |
| Sodium | 186 | 640 | 640 | 220 | 190 | 1,700 |
| Potassium | 186 | 64 | 57 | 36 | 15 | 310 |
| Bicarbonate | 186 | 280 | 280 | 68 | 120 | 570 |
| Sulfate | 186 | 2,900 | 3,000 | 660 | 800 | 5,000 |
| Chloride | 186 | 680 | 650 | 280 | 140 | 3,000 |
| Silica | 186 | 75 | 76 | 16 | 21 | 120 |

[1] Degrees Celsius (°C).

[2] Microsiemens per centimeter at 25 °C.

[3] Residue on evaporation at 180 °C.

Linear correlation coefficients among major constituents and dissolved solids reveal a strong statistical relation between dissolved solids and magnesium, sodium, potassium, sulfate, and chloride (table 6). Correlation among the latter five constituents is statistically significant, with coefficients ranging from 0.90 to 0.98. Ground water at well site WG014 contains an anomalously high dissolved-solids concentration which, as a result, accounts for a large part of the total range in concentration. Even if the data for this well are removed from the statistical evaluation, the correlation coefficients among dissolved solids and magnesium, sodium, and sulfate remain favorable, ranging from 0.82 to 0.96 (table 6).

Calcium, bicarbonate, and silica yield little or no correlation with dissolved solids or other ions. These three constituents may be controlled by processes that differ from those that control the ions correlated with dissolved solids. For example, calcium and bicarbonate may be affected by mineral solubility, and silica is near or at saturation with respect to amorphous silica in all samples.

TABLE 6.--*Correlation coefficients (r values) among dissolved solids and major ions in ground-water samples*[1]

[Analyses by U.S. Bureau of Reclamation Soils Laboratory, Boulder City, Nev.]

| Constituent | Dissolved solids | Sodium | Potassium | Calcium | Magnesium | Chloride | Sulfate | Bicarbonate | Nitrate |
|---|---|---|---|---|---|---|---|---|---|
| All data (including site WG014) | | | | | | | | | |
| Sodium | 0.99 | | | | | | | | |
| Potassium | .92 | 0.93 | | | | | | | |
| Calcium | .10 | .06 | 0.07 | | | | | | |
| Magnesium | .98 | .96 | .90 | 0.02 | | | | | |
| Chloride | .95 | .96 | .90 | .23 | 0.91 | | | | |
| Sulfate | .99 | .97 | .90 | .06 | .98 | 0.90 | | | |
| Bicarbonate | .53 | .51 | .50 | - .29 | .59 | .38 | 0.56 | | |
| Nitrate | .00 | .02 | - .03 | .08 | - .04 | .01 | - .01 | -0.32 | |
| Silica | - .16 | - .20 | - .18 | .13 | - .14 | - .20 | - .15 | .13 | -0.39 |
| Excluding site WG014 (anomalously high dissolved solids) | | | | | | | | | |
| Sodium | 0.94 | | | | | | | | |
| Potassium | .66 | 0.68 | | | | | | | |
| Calcium | .11 | - .04 | 0.10 | | | | | | |
| Magnesium | .93 | .82 | .54 | -0.08 | | | | | |
| Chloride | .73 | .69 | .59 | .46 | 0.56 | | | | |
| Sulfate | .96 | .91 | .62 | .02 | .93 | 0.58 | | | |
| Bicarbonate | .23 | .18 | .11 | - .36 | .38 | - .23 | 0.31 | | |
| Nitrate | .22 | .31 | .20 | .09 | .10 | .33 | .17 | -0.31 | |
| Silica | .02 | - .10 | - .04 | .14 | .05 | - .11 | .03 | .26 | -0.42 |

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[1] The correlation coefficient (r value) is used to describe the intensity and direction of interdependence between two variables. In this table, it is a way of evaluating how well concentrations of major ions relate linearly to concentrations of other major ions or to dissolved-solids concentrations. If the correlation coefficient approaches zero, no linear correlation exists between two variables. If the correlation coefficient approaches either +1 or -1, then the values of the two variables closely correlate linearly. A positive correlation coefficient indicates a relation where both variables either increase or decrease. A negative correlation coefficient indicates that one variable decreases as the other increases.

A plot of sodium as related to chloride, in samples from shallow gruond water and from potential recharge sources, indicates that the two constituents increase proportionally (figure 5A). Assuming that chloride behaves conservatively, this suggests the possibility of (1) the evaporative or transpirative concentration of sodium in ground water in the study area or (2) the dissolution of halite (NaCl) in the sediments. Halite was not detected in shallow sediments within the study area (table 1), but this does not rule out the possibility that the mineral is present in shallow sediments elsewhere in Las Vegas Valley. Halite is known to be present as lenses in the Muddy Creek Formation, which presumably underlies much of eastern Las Vegas Valley. If halite is present in the deeper sediments upgradient from the site, it could explain the relation in figure 5. Sodium and chloride concentrations in water collected from well site WG014 are much higher than those in water collected from wells elsewhere in the study area. Possible reasons for the elevated concentrations are discussed in the next section.

A similar plot (figure 5B) of sulfate as related to chloride, in samples from shallow ground water and from potential recharge sources, indicate that sulfate and chloride increase proportionately. However, data from well site WG014 plot to the right of the line of proportionality (figure 5B). This suggests that sulfate may be precipitating as gypsum ($CaSO_4$) in the vicinity of that well.

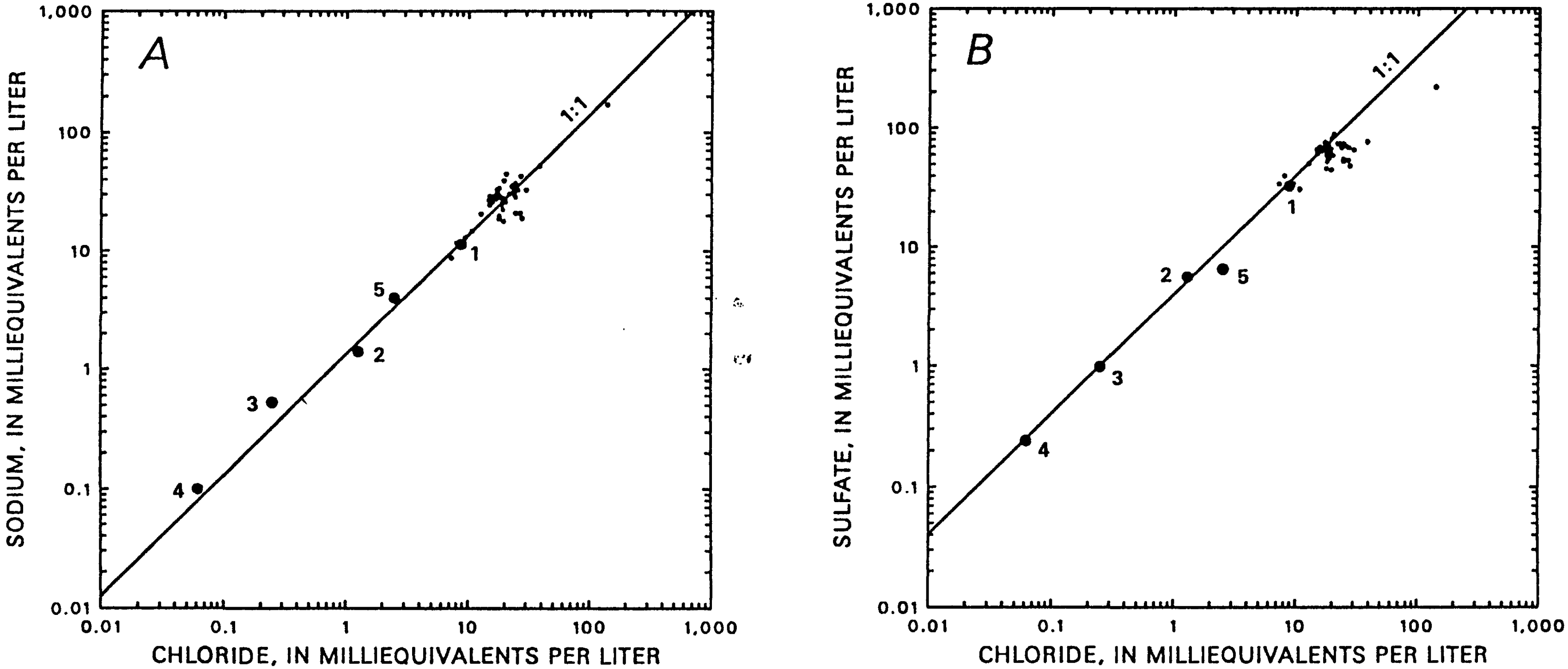
The computer program WATEQF (Plummer and others, 1976) was used to determine if ground water in the study area could be dissolving minerals or precipitating minerals. The program is used to calculate saturation indices [log (IAP/KT), where IAP is the ion-activity product and KT is the temperature-dependent equilibrium constant for a specific chemical reaction] for each mineral. The minerals considered in the study area were calcite ($CaCO_3$), dolomite [$CaMg(CO_3)_2$], and gypsum ($CaSO_4$), on the basis of mineralogy of sediments in the study area (table 1) and water chemistry (table 10).

Saturation indices calculated for calcite, dolomite, and gypsum for water samples collected during September 1986 are shown in table 7 (careful sampling techniques were used and field measurements of pH and alkalinity were made on these samples). A saturation index ranging from 0.1 to -0.1 is assumed to indicate saturation of the water with respect to these minerals. A value greater than 0.1 indicates oversaturation (and possible mineral precipitation), whereas a value less than -0.1 indicates undersaturation (and possible dissolution).

Gypsum may be oversaturated and precipitating at well WG014 and water may be dissolving gypsum from the sediments at wells PG264 and PG271. Water collected from the other wells are at saturation with respect to gypsum.

Saturation indices for calcite indicate that the ground water in the study area is saturated to oversaturated with respect to this mineral. Therefore, calcite should be precipitating from the ground water in the study area. Examination of sediments collected during the drilling of wells at site WG062 found calcite nodules around root hairs to depths of about 15 feet, confirming that calcite was being precipitated in the study area. This may account for the relatively minor variation in calcium concentration and lack of linear correlation between calcium and dissolved-solids concentrations.

Saturation indices for dolomite indicate the ground water in the study area also is saturated to oversaturated with respect to this mineral. However, a kinetically slow reaction rate for dolomite (Bohn and others, 1979, p. 131) and an unfavorable calcium-to-magnesium ratio probably prevent dolomite from precipitating in the study area.



EXPLANATION

- SHALLOW GROUND WATER IN STUDY AREA -- Samples collected during September 1986

2 ● POTENTIAL SOURCES -- See table 4 for water-chemistry data

1 Average for 35 samples of shallow ground water (well depths less than 100 feet; Dinger, 1977, p. 48)
2 Average for 250 samples of intermediate ground water (well depths range from 101 to 300 feet; Dinger, 1977, p. 48)
3 Average for 3 samples of deep ground water (well depths greater than 300 feet; Dinger, 1977, p. 48)
4 Average for 4 samples collected from springs in the Spring Mountains west of Las Vegas (U.S. Geological Survey, data in WATSTORE data base)
5 Average for 4 samples of Colorado River water imported to Las Vegas Valley (Dinger, 1977, p. 48)

FIGURE 5.--Relation of *(A)* sodium and *(B)* sulfate to chloride for (1) shallow ground water in the study area and (2) potential sources of the ground water. Diagonal lines indicate position of equivalent (one-to-one) increases in sodium or sulfate relative to chloride with respect to average values for group 4.

TABLE 7.--*Saturation indices of calcite, dolomite, and gypsum for ground-water samples collected in September 1986*[a]

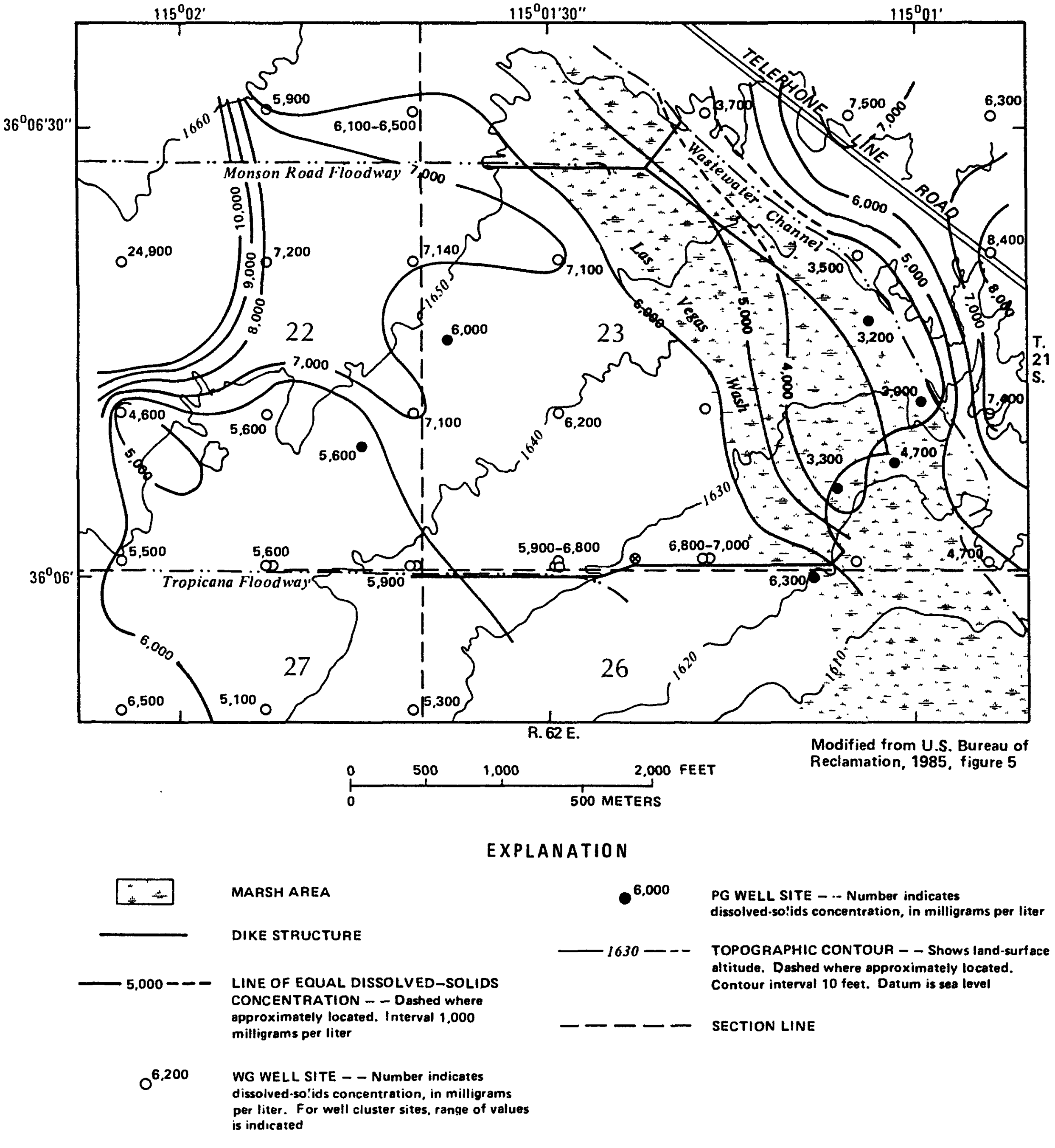
| Well name | $SI_{calcite}$ | $SI_{dolomite}$ | $SI_{gypsum}$ | Well name | $SI_{calcite}$ | $SI_{dolomite}$ | $SI_{gypsum}$ |
|---|---|---|---|---|---|---|---|
| WG011B | 0.39 | 1.00 | 0.02 | WG052 | 0.25 | 0.80 | 0.02 |
| WG012 | .14 | .34 | .00 | WG053AN | .51 | 1.21 | .02 |
| WG012B | .63 | 1.20 | .05 | WG053BN | .40 | .98 | .03 |
| WG013 | .13 | .09 | .02 | WG053CN | .44 | 1.09 | .02 |
| WG014 | .22 | 1.28 | .14 | WG053DN | .32 | .85 | .04 |
| WG021B | .42 | .95 | -.02 | WG053EN | .79 | 1.87 | .06 |
| WG022 | .18 | .27 | .01 | WG055 | .20 | .16 | -.03 |
| WG023 | .16 | .36 | .02 | WG065 | .21 | .75 | .01 |
| WG024 | .13 | .54 | -.06 | WG072 | .24 | .42 | -.01 |
| WG025 | .25 | .71 | -.05 | WG073 | .07 | .36 | .05 |
| WG031 | .12 | .33 | -.01 | WG074 | .33 | .86 | .06 |
| WG033 | .26 | .74 | .03 | WG075 | .18 | .55 | .04 |
| WG034 | .16 | .59 | .00 | WG123 | .16 | .26 | .07 |
| WG035AN | .45 | 1.18 | -.03 | WG126 | .28 | .62 | .02 |
| WG035BN | .53 | 1.41 | -.06 | WG129 | .11 | .34 | .00 |
| WG035CN | .24 | .81 | -.07 | WG132 | .32 | .88 | .04 |
| WG035DN | .29 | .92 | -.06 | PG263 | .29 | .20 | -.08 |
| WG042 | .15 | .55 | .02 | PG264 | .22 | .49 | -.29 |
| WG043 | .24 | .80 | -.08 | PG269 | .18 | .26 | .02 |
| WG043B | .48 | 1.20 | -.04 | PG270 | .45 | 1.04 | .08 |
| WG044BN | .45 | 1.17 | -.01 | PG271 | .45 | .90 | -.21 |
| WG044CN | .47 | 1.22 | -.03 | PG273 | .29 | .67 | -.01 |
| WG044DN | .36 | .94 | .02 | PG274 | .28 | .83 | -.05 |

[a] See text for discussion of saturation indices (SI) and their geochemical significance.

## Areal Differences in Chemical Character

Dissolved-solids concentrations decrease from more than 6,500 mg/L west of the marsh area to 3,000-5,000 mg/L in the marsh area (figure 6). The more dilute water in the marsh area may be due to seepage of treated effluent into the ground both upgradient from and within the study area. The dissolved-solids concentrations of surface water in the channel of Las Vegas Wash near well WG055 (figure 2) ranged from an average of 1,120 mg/L in 1970 to 1,570 mg/L in 1978 (Schmidt and Hess, 1980, p. 28). Dissolved-solids concentrations of water in the wastewater channel near well WG055 ranged from 1,290 to 1,530 mg/L for three dates in 1983 (Roline and Sartoris, 1984, table N-3). Prior to the excavation of the wastewater channel, much of the treated effluent flowed in small channels in the marsh area south of the new channel. Some treated effluent still entered the marsh area from the northwest and flowed through the marsh area during the study.

Water in the Monson Road floodway may also seep into the shallow ground water in the marsh area. The floodway ends in the study area and flow from it also meanders through the marsh area where it mixes with the treated effluent. Dissolved-solids concentrations ranged from about 680 to 4,500 mg/L for samples collected during three dates in 1983 (Roline and Sartoris, 1984, table N-3). The most dilute concentration (680 mg/L) may reflect urban runoff from lawn irrigation or storm runoff. The highest concentration is more indicative of shallow ground water in the western part of the study area and in areas farther west. During periods of little urban runoff or storm runoff, much of the flow in the floodway is from ground-water seepage.



Modified from U.S. Bureau of Reclamation, 1985, figure 5

FIGURE 6.--Dissolved-solids concentrations, September 1986.

Further evidence that treated effluent is mixing with shallow ground water in the study area is provided by ammonium-nitrogen concentrations. Ammonium concentrations exceeded 1 mg/L as nitrogen in wells WG055, WG064, WG072, and PG263 (table 3). These wells are adjacent to the wastewater channel, and the concentrations suggest that the nitrogen-rich treated effluent may be seeping into the ground, at least seasonally, along parts of the channel. The average ammonium concentration in the wastewater channel near well WG064 is 14.6 mg/L as nitrogen (Roline and Sartoris, 1984, table N-4).

Dissolved-solids concentrations in water samples collected from wells WG014 and WG014B were anomalously high (range from 18,600 to 27,500 mg/L). The reason for this anomaly is unclear, because nearby well waters do not have similarly high concentrations. The occurrence of saline water in wells WG014 and WG014B could be attributed to a relatively recent source of contamination, because downgradient wells seem unaffected. Another possibility is that the water at wells WG014 and WG014B is influenced by upward-leaking water from the underlying Muddy Creek Formation that has dissolved gypsum and halite. The hypothetical saline water may then disperse and mix with less saline water in the shallow deposits, resulting in a much lower dissolved-solids concentration in downgradient wells. This hypothesis cannot be evaluated with current data because no study-area wells are completed solely in the underlying deposits (presumably the Muddy Creek Formation), and, therefore, hydraulic heads and the quality of water in the underlying deposits are unknown.

## Vertical Variations in Chemical Character

Analyses of dissolved-solids concentrations at cluster-well sites WG035, WG044, and WG053 (location shown in figure 2) indicate that dissolved-solids concentrations are highest in the shallowest wells (figure 7). These higher concentrations are probably due to evapotranspiration during warmer months from April through September which results in the precipitation of dissolved solids in the capillary fringe above the water table. In the winter months, the water table rises and dissolves some of the minerals that formed during the summer months. This process, which has been previously discussed by Smith and Drever (1976, p. 1081) and Naff and others (1975), is most apparent in the shallowest well at site WG035 (well WG035AN, shown in figure 7).

The shallowest well at site WG044 (well WG044AN) does not show as great a change in dissolved solids as the shallowest wells at sites WG035 and WG053 (wells WG035AN and WG053AN in figure 7). In addition, the highest concentration at well WG044AN was for a sample collected in June rather than January 1987, whereas the January samples for wells WG035AN and WG053AN contained the highest concentration of dissolved solids. This difference can be explained by the location of the slotted interval compared with the location of the water table for each shallow well. The slotted interval for well WG044AN is farther below the water table than for either well WG035AN or WG053AN (figure 8). The lowest dissolved-solids concentrations of the three shallow wells are from well WG044AN, whereas the highest concentrations of dissolved solids are from well WG035AN where the water table is within the slotted interval. This suggests a thin layer of more saline ground water near the water table.

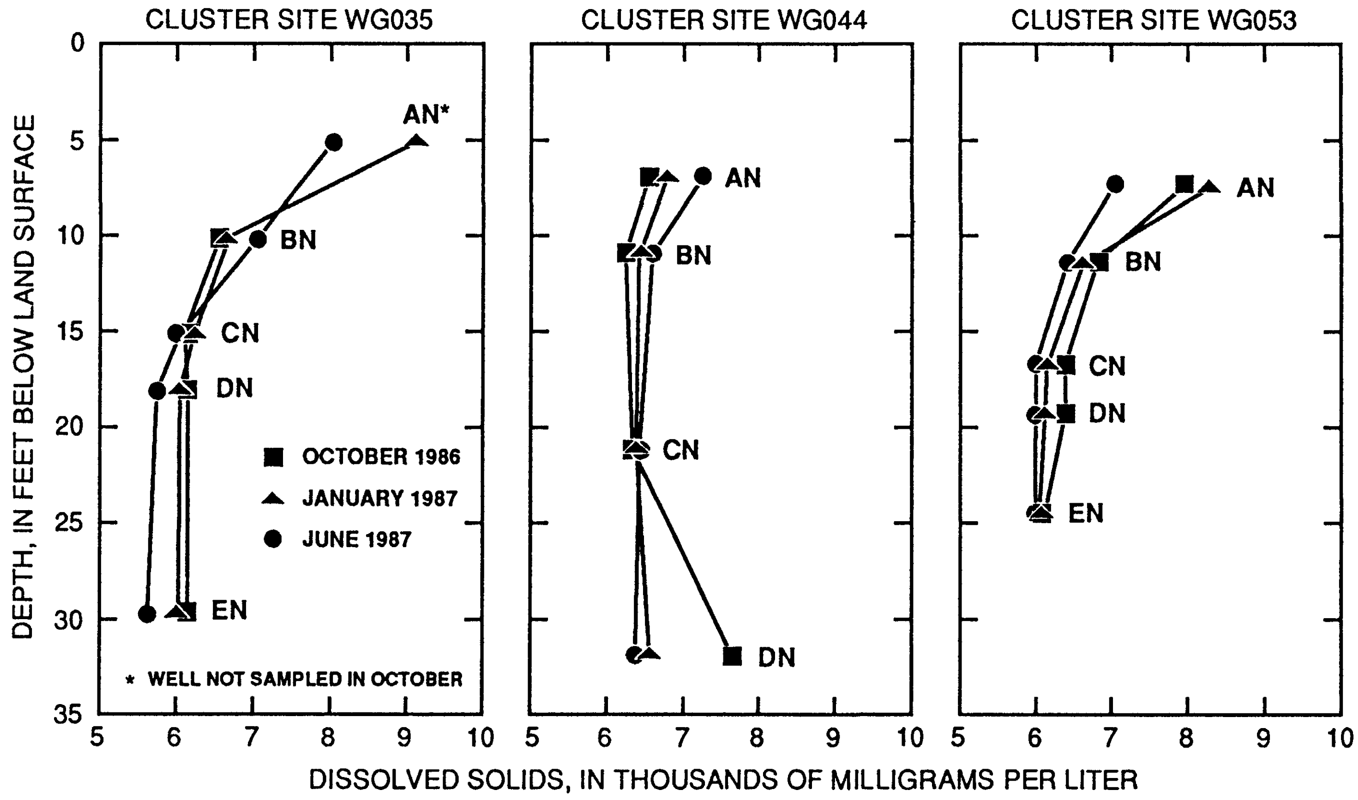


FIGURE 7.--Relation between dissolved-solids concentration and depth for water from well clusters at sites WG035, WG044, and WG053, October 1986-June 1987. These sites are aligned approximately parallel to the hydraulic gradient, with site WG035 farthest upgradient (see figure 2 for site locations).

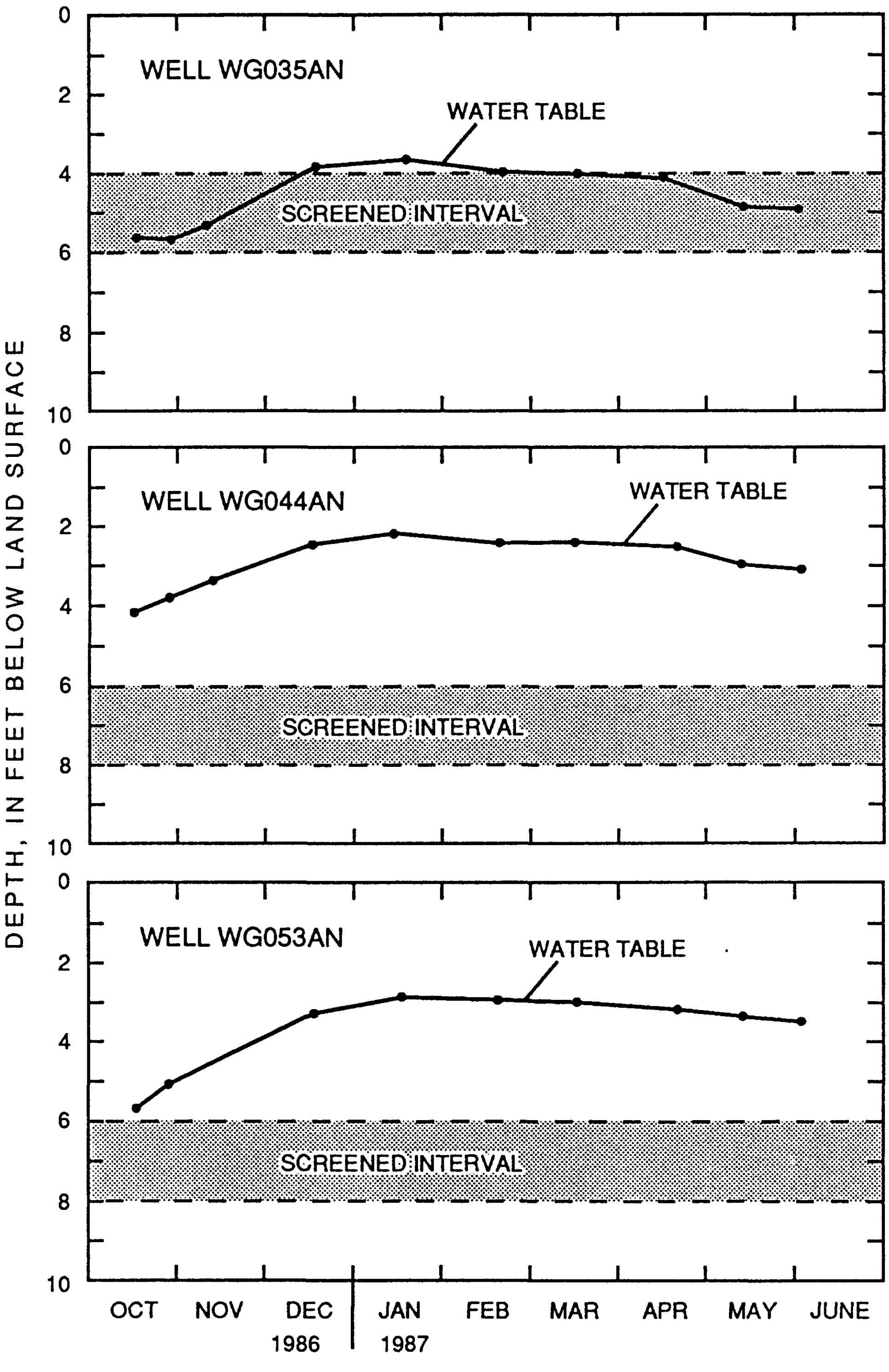


FIGURE 8.--Relation between water-table depth and position of screened interval for wells WG035AN, WG044AN, and WG053AN, October 1986-June 1987.

The presence of ubiquitous salt crusts at land surface over parts of the study area testifies to evaporative losses of water from the ground. A sample of the salt crust was collected near a pit midway between sites WG042 and WG052 and analyzed for mineral content using x-ray diffraction. The results of the analyses are shown in table 1. Analyses of water samples collected in adjacent wells were used with the computer program SNORM (Bodine and Jones, 1986) to identify the minerals that may precipitate from the water if it were allowed to evaporate. The results suggest that the minerals bloedite, halite, gypsum (or anhydrite), and epsomite would form if the water from the adjacent wells were evaporated (table 8). These minerals are nearly the same as those identified from x-ray diffraction (table 1), thus providing further evidence that the surface salt crust is the result of evaporation of shallow ground water.

TABLE 8.--*Results from simulation of complete evaporation of water represented by wells WG042 and WG052 sampled on September 23, 1986*[a]

| Normative salt assemblage | | Percentage, on basis of anhydrous weight | |
|---|---|---|---|
| Mineral | Formula | Well WG042 | Well WG052 |
| Epsomite | $MgSO_4.7H_2O$ | 24 | 25 |
| Anhydrite | $CaSO_4$ | 28 | 26 |
| Halite | NaCl | 23 | 20 |
| Bloedite | $Na_2Mg(SO_4)_2.4H_2O$ | 15 | 19 |
| Polyhalite | $Ca_2K_2Mg(SO_4)_4.2H_2O$ | 7 | 6 |
| Magnesite | $MgCO_3$ | 3 | 3 |
| | Total | 100 | 99 |

[a] Results from computer program written by Bodine and Jones (1986).

## Seasonal Variations in Chemical Character

The interpretation of seasonal variation is limited by availability of a maximum of four samples from each well. Changes in dissolved-solids concentrations in the Whitney study area are represented by frequency plots of the percentage change from April-May to September 1986, from September-October 1986 to January 1987, and from January to June 1987 (figure 9). Except for seemingly anomalous changes in dissolved solids that exceeded 50 percent for water collected from wells PG263, PG264, PG270, and WG013, changes at most other wells were less than 25 percent. Dissolved-solids concentrations of water both decreased and increased between sampling periods, suggesting differing trends depending on the location and sampling depth of each well.

Changes in dissolved-solids concentrations of greater than 25 percent in wells PG270, PG263, and PG264 (figure 9) probably are related to changes in the seepage of nearby surface water. The increase in dissolved-solids concentration in well PG270, from 1,840 mg/L in May 1986 to 6,280 mg/L in September 1986 (figure 9 and table 10), may be caused by the diversion of surface flow away from the well after construction of a dike for the detention basin in August 1986. A small channel was located next to the well prior to the dike. Wells PG263 and PG264 are within 100 feet of the wastewater channel. Variations in these wells may be related to seasonal changes in seepage between the wastewater channel and the shallow ground water.

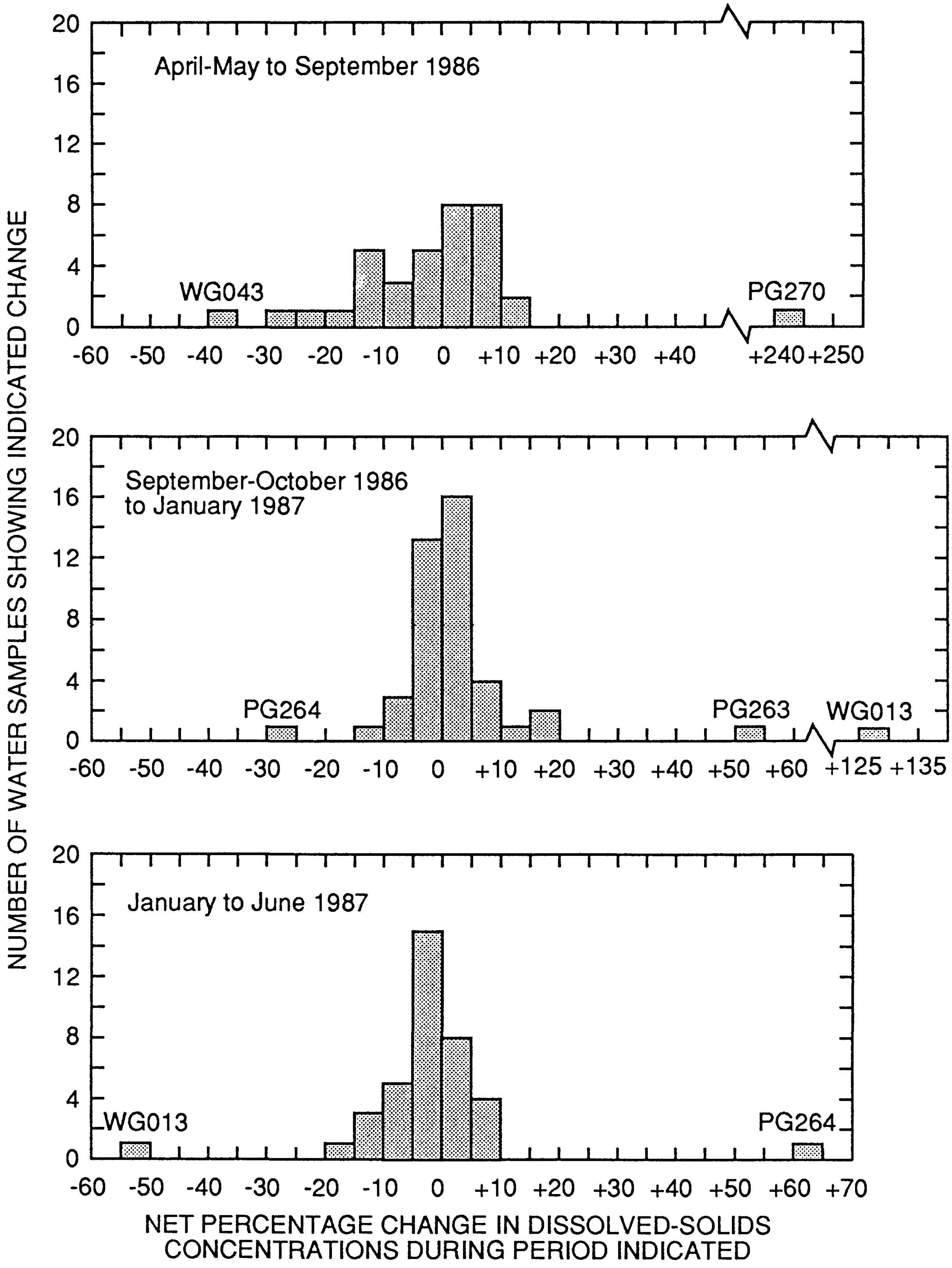


FIGURE 9.--Comparison of net percentage change in dissolved-solids concentration during three periods between April 1986 and June 1987. Specific wells showing abnormally large change are identified using U.S. Bureau of Reclamation designation.

Changes in dissolved-solids concentrations of more than 25 percent in wells WG013 and WG043 are not related to nearby surface-water sources. The dissolved-solids concentration of water collected from well WG013 increased from 4,620 mg/L in September 1986 to 10,500 mg/L in January 1987. The cause of the increase in well WG013 is unknown, but it might be the result of dissolution of salts that had previously precipitated near land surface, when the water table rose during the winter. The well is slotted over the entire length of the casing. The dissolved-solids concentration for water collected at WG013 in June 1987 was again about 5,000 mg/L (table 10). Given that the dissolved solids returned to concentrations observed for samples collected in April and September 1986 (table 10), another possibility is that a sample was mislabeled either in the field or in the laboratory.

The dissolved-solids concentration of water from well WG043 decreased from 9,750 mg/L in April 1986 to 6,220 mg/L in September 1986. The reason for this decrease is unknown but it may be the result of poor well development prior to the initial sample in April 1986. The maximum change between subsequent samples is only about 15 percent.

General seasonal trends in concentrations of dissolved constituents within and among the four sample dates (April-May 1986; September 1986; January 1987; and June 1987) were evaluated using descriptive statistics. A total of 17 wells had analyses for each sample date (table 10), but the analyses from wells PG270 and WG013 were not used because changes in water quality are attributed to other causes (as previously discussed).

The distributions of dissolved-solids concentrations and concentrations of major constituents of water sampled from 15 wells are similar for each sample date (figure 10). Median concentrations do not show a consistent pattern of change between sample dates. However, with the exceptions of bicarbonate and silica, the 75 percentile for concentrations of dissolved solids and major constituents is consistently lowest for samples collected during September 1986.

Possible seasonal trends in the data for the 15 wells were investigated by calculating the percentage change in concentrations of dissolved solids and major constituents between the four sample dates (April-May to September 1986; September 1986 to January 1987; January to June 1987). The percentage changes in concentration were then linearly regressed against the three periods to determine whether a parametric statistical test could be used in the analysis of trends. The resultant residuals from the regression equations were homogeneous and normally distributed about a mean of zero. Thus, an analysis-of-variance procedure was used to determine whether a significant part of the variability in the percent change for each constituent could be attributed to the three periods.

Means of percentage change in concentrations were compared using Fisher's least-significant-difference test (Steel and Torrie, 1980, p. 172-177) at the 0.05 probability level. Results of the statistical analyses are summarized in figure 11. With the exceptions of magnesium, sodium, and potassium, the differences in means of percentage change in concentrations were not significant at the 0.05 probability level during the three periods. Also, the mean percentage change in concentrations was usually less than 5 percent, which is within the range of uncertainty for the analytical procedures used to determine concentrations of dissolved constituents in the water (Hem, 1985, p. 163). Differences in means of percentage change for magnesium, sodium, and potassium were significant at the 0.05 probability level. For these constituents, the mean percentage changes in concentrations from April to September 1986 were significantly different from the mean percentage changes from September 1986 to January 1987. This suggests that the decrease in concentration for these constituents may be related to seasonal changes whereby concentrations of magnesium, sodium, and potassium decrease during the summer and increase during the winter. Although not statistically significant, means of percentage changes in concentrations of dissolved solids and the other constituents (except bicarbonate and silica) show a similar trend (figure 11).

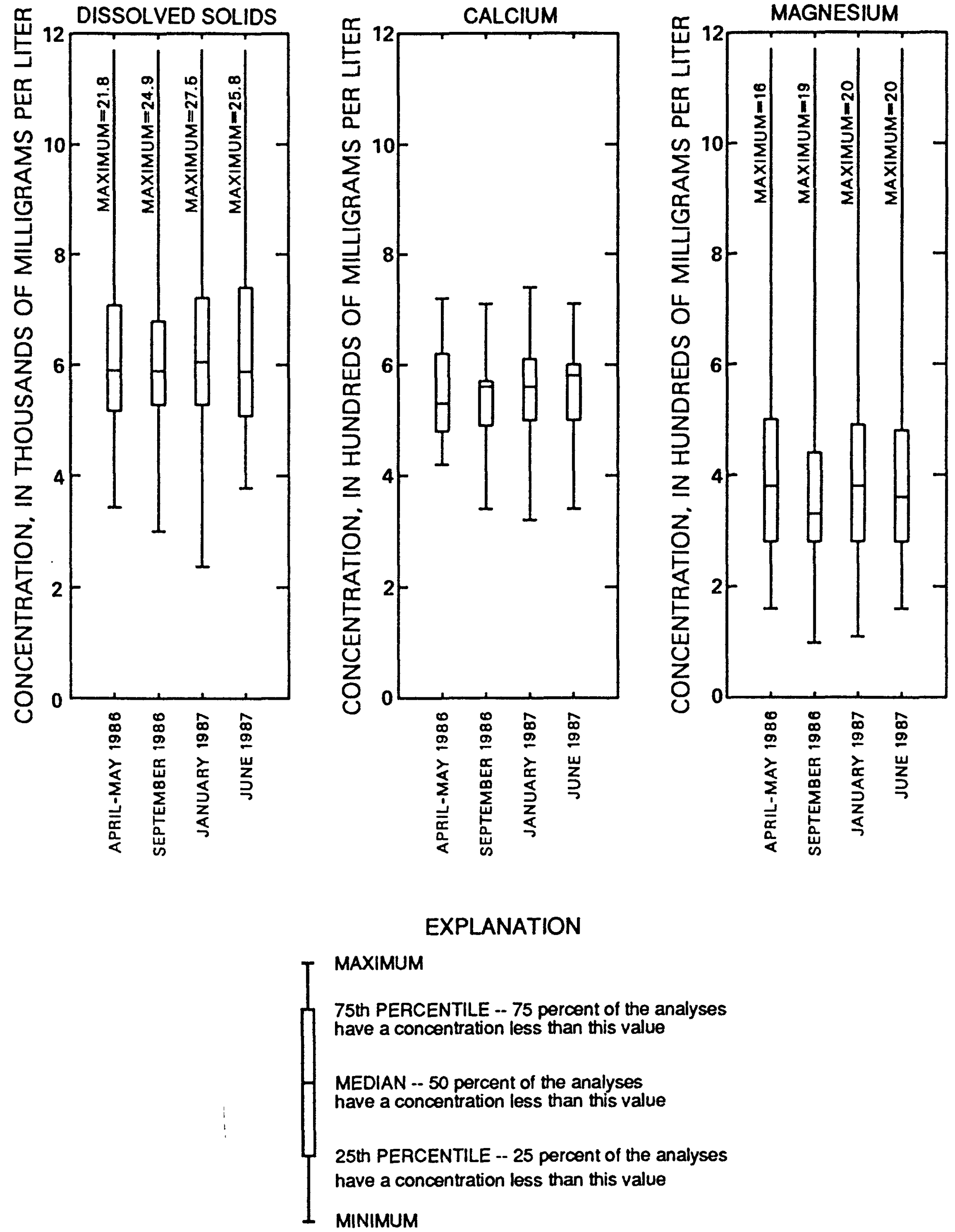


FIGURE 10.--Distribution of concentrations of dissolved solids and major dissolved constituents for water samples collected between April 1986 and June 1987. The distributions are based on analyses of water sampled from 15 wells during April-May 1986, September 1986, January 1987, and June 1987 (table 10; wells WG013 and PG270 were excluded).

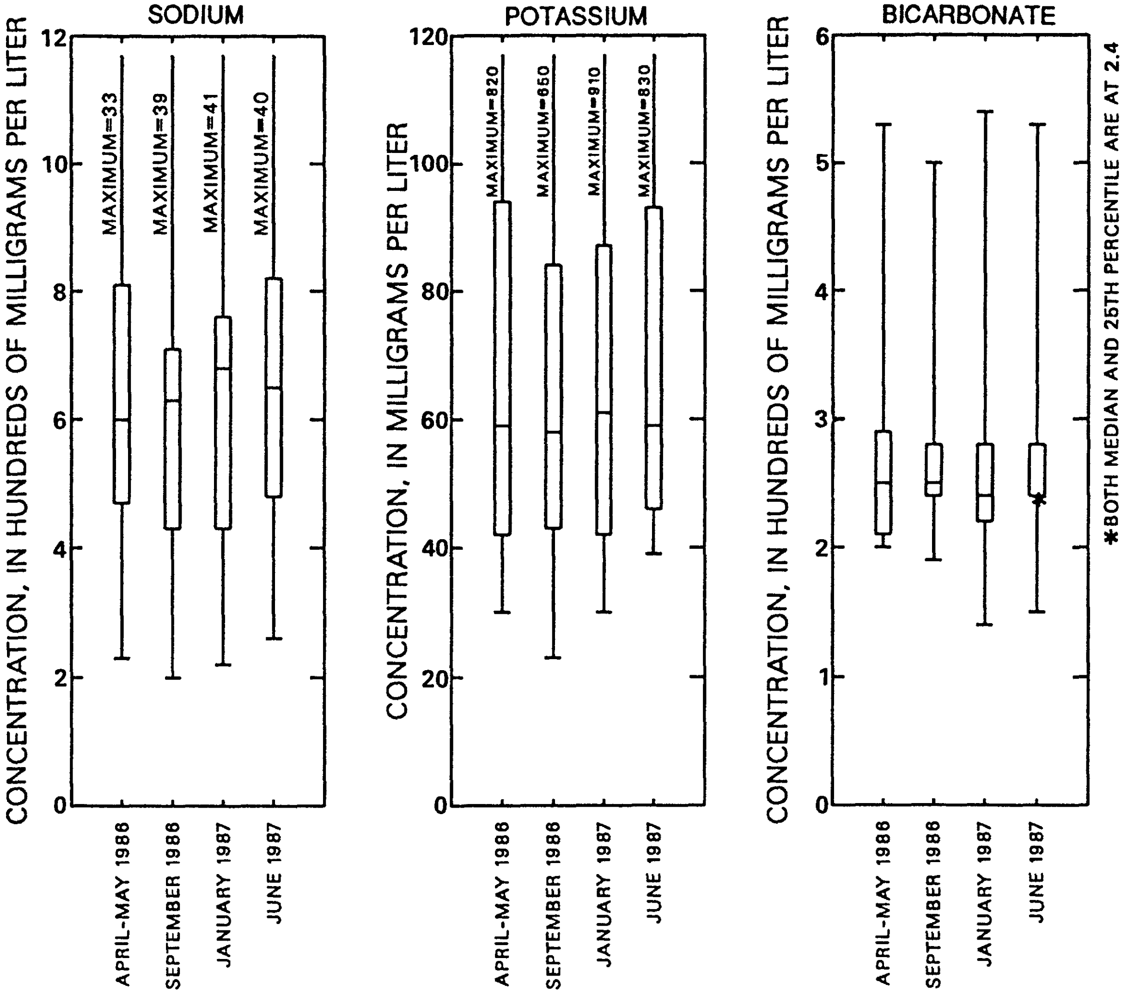


FIGURE 10.--Continued.

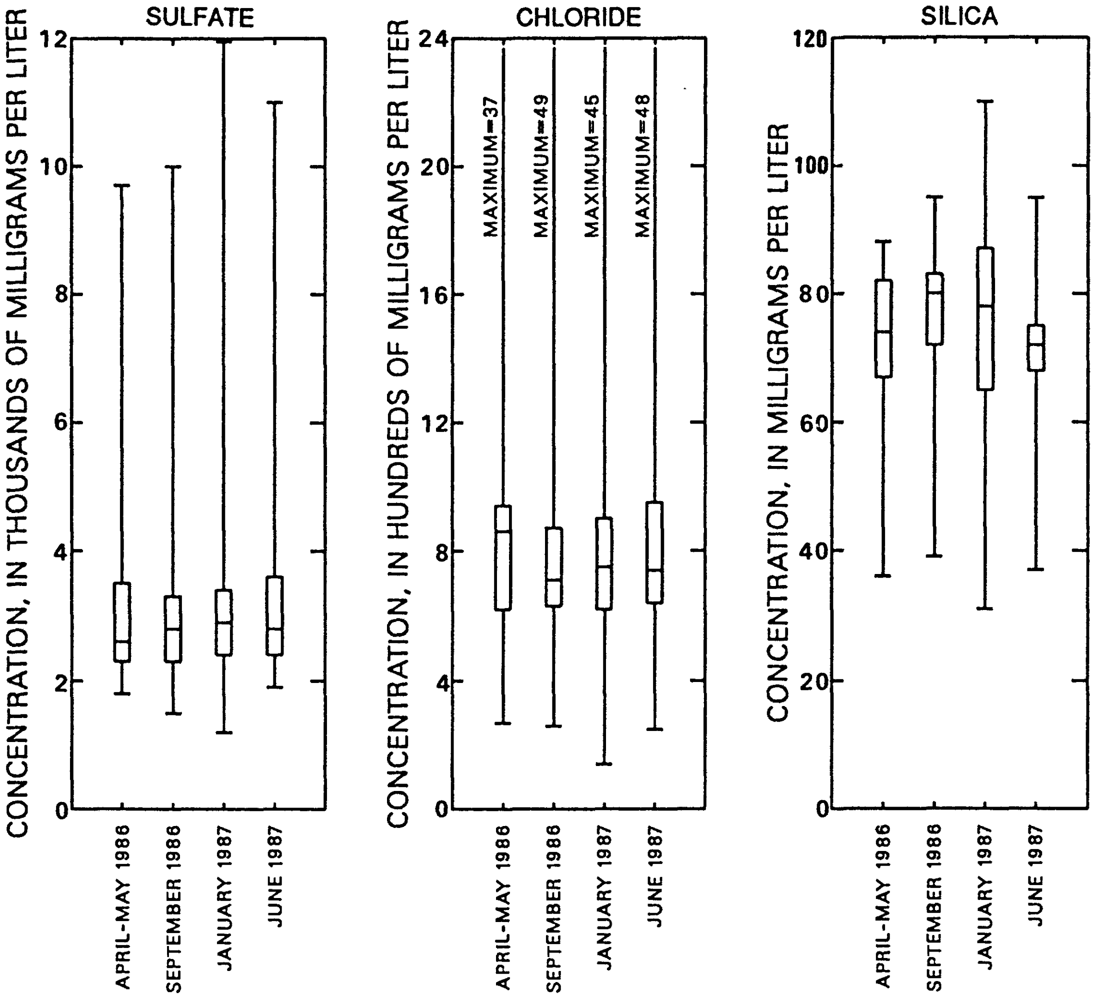


FIGURE 10.--Continued.

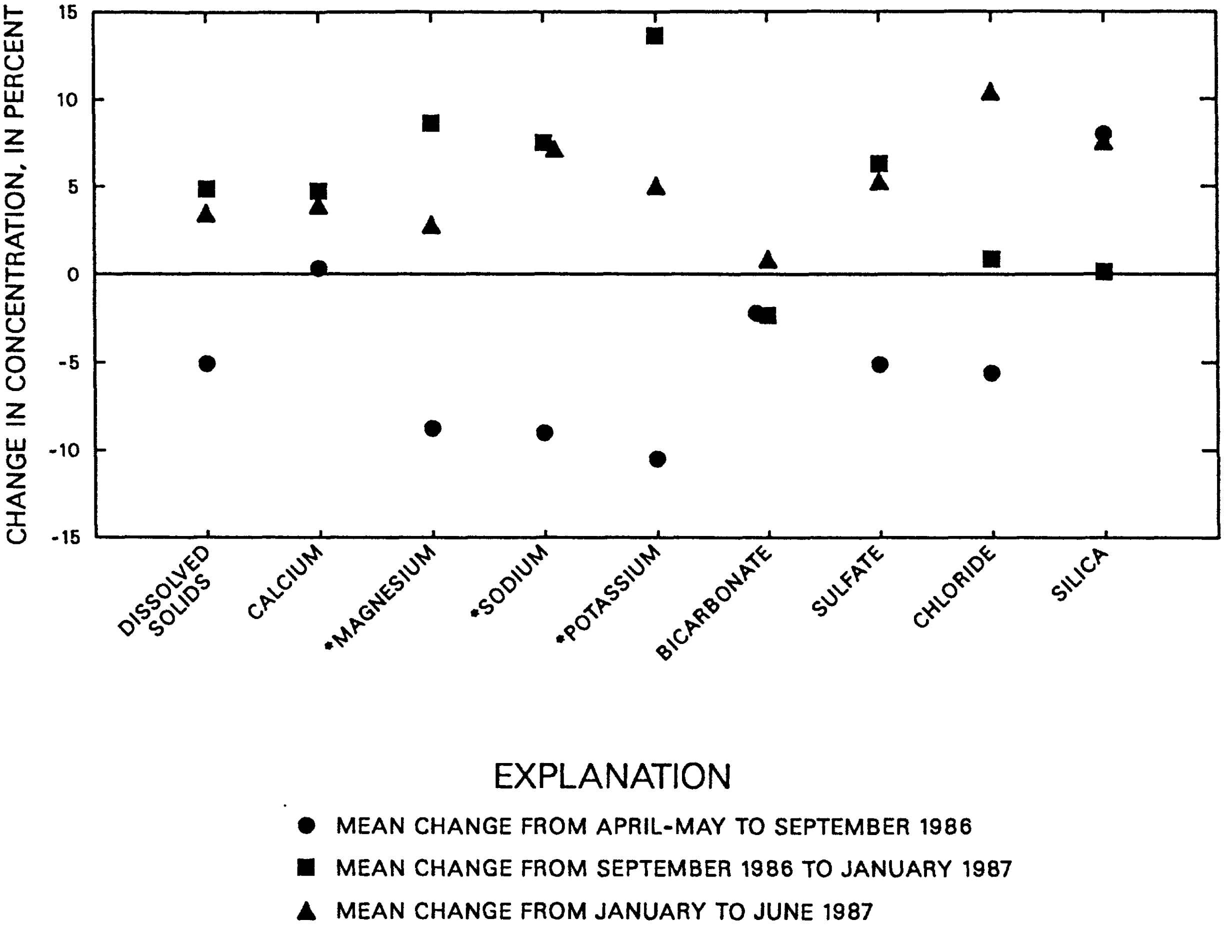


FIGURE 11.--Mean change in concentration of dissolved solids and major dissolved constituents during three periods between April 1986 and June 1987. Means are based on analyses of water from 15 wells that were sampled in April-May 1986, September 1986, January 1987, and June 1987 (table 10; wells WG013 and PG270 were excluded). Asterisks next to magnesium, sodium, and potassium indicate significant differences between some of the mean-change values at the 0.05 probability level, on the basis of the Fischer's-least-significant-difference statistical test. For these three constituents, the difference between mean-change values from April-May to September 1986 and from September 1986 to January 1987 exceeds the least significant difference at the 0.05 probability level. The least significant differences are: 12.4 percent for magnesium; 14.4 percent for sodium; and 16.7 percent for potassium. For sodium, the difference between the mean-change values from September 1986 to January 1987 and from January to June 1987 also exceeds the least significant difference. Differences between all other pairs of mean-change values in the graph are not significantly different.

## Distribution of Nitrate and Nitrite

The proximity of the study area to the wastewater facilities and to the urban environment increases the possibility of elevated concentrations of dissolved nitrogen in the shallow ground water. The distribution of nitrate plus nitrite is shown in figure 12 and is based on analyses done by the U.S. Bureau of Reclamation Soils Laboratory for September and October 1986. Total-nitrogen concentrations analyzed by the U.S. Geological Survey laboratory for wells also are shown. The distribution of nitrate plus nitrite is much different from the distribution of dissolved-solids concentrations (figure 6). Anomalously high concentrations of nitrate plus nitrite (10 mg/L or more, as nitrogen) in wells generally correspond to areas where sludge from the wastewater facilities periodically is tilled into the ground (figure 12). Anomalously high concentrations were also determined from two wells adjacent to the wastewater channel.

In contrast, relatively low nitrogen concentrations correspond with the marsh area (figure 12). Inflow to the marsh area includes seepage from the Monson Road floodway and treated effluent that seeps into the ground upstream from the study area, within the marsh area, and along the wastewater channel. Assimilation of nitrogen by marsh vegetation may be responsible for the more dilute nitrate and nitrite concentrations in this part of the study area.

Dinger (1977, p. 52), in his investigation of ground-water quality in Las Vegas Valley, related much of the elevated nitrate concentrations in water from two-thirds of the wells he sampled in the eastern part (including the Whitney study area) to sewage effluent. The dissolution of natural nitrogen-rich deposits may also contribute to the elevated nitrate and nitrite concentrations in the ground water; however, no nitrate-bearing minerals were detected by the x-ray diffraction analysis of sediments in the study area.

The distribution of nitrate-plus-nitrite and dissolved-oxygen concentrations in water sampled at cluster-well sites WG035, WG044, WG053, and WG062 (figure 13) indicate that denitrification by plant uptake, and perhaps reduction by organic material, is decreasing the concentration of nitrate plus nitrite in the shallow ground water. This is evidenced by substantially lower concentrations of nitrate plus nitrite and dissolved oxygen in water from the shallow wells than in water from the deeper wells (figure 13), and by an opposite trend for bicarbonate. Dissolved-oxygen concentrations are not available for water from cluster-well site WG062. Within the marsh area, a layer of organic muck 1 to 2 feet thick commonly is present near land surface. Organic matter was detected primarily in sandy silts to a depth of about 8 feet below land surface at cluster well site WG062 (within the marsh area). This organic matter, in addition to decreasing nitrate-plus-nitrite and dissolved-oxygen concentrations, may be increasing bicarbonate concentrations in the shallow ground water.

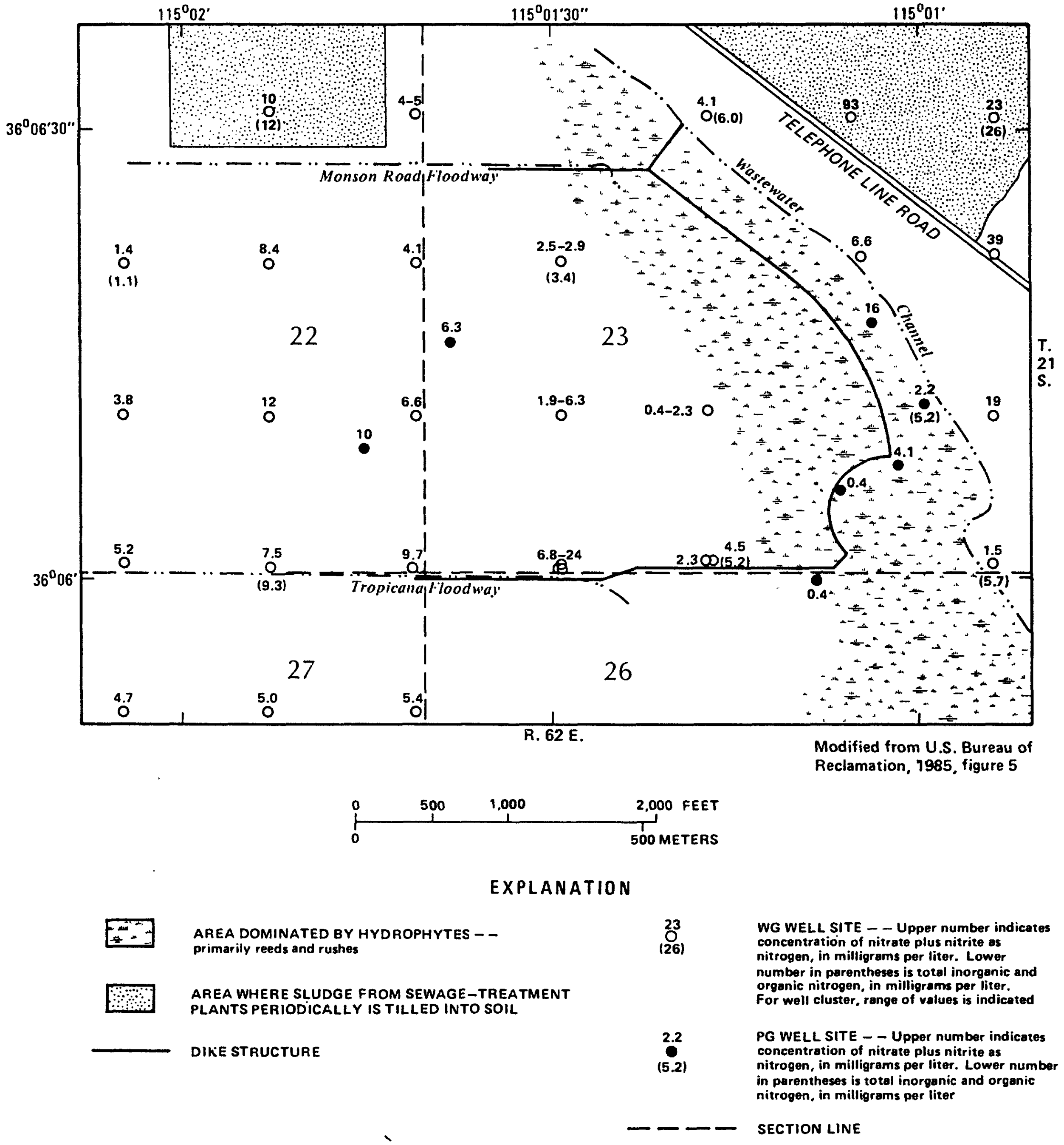


FIGURE 12.--Nitrogen concentrations, September and October 1986. Data on nitrate plus nitrite are from U.S. Bureau of Reclamation Soils Laboratory, Boulder City, Nev. Data on total inorganic and organic nitrogen are from U.S. Geological Survey Laboratory, Arvada, Colo., and are given in table 3.

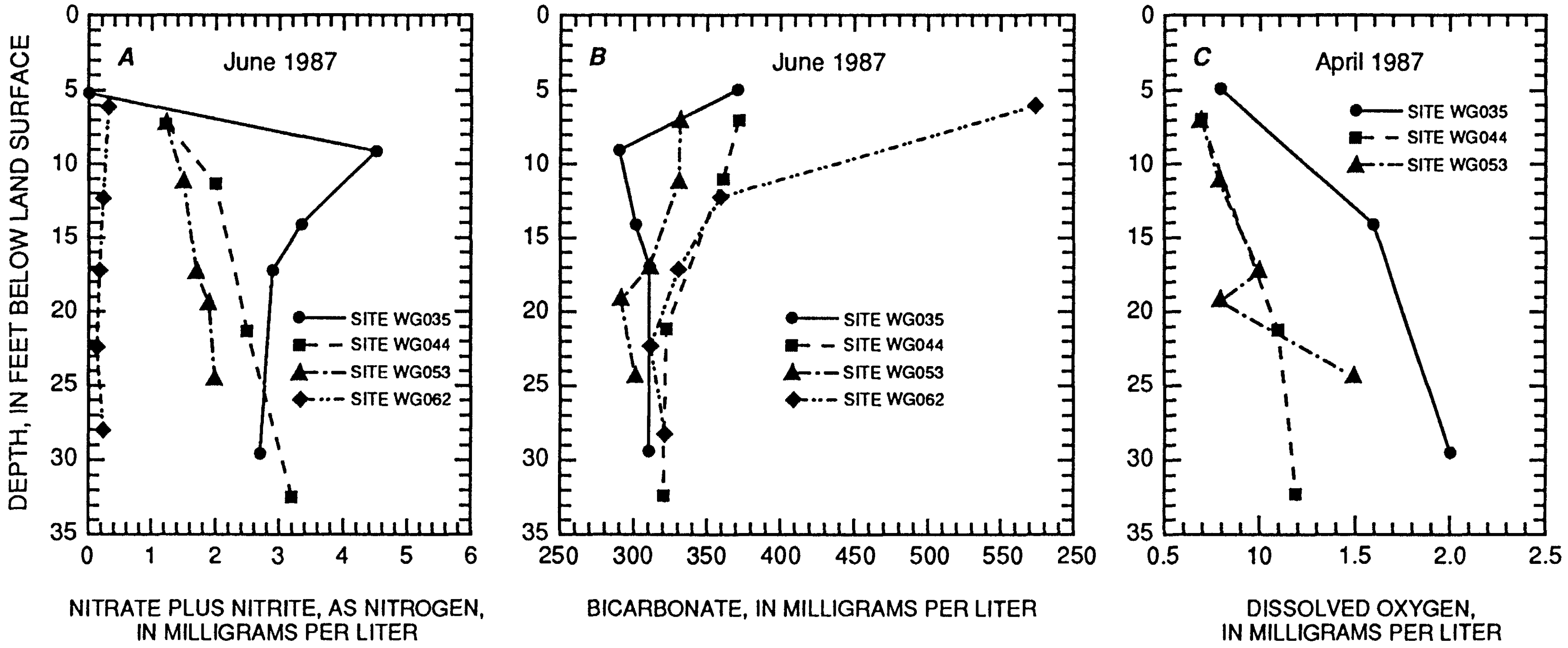


FIGURE 13.--Relation between nitrate-plus-nitrite, bicarbonate, and dissolved-oxygen concentrations and depth for well water from cluster-well sites WG035, WG044, WG053, and WG062. These sites are aligned approximately parallel to the hydraulic gradient, with site WG035 farthest upgradient (see figure 2 for site locations). Dissolved-oxygen concentrations are not available for cluster-well site WG062.

# SUMMARY AND CONCLUSIONS

Las Vegas Wash was identified by the U.S. Bureau of Reclamation as one of four areas where structures might be built to control salinity input to the Colorado River. Shallow ground-water detention basins along Las Vegas Wash were proposed to reduce the amount of dissolved solids entering the wash from ground-water seepage. A prototype basin was designed and the natural ground-water system was studied to determine if the detention basin concept would work as planned. This report describes the distribution and seasonal variations of ground-water quality in the vicinity of the prototype detention basin prior to construction of a slurry wall. The report also describes the processes that may control the chemistry of the ground water.

The area that incorporates the prototype detention basin is referred to as the Whitney study area and is about 7 miles southeast of downtown Las Vegas. It is a rectangular parcel of land approximately 1 $mi^2$ in area. A wastewater channel transverses the northeast part of the study area. The Tropicana and Monson Road floodways, which carry urban and storm runoff, enter the area from the west. The floodway channels end within the study area, and water from the floodways meanders through marsh areas. Some treated effluent also meanders through the marshland; prior to construction of a wastewater channel, all upstream effluent flowed through the marshland.

The surficial deposits are composed of alluvial-fan and flood-plain sediments. The alluvial-fan deposits are in the northeast part of the study area, whereas flood-plain deposits dominate elsewhere. The Muddy Creek Formation of late Tertiary age is thought to underlie the surficial deposits, but it was not absolutely identified in the study area. Minerals in the surficial deposits were identified by x-ray diffraction. In general, the deposits consist of quartz, calcite, and dolomite, but seven samples contained 1 to 15 percent gypsum.

The general direction of ground-water flow through the surficial deposits is from northwest to southeast, paralleling the course of Las Vegas Wash. The water table is generally 1 to 7 feet below land surface, except beneath the alluvial-fan deposits where the depth to water may exceed 20 feet. The water table fluctuates annually, declining during the summer in response to evapotranspiration and rising in the winter, when evapotranspiration is minimal.

Geochemical interpretations of water-quality analyses of samples collected from about 65 shallow wells in the Whitney study area suggest that the amounts and distribution of major ions in the shallow ground water are influenced or controlled by: (1) infiltration of treated effluent upgradient from and within the study area and infiltration of urban runoff primarily from Monson Road floodway; (2) land disposal of sludge from sewage-treatment facilities over parts of the study area; (3) dissolution of minerals as water moves through sediments in Las Vegas Valley, including those of the study area; and (4) evapotranspiration, which tends to concentrate solutes near the water table.

Dissolved-solids concentrations of ground water vary throughout the study area, and range from about 2,000 to about 28,000 mg/L. Concentrations generally decrease from more than 6,500 mg/L west of the marsh areas to 3,000-5,000 mg/L within the marsh areas. This decrease may also be caused by seepage of more dilute sewage effluent in the marsh area or along the wastewater channel. The average dissolved-solids concentration of water in the wastewater channel is about 1,400 mg/L.

Sulfate is the dominant anion in the shallow ground water in the study area. Sodium, calcium, and magnesium are generally the dominant cations.

Dissolved-solids concentrations are linearly correlated with concentrations of magnesium, sodium, potassium, sulfate, and chloride, whereas calcium, bicarbonate, and silica do not correlate. This suggests that calcium, bicarbonate, and silica concentrations (1) may be controlled by different processes than those controlling the concentrations of the other constituents, and (2) may be affected by mineral solubility.

Sodium and chloride concentrations increase proportionally, suggesting that evapotranspiration or dissolution of halite are responsible. Sulfate does not increase as much as chloride in water from several wells in the study area, suggesting that sulfate may be precipitating as gypsum in some places. This conclusion is also supported by mineral saturation indices, which indicate that the shallow ground water is generally saturated with respect to gypsum, as well as calcite and dolomite. However, the saturation indices of water from a few wells near the wastewater channel indicate that the ground water may be dissolving gypsum locally.

Dissolved-solids concentrations generally increase near the water table at sites where multiple wells were drilled to different depths. The higher concentrations of dissolved solids in ground water near the water table are caused, presumably, by evapotranspiration. In summer months, when evapotranspiration is at a maximum, and in locations where the depth to water is only a foot or so, water in the capillary fringe may become concentrated with dissolved solids. This process may explain the formation of a salt crust at land surface over much of the western part of the Whitney study area. During the cooler winter months, when evapotranspiration is minimal, the water table rises, and the previously deposited salts may be redissolved into the water near the water table.

Dissolved nitrate and nitrite concentrations in the shallow ground water also vary in the study area. They are generally highest below areas where sludge from nearby sewage-treatment facilities is tilled into the earth, and generally lowest in the marshy areas. Denitrification probably depletes nitrate and nitrite concentrations in these areas.

# BASIC DATA

This section includes compilations of the principal data used in preparation of this report. Table 9 gives locations, construction data, and representative water-level measurements for wells in the study area. Additional water-level measurements are available from the U.S. Geological Survey in Carson City, Nev. Table 10 gives water-quality data for wells in the study area.

TABLE 9.--*Location, construction, and selected water levels for wells*

[All wells are constructed of 2-inch polyvinylchloride casing, and except for wells at site WG062, all were drilled by U.S. Bureau of Reclamation. --, no data available]

| | | | Depth[1] (feet below land surface) | | | Water level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Reported slotted interval | | | | |
| Well name | Standard identification[2] number | Local identification[3] number | Measured total | Top | Bottom | Feet below land surface | Date measured | Land-surface altitude (feet above sea level) |
| WG011N | 360551115020702 | 212 S21 E62 27ABCA2 | 17 | 15 | 17 | 4.04 | 10-15-86 | 1,642 |
| WG012 | 360602115020701 | 212 S21 E62 22DCCD1 | 32 | 0 | 33 | 6.08 | 03-25-86 | 1,650 |
| WG012B | 360602115020702 | 212 S21 E62 22DCCD2 | 20 | 18 | 20 | 6.46 | 10-15-86 | 1,650 |
| WG013 | 360612115020701 | 212 S21 E62 22DCBA1 | 29 | 0 | 31 | 4.43 | 03-25-86 | 1,651 |
| WG014 | 360621115020701 | 212 S21 E62 22DBBD1 | 22 | 0 | 22 | 2.68 | 03-25-86 | 1,656 |
| WG014B | 360621115020702 | 212 S21 E62 22DBBD2 | 20 | 18 | 20 | 5.13 | 11-12-86 | 1,656 |
| WG021 | 360551115015501 | 212 S21 E62 27AACB1 | 24 | 0 | 24 | 4.12 | 03-26-86 | 1,642 |
| WG021N | 360551115015502 | 212 S21 E62 27AACB2 | 20 | 18 | 20 | 4.21 | 10-15-86 | 1,640 |
| WG022 | 360602115015502 | 212 S21 E62 22DDCD2 | 26 | 0 | 22 | 3.86 | 03-25-86 | 1,645 |
| WG023 | 360612115015501 | 212 S21 E62 22DDBB1 | 22 | 0 | 22 | 0.1 | 03-26-86 | 1,647 |
| WG023B | 360612115015502 | 212 S21 E62 22DDBB2 | 20 | 18 | 20 | 2.03 | 10-16-86 | 1,647 |
| WG024 | 360622115015501 | 212 S21 E62 22DABC1 | 24 | 0 | 24 | 7.0 | 03-26-86 | 1,656 |
| WG025 | 360632115015501 | 212 S21 E62 22ADCB1 | 23 | 0 | 23 | 4.65 | 03-25-86 | 1,659 |
| WG031 | 360552115014301 | 212 S21 E62 27AADA1 | 34 | -- | -- | 2.76 | 03-26-86 | 1,635 |
| WG032 | 360602115014101 | 212 S21 E62 23CCCC1 | 22 | -- | -- | 1.85 | 03-26-86 | 1,638 |
| WG033 | 360612115014301 | 212 S21 E62 22DDAA1 | 29 | 0 | 29 | 4.84 | 03-26-86 | 1,646 |
| WG034 | 360622115014201 | 212 S21 E62 22DADA1 | 28 | 0 | 29 | 4.82 | 03-26-86 | 1,653 |
| WG034B | 360622115014202 | 212 S21 E62 22DADA2 | 20 | 18 | 20 | 6.98 | 10-17-86 | 1,653 |
| WG035A | 360632115014301 | 212 S21 E62 22ADDA1 | 6 | 0 | 6 | 3.14 | 03-25-86 | 1,654 |
| WG035B | 360632115014302 | 212 S21 E62 22ADDA2 | 11 | 5 | 10 | 3.14 | 03-25-86 | 1,654 |
| WG035C | 360632115014303 | 212 S21 E62 22ADDA3 | 16 | 10 | 15 | 3.24 | 03-25-86 | 1,654 |
| WG035D | 360632115014304 | 212 S21 E62 22ADDA4 | 20 | 15 | 20 | 3.33 | 03-25-86 | 1,654 |
| WG035E | 360632115014305 | 212 S21 E62 22ADDA5 | 25 | 20 | 25 | 4.32 | 03-25-86 | 1,654 |
| WG035AN | 360632115014310 | 212 S21 E62 22ADDA10 | 6 | 4 | 6 | 5.63 | 10-17-86 | 1,654 |
| WG035BN | 360632115014309 | 212 S21 E62 22ADDA9 | 10 | 8 | 10 | 5.88 | 10-17-86 | 1,654 |
| WG035CN | 360632115014308 | 212 S21 E62 22ADDA8 | 15 | 13 | 15 | 5.88 | 10-17-86 | 1,654 |
| WG035DN | 360632115014307 | 212 S21 E62 22ADDA7 | 18 | 16 | 18 | 5.86 | 10-17-86 | 1,654 |
| WG035EN | 360632115014306 | 212 S21 E62 22ADDA6 | 30 | 28 | 30 | 5.86 | 10-17-86 | 1,654 |
| WG042 | 360602115012901 | 212 S21 E62 23CCDD1 | 23 | -- | -- | 2.08 | 03-26-86 | 1,632 |
| WG043 | 360612115013001 | 212 S21 E62 23DCAB1 | 24 | 0 | 26 | 2.29 | 03-26-86 | 1,640 |
| WG043B | 360612115013002 | 212 S21 E62 23DCAB2 | 22 | 19 | 21 | 4.55 | 10-15-86 | 1,640 |
| WG044A | 360622115013001 | 212 S21 E62 23CBAC1 | 5 | 0 | 5 | 2.30 | 03-26-86 | 1,645 |
| WG044B | 360622115013002 | 212 S21 E62 23CBAC2 | 11 | 5 | 10 | 2.32 | 03-26-86 | 1,645 |
| WG044C | 360622115013003 | 212 S21 E62 23CBAC3 | 11 | 6 | 11 | 2.29 | 03-26-86 | 1,645 |
| WG044AN | 360622115013007 | 212 S21 E62 23CBAC7 | 8 | 6 | 8 | 4.17 | 10-16-86 | 1,645 |
| WG044BN | 360622115013006 | 212 S21 E62 23CBAC6 | 13 | 10 | 12 | 3.95 | 10-16-86 | 1,645 |
| WG044CN | 360622115013005 | 212 S21 E62 23CBAC5 | 23 | 20 | 22 | 3.83 | 10-16-86 | 1,645 |
| WG044DN | 360622115013004 | 212 S21 E62 23CBAC4 | 33 | 31 | 33 | 4.06 | 10-16-86 | 1,645 |
| WG052 | 360602115011701 | 212 S21 E62 23CDDC1 | 20 | -- | -- | 1.18 | 03-26-86 | 1,627 |
| WG053AN | 360612115011705 | 212 S21 E62 23CDBA5 | 8 | 6 | 8 | 5.73 | 10-16-86 | 1,627 |
| WG053BN | 360612115011704 | 212 S21 E62 23CDBA4 | 12 | 10 | 12 | 5.88 | 10-16-86 | 1,627 |
| WG053CN | 360612115011703 | 212 S21 E62 23CDBA3 | 19 | 16 | 18 | 5.89 | 10-16-86 | 1,627 |
| WG053DN | 360612115011702 | 212 S21 E62 23CDBA2 | 21 | 18 | 20 | 5.84 | 10-16-86 | 1,627 |
| WG053EN | 360612115011701 | 212 S21 E62 23CDBA1 | 24 | 23 | 25 | 5.94 | 10-16-86 | 1,627 |

TABLE 9.--*Location, construction, and selected water levels for wells--Continued*

| Well name | Standard identification[2] number | Local identification[3] number | Depth[1] (feet below land surface) | | | Water level | | Land-surface altitude (feet above sea level) |
|---|---|---|---|---|---|---|---|---|
| | | | Measured total | Reported slotted interval | | Feet below land surface | Date measured | |
| | | | | Top | Bottom | | | |
| WG055 | 360631115011801 | 212 S21 E62 23BDDB1 | 15 | 0 | 17 | 6.75 | 03-25-86 | 1,648 |
| WG062A | 360601115010501 | 212 S21 E62 23DCCD1 | 6 | 4 | 6 | 2.21 | 02-20-87 | 1,618 |
| WG062B | 360601115010502 | 212 S21 E62 23DCCD2 | 12 | 10 | 12 | 1.44 | 02-20-87 | 1,618 |
| WG062C | 360601115010503 | 212 S21 E62 23DCCD3 | 17 | 15 | 17 | 2.12 | 02-20-87 | 1,618 |
| WG062D | 360601115010504 | 212 S21 E62 23DCCD4 | 22 | 20 | 22 | 1.84 | 02-20-87 | 1,618 |
| WG062E | 360601115010505 | 212 S21 E62 23DCCD5 | 28 | 26 | 28 | 3.11 | 02-20-87 | 1,618 |
| WG064 | 360621115010501 | 212 S21 E62 23DBBD1 | 10 | 0 | 10 | 5.19 | 03-25-86 | 1,641 |
| WG065 | 360631115010501 | 212 S21 E62 23ACCD1 | 33 | 0 | 34 | 14.0 | 03-25-86 | 1,652 |
| WG072 | 360601115005301 | 212 S21 E62 23DDCC1 | 18 | 0 | 19 | 13.1 | 03-27-86 | 1,621 |
| WG073 | 360612115005301 | 212 S21 E62 23DDBB1 | 25 | 0 | 25 | 14.6 | 03-25-86 | 1,633 |
| WG074 | 360622115005301 | 212 S21 E62 23DABC1 | 45 | 0 | 45 | 12.6 | 03-25-86 | 1,644 |
| WG075 | 360631115005301 | 212 S21 E62 23ADCB1 | 36 | 0 | 36 | 20.7 | 03-25-86 | 1,658 |
| WG123 | 360602115015501 | 212 S21 E62 22DDCD1 | 23 | -- | -- | 3.98 | 03-25-86 | 1,645 |
| WG126 | 360602115014102 | 212 S21 E62 23CCCC2 | 25 | 0 | 25 | 1.77 | 03-26-86 | 1,638 |
| WG129 | 360602115012902 | 212 S21 E62 23CCDD2 | 31 | 0 | 30 | 2.11 | 03-26-86 | 1,632 |
| WG131 | 360602115012903 | 212 S21 E62 23CCDD3 | 23 | 20 | 22 | 4.36 | 10-15-86 | 1,632 |
| WG132 | 360602115011702 | 212 S21 E62 23CDDC2 | 25 | 1 | 25 | 1.17 | 03-26-86 | 1,627 |
| PG263 | 360612115005801 | 212 S21 E62 23DCAA1 | 21 | 12 | 22 | 9.95 | 03-25-86 | 1,635 |
| PG264 | 360617115010501 | 212 S21 E62 23DBCD1 | 15 | 5 | 16 | 6.05 | 03-25-86 | 1,639 |
| PG269 | 360607115010001 | 212 S21 E62 23DCDB1 | 18 | 0 | 18 | 2.81 | 03-25-86 | 1,622 |
| PG270 | 360601115010701 | 212 S21 E62 23DCCC1 | 11 | 2 | 12 | .77 | 03-25-86 | 1,620 |
| PG271 | 360606115010501 | 212 S21 E62 23DCCA1 | 11 | 1 | 11 | .37 | 03-25-86 | 1,623 |
| PG273 | 360609115014701 | 212 S21 E62 22DDAC1 | 35 | 29 | 39 | 3.51 | 03-26-86 | 1,646 |
| PG274 | 360616115013901 | 212 S21 E62 23CBCC1 | 21 | 17 | 27 | 4.35 | 03-26-86 | 1,648 |

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[1] Well depths below land surface were measured with a steel tape. Not all measured depths correspond to the reported bottom of the slotted interval. The shallow measured depths may be caused by (1) silt that had entered the wells after drilling, or (2) a slight error in the reported depth. The top of the slotted interval in many wells is at land surface (designated at 0).

[2] Sites are identified by the standard Geological Survey identification (ID), which is based on the grid system of latitude and longitude. The ID indicates the geographic location of each site, and provides a unique number for each. The ID consists of 15 digits: The first 6 denote the degrees, minutes, and seconds of latitude; the next 7 denote degrees, minutes, and seconds of longitude; and the last 2 digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 360551115020702 is at 36°05'51" latitude and 115°02'07" longitude, and it is the second site recorded in that 1-second grid.

[3] The local site-identification system used in this report is based on an index of hydrographic areas in Nevada (Rush, 1968) and the rectangular subdivision of the public lands referenced to the Mount Diablo base line and meridian. Each site designation consists of four units separated by spaces: The first unit is the hydrographic area number. The second unit is the township, preceded by an N or S to indicate location north or south of the base line. The third unit is the range, preceded by an E to indicate location east of the meridian. The fourth unit consists of the section number and letters designating the quarter section, quarter-quarter section, and so on (A, B, C, and D indicate the northeast, northwest, southwest, and southeast quarters, respectively), followed by a number indicating the sequence in which the site was recorded. For example, site 212 S21 E62 27ABCA2 is in Las Vegas Valley (hydrographic area 212). It is the second site recorded in the northeast quarter of the southwest quarter of the northwest quarter of the northeast quarter of section 27, Township 21 South, Range 62 East, Mount Diablo base line and meridian.

TABLE 10.--*Data on ground-water quality for the period April 1986 through June 1987*

[Analysis by U.S. Bureau of Reclamation Soils Laboratory, Boulder City, Nev., except for water temperature, pH, specific conductance, and bicarbonate, which were determined when sample was collected; results are in milligrams per liter, except for temperature, pH, and specific conductance. Abbreviations: °C, degrees Celsius; microsiemens, microsiemens per centimeter at 25 °C; --, not determined]

| Well name | Sample date | Water temperature (°C) | pH (units) | Specific conductance (microsiemens) | Dissolved solids[1] | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WG011N | 10-21-86 | 23.5 | 7.22 | 7,400 | 6,810 | 590 | 410 | 750 | 150 | 280 | 3,100 | 1,100 | 78 |
| | 01-12-87 | 19.5 | 6.99 | 7,000 | 6,600 | 590 | 410 | 700 | 140 | 270 | 3,000 | 1,000 | 99 |
| | 06-03-87 | 19.0 | 7.26 | 7,300 | 6,350 | 510 | 350 | 690 | 140 | 280 | 2,800 | 1,000 | 74 |
| WG012 | 04-28-86 | 20.3 | 7.20 | 7,500 | 6,180 | 660 | 380 | 600 | 91 | 210 | 2,400 | 1,200 | 76 |
| | 09-22-86 | 23.0 | 7.03 | 6,100 | 5,500 | 660 | 330 | 440 | 87 | 190 | 2,300 | 980 | 83 |
| | 01-12-87 | 20.0 | 7.14 | 6,100 | 5,730 | 740 | 360 | 430 | 84 | 180 | 2,400 | 1,000 | 100 |
| | 06-01-87 | 19.0 | 7.21 | 6,600 | 5,660 | 650 | 350 | 510 | 93 | 180 | 2,400 | 1,000 | 68 |
| WG012B | 10-22-86 | 20.0 | 7.58 | 6,300 | 5,730 | 650 | 260 | 660 | 60 | 190 | 2,600 | 870 | 71 |
| | 01-12-87 | 20.0 | 7.10 | 5,500 | 5,100 | 680 | 260 | 420 | 56 | 180 | 2,300 | 800 | 84 |
| | 06-01-87 | 19.5 | 7.23 | 5,900 | 5,100 | 720 | 280 | 400 | 61 | 180 | 2,300 | 800 | 65 |
| WG013 | 04-28-86 | 20.3 | 7.20 | 5,300 | 4,520 | 660 | 160 | 400 | 28 | 170 | 1,900 | 750 | 73 |
| | 09-22-86 | 22.0 | 7.04 | 5,300 | 4,620 | 640 | 200 | 410 | 26 | 180 | 2,200 | 690 | 75 |
| | 01-13-87 | 18.0 | 7.02 | 12,000 | 10,500 | 720 | 510 | 1,700 | 260 | 240 | 3,600 | 3,000 | 73 |
| | 06-04-87 | 20.0 | 7.19 | 5,900 | 4,980 | 680 | 220 | 500 | 35 | 190 | 2,300 | 810 | 66 |
| WG014 | 04-29-86 | 18.3 | 7.20 | 24,000 | 21,800 | 440 | 1,600 | 3,300 | 820 | 530 | 9,700 | 3,700 | 53 |
| | 09-23-86 | 22.0 | 7.04 | 26,000 | 24,900 | 620 | 1,900 | 3,900 | 650 | 500 | 10,000 | 4,900 | 72 |
| | 01-13-87 | 14.0 | 7.10 | 23,000 | 27,500 | 560 | 2,000 | 4,100 | 910 | 540 | 12,000 | 4,500 | 42 |
| | 06-04-87 | 17.5 | 7.21 | 26,000 | 25,800 | 580 | 2,000 | 4,000 | 830 | 530 | 11,000 | 4,800 | 66 |
| WG014B | 01-13-87 | 18.0 | 7.13 | 20,000 | 19,800 | 600 | 1,400 | 3,000 | 290 | 410 | 8,700 | 3,800 | 54 |
| | 06-04-87 | 17.5 | 7.22 | 21,000 | 18,600 | 580 | 1,400 | 3,000 | 310 | 390 | 8,100 | 3,800 | 63 |
| WG021N | 10-21-86 | 23.0 | 7.25 | 5,600 | 5,110 | 560 | 310 | 460 | 64 | 260 | 2,500 | 640 | 70 |
| | 01-13-87 | 19.0 | 7.00 | 5,400 | 5,110 | 540 | 310 | 450 | 64 | 250 | 2,400 | 670 | 58 |
| WG022 | 04-29-86 | 21.2 | 7.00 | 6,300 | 5,280 | 720 | 250 | 440 | 54 | 190 | 2,300 | 820 | 74 |
| | 09-23-86 | 20.5 | 7.05 | 6,200 | 5,630 | 750 | 280 | 480 | 57 | 190 | 2,600 | 950 | 74 |
| | 01-12-87 | 18.0 | 7.11 | 6,100 | 5,800 | 740 | 280 | 520 | 58 | 200 | 2,600 | 870 | 110 |
| WG023 | 04-28-86 | 18.9 | 7.10 | 5,800 | 5,340 | 660 | 290 | 470 | 39 | 220 | 2,300 | 680 | 70 |
| | 09-22-86 | 23.0 | 7.04 | 6,200 | 5,570 | 600 | 290 | 580 | 37 | 220 | 2,700 | 670 | 69 |
| WG024 | 04-28-86 | 19.0 | 7.00 | 9,000 | 6,680 | 450 | 370 | 890 | 99 | 260 | 2,900 | 910 | 68 |
| | 09-22-86 | 20.2 | 7.12 | 8,500 | 7,180 | 460 | 410 | 980 | 100 | 270 | 3,300 | 960 | 71 |
| | 01-13-87 | 18.0 | 7.23 | 7,100 | 6,510 | 460 | 380 | 850 | 79 | 270 | 3,000 | 790 | 80 |
| WG025 | 05-01-86 | 20.0 | 7.10 | 7,700 | 6,760 | 490 | 420 | 800 | 94 | 300 | 3,300 | 900 | 75 |
| | 09-25-86 | 21.0 | 7.18 | 6,500 | 5,900 | 490 | 360 | 630 | 87 | 260 | 2,800 | 710 | 81 |
| | 01-17-87 | 18.3 | 7.13 | 6,500 | 6,300 | 570 | 380 | 680 | 87 | 280 | 2,900 | 810 | 87 |
| | 06-04-87 | 19.5 | 7.29 | 6,600 | 5,980 | 540 | 370 | 660 | 77 | 260 | 2,800 | 740 | 76 |
| WG031 | 04-28-86 | 19.9 | 7.00 | 5,900 | 5,170 | 580 | 340 | 430 | 59 | 230 | 2,300 | 650 | 74 |
| | 09-23-86 | 20.5 | 7.00 | 5,800 | 5,280 | 570 | 320 | 430 | 63 | 240 | 2,500 | 640 | 75 |
| | 01-13-87 | 20.0 | 6.94 | 5,400 | 5,280 | 590 | 340 | 450 | 61 | 240 | 2,500 | 640 | 85 |
| | 06-03-87 | 21.0 | 7.11 | 5,800 | 5,080 | 600 | 360 | 480 | 65 | 250 | 2,600 | 710 | 69 |
| WG032 | 04-29-86 | 19.5 | 7.00 | 6,300 | 5,270 | 520 | 280 | 590 | 43 | 240 | 2,400 | 570 | 72 |
| | 01-16-87 | 11.0 | 7.31 | 6,100 | 5,750 | 550 | 310 | 650 | 47 | 240 | 2,700 | 680 | 110 |
| WG033 | 04-29-86 | 18.0 | 7.10 | 7,700 | 7,060 | 570 | 470 | 810 | 66 | 290 | 3,300 | 880 | 84 |
| | 09-23-86 | 20.0 | 7.15 | 7,800 | 7,100 | 570 | 450 | 750 | 62 | 280 | 3,400 | 910 | 83 |
| | 01-14-87 | 19.0 | 7.24 | 7,200 | 7,080 | 610 | 460 | 750 | 60 | 290 | 3,300 | 840 | 110 |
| | 06-04-87 | 19.0 | 7.18 | 8,000 | 7,550 | 630 | 480 | 820 | 66 | 280 | 3,500 | 980 | 75 |
| WG034 | 04-30-86 | 17.8 | 7.10 | 9,000 | 7,560 | 530 | 500 | 930 | 100 | 290 | 3,500 | 900 | 84 |
| | 09-22-86 | 20.5 | 7.10 | 7,700 | 7,140 | 520 | 440 | 820 | 84 | 270 | 3,400 | 820 | 80 |
| | 01-13-87 | 18.0 | 7.20 | 7,900 | 7,580 | 560 | 490 | 890 | 95 | 270 | 3,700 | 910 | 89 |
| | 06-04-87 | 18.0 | 7.25 | 8,300 | 8,010 | 580 | 490 | 920 | 100 | 280 | 3,800 | 950 | 74 |

TABLE 10.--*Data on ground-water quality for the period April 1986 through June 1987*--Continued

| Well name | Sample date | Water temperature (°C) | pH (units) | Specific conductance (microsiemens) | Dissolved solids[1] | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WG034B | 01-13-87 | 18.0 | 7.19 | 8,000 | 7,690 | 600 | 490 | 860 | 72 | 200 | 3,700 | 900 | 90 |
| | 06-04-87 | 18.0 | 7.24 | 8,100 | 7,800 | 600 | 500 | 910 | 75 | 280 | 3,700 | 940 | 77 |
| WG035A | 05-01-86 | 16.5 | 7.10 | 8,500 | 7,810 | 570 | 600 | 820 | 92 | 350 | 3,800 | 750 | 97 |
| WG035B | 05-01-86 | 16.5 | 7.15 | 7,600 | 7,090 | 520 | 530 | 750 | 57 | 340 | 3,600 | 680 | 88 |
| | 09-26-86 | 21.5 | 7.16 | 6,600 | 6,460 | 430 | 460 | 670 | 56 | 320 | 3,200 | 530 | 90 |
| WG035C | 05-01-86 | 17.5 | 7.10 | 6,400 | 5,690 | 440 | 420 | 600 | 45 | 310 | 2,800 | 500 | 88 |
| | 09-26-86 | 18.0 | 7.11 | 6,300 | 6,160 | 430 | 430 | 630 | 48 | 300 | 3,100 | 550 | 87 |
| WG035D | 05-01-86 | 17.5 | 7.10 | 6,900 | 6,250 | 420 | 470 | 660 | 60 | 340 | 3,000 | 570 | 85 |
| | 09-26-86 | 18.5 | 6.94 | 6,600 | 6,120 | 420 | 430 | 630 | 49 | 310 | 3,100 | 550 | 84 |
| WG035E | 05-01-86 | 18.1 | 7.10 | 6,200 | 5,720 | 410 | 430 | 590 | 48 | 300 | 2,800 | 500 | 89 |
| | 09-26-86 | 19.0 | 6.89 | 6,500 | 6,090 | 410 | 430 | 600 | 48 | 300 | 3,100 | 560 | 80 |
| WG035AN | 01-17-87 | 12.0 | 7.41 | 8,500 | 9,170 | 530 | 700 | 990 | 55 | 450 | 4,500 | 870 | 47 |
| | 06-01-87 | 24.0 | 7.42 | 7,900 | 8,030 | 440 | 500 | 870 | 59 | 370 | 4,000 | 710 | 86 |
| WG035BN | 10-29-86 | 21.5 | 7.18 | 7,100 | 6,540 | 460 | 460 | 710 | 55 | 320 | 3,100 | 620 | 82 |
| | 01-17-87 | 16.0 | 7.21 | 6,500 | 6,640 | 470 | 470 | 680 | 51 | 300 | 3,300 | 590 | 59 |
| | 06-01-87 | 17.5 | 7.14 | 7,400 | 7,090 | 500 | 540 | 760 | 57 | 290 | 3,500 | 700 | 79 |
| WG035CN | 10-29-86 | 21.0 | 7.15 | 6,700 | 6,160 | 460 | 440 | 640 | 50 | 310 | 3,000 | 580 | 78 |
| | 01-17-87 | 16.5 | 7.14 | 6,200 | 6,240 | 460 | 440 | 630 | 46 | 300 | 3,100 | 530 | 52 |
| | 06-01-87 | 18.0 | 7.10 | 6,400 | 6,100 | 440 | 440 | 630 | 50 | 300 | 3,100 | 530 | 77 |
| WG035DN | 10-29-86 | 24.5 | 7.40 | 6,400 | 6,140 | 460 | 440 | 640 | 49 | 310 | 3,200 | 590 | 78 |
| | 01-17-87 | 17.0 | 7.24 | 6,000 | 6,060 | 440 | 430 | 600 | 46 | 300 | 2,900 | 500 | 84 |
| | 06-01-87 | 24.0 | 7.04 | 6,100 | 5,750 | 420 | 420 | 600 | 50 | 310 | 2,900 | 460 | 76 |
| WG035EN | 10-29-86 | 20.5 | 7.34 | 6,600 | 6,150 | 500 | 430 | 620 | 47 | 310 | 3,100 | 520 | 74 |
| | 01-17-87 | 17.0 | 7.28 | 6,100 | 5,980 | 460 | 420 | 610 | 45 | 310 | 3,000 | 510 | 85 |
| | 06-01-87 | 19.0 | 7.09 | 6,200 | 5,650 | 420 | 410 | 590 | 50 | 310 | 2,800 | 470 | 80 |
| WG042 | 04-30-86 | 20.3 | 7.10 | 8,900 | 7,080 | 720 | 510 | 700 | 65 | 290 | 3,600 | 940 | 77 |
| | 09-23-86 | 21.5 | 7.07 | 6,900 | 6,790 | 560 | 440 | 710 | 56 | 250 | 3,300 | 840 | 81 |
| | 01-16-87 | 18.0 | 7.24 | 7,300 | 7,310 | 580 | 490 | 760 | 62 | 260 | 3,400 | 870 | 78 |
| | 06-02-87 | 18.5 | 7.15 | 7,200 | 6,520 | 580 | 430 | 680 | 48 | 240 | 3,100 | 770 | 72 |
| WG043 | 04-30-86 | 17.0 | 7.30 | 11,000 | 9,750 | 620 | 640 | 1,200 | 310 | 320 | 5,000 | 1,100 | 65 |
| | 09-25-86 | 17.0 | 7.21 | 7,200 | 6,220 | 440 | 420 | 650 | 63 | 280 | 3,100 | 680 | 84 |
| | 01-14-87 | 21.0 | 7.23 | 6,900 | 7,210 | 460 | 500 | 790 | 97 | 270 | 3,600 | 750 | 45 |
| | 06-02-87 | 18.5 | 7.17 | 8,000 | 7,400 | 480 | 540 | 830 | 120 | 280 | 3,700 | 810 | 75 |
| WG043B | 10-21-86 | 23.0 | 7.41 | 6,200 | 5,630 | 500 | 380 | 560 | 39 | 250 | 3,000 | 530 | 71 |
| | 01-14-87 | 19.0 | 7.28 | 5,900 | 5,720 | 490 | 400 | 550 | 37 | 230 | 2,800 | 540 | 60 |
| | 06-02-87 | 19.0 | 7.20 | 6,600 | 5,640 | 500 | 410 | 560 | 41 | 240 | 2,700 | 560 | 72 |
| WG044A | 04-30-86 | 17.5 | 7.40 | 8,200 | 7,640 | 520 | 550 | 820 | 110 | 410 | 3,600 | 760 | 97 |
| WG044B | 04-30-86 | 17.5 | 7.10 | 7,800 | 7,260 | 500 | 510 | 770 | 98 | 360 | 3,700 | 710 | 92 |
| | 09-25-86 | 20.5 | 7.11 | 7,300 | 7,100 | 480 | 470 | 760 | 82 | 350 | 3,600 | 620 | 100 |
| WG044C | 04-30-86 | 16.7 | 7.20 | 7,700 | 7,300 | 560 | 520 | 750 | 75 | 360 | 3,600 | 730 | 94 |
| | 09-25-86 | 19.5 | 7.20 | 7,200 | 7,050 | 480 | 470 | 750 | 78 | 360 | 3,600 | 610 | 98 |
| WG044AN | 10-23-86 | 20.0 | 7.18 | 6,700 | 6,580 | 540 | 420 | 700 | 71 | 340 | 3,300 | 600 | 93 |
| | 01-13-87 | 14.5 | 7.28 | 7,200 | 6,790 | 490 | 450 | 800 | 70 | 350 | 3,600 | 670 | 88 |
| | 06-01-87 | 19.0 | 7.20 | 7,500 | 7,250 | 540 | 510 | 800 | 77 | 370 | 3,600 | 660 | 86 |
| WG044BN | 10-23-86 | 23.0 | 7.31 | 6,400 | 6,220 | 500 | 410 | 670 | 73 | 310 | 3,100 | 530 | 81 |
| | 01-13-87 | 17.0 | 7.14 | 6,800 | 6,450 | 480 | 440 | 760 | 71 | 320 | 3,400 | 620 | 86 |
| | 06-01-87 | 23.0 | 7.09 | 6,800 | 6,600 | 490 | 440 | 740 | 65 | 360 | 3,300 | 600 | 79 |
| WG044CN | 10-23-86 | 22.0 | 7.31 | 6,400 | 6,340 | 500 | 420 | 670 | 64 | 310 | 3,300 | 560 | 83 |
| | 01-13-87 | 18.0 | 7.29 | 6,700 | 6,370 | 460 | 430 | 730 | 68 | 320 | 3,300 | 550 | 82 |
| | 06-01-87 | 18.0 | 7.09 | 6,900 | 6,440 | 400 | 370 | 570 | 65 | 320 | 2,400 | 590 | 78 |

TABLE 10.--*Data on ground-water quality for the period April 1986 through June 1987*--Continued

| Well name | Sample date | Water temperature (°C) | pH (units) | Specific conductance (microsiemens) | Dissolved solids[1] | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WG044DN | 10-23-86 | -- | 7.20 | 7,500 | 7,680 | 580 | 470 | 900 | 75 | 360 | 3,900 | 700 | 84 |
| | 10-28-86 | -- | 7.9 | 6,900 | 6,840 | 560 | 460 | 720 | 53 | 330 | 3,500 | 620 | 80 |
| | 01-13-87 | 16.0 | 7.14 | 6,600 | 6,560 | 520 | 420 | 760 | 57 | 320 | 3,400 | 600 | 79 |
| | 06-01-87 | 20.0 | 7.10 | 7,000 | 6,330 | 500 | 400 | 700 | 54 | 320 | 3,200 | 550 | 80 |
| WG052 | 05-03-86 | 18.0 | 7.10 | 8,900 | 8,620 | 550 | 660 | 910 | 85 | 390 | 4,300 | 1,000 | 75 |
| | 09-23-86 | 19.0 | 7.18 | 7,500 | 7,020 | 530 | 500 | 700 | 54 | 290 | 3,600 | 770 | 80 |
| WG053AN | 10-27-86 | 23.0 | 7.61 | 9,100 | 7,980 | 550 | 460 | 1,000 | 150 | 350 | 4,200 | 730 | 66 |
| | 01-15-87 | 11.5 | 7.81 | 8,400 | 8,260 | 450 | 480 | 1,200 | 200 | 440 | 4,300 | 750 | 70 |
| | 06-02-87 | 19.5 | 7.32 | 7,600 | 7,040 | 550 | 430 | 820 | 110 | 330 | 3,500 | 660 | 100 |
| WG053BN | 10-27-86 | 21.0 | 7.15 | 7,300 | 6,830 | 560 | 420 | 780 | 84 | 320 | 3,500 | 640 | 88 |
| | 01-15-87 | 16.0 | 7.13 | 6,800 | 6,640 | 510 | 410 | 820 | 96 | 320 | 3,400 | 630 | 85 |
| | 06-02-87 | 17.0 | 7.02 | 7,000 | 6,430 | 520 | 400 | 740 | 88 | 330 | 3,100 | 580 | 86 |
| WG053CN | 10-22-86 | 22.0 | 7.26 | 6,800 | 6,340 | 560 | 390 | 700 | 57 | 320 | 3,300 | 610 | 81 |
| | 01-15-87 | 17.0 | 7.07 | 6,400 | 6,210 | 520 | 390 | 720 | 63 | 310 | 3,200 | 610 | 85 |
| | 06-02-87 | 17.5 | 7.08 | 6,700 | 6,010 | 520 | 380 | 640 | 59 | 310 | 3,000 | 550 | 81 |
| WG053DN | 10-22-86 | 21.0 | 7.23 | 6,700 | 6,370 | 560 | 390 | 680 | 56 | 310 | 3,200 | 610 | 81 |
| | 01-15-87 | 17.0 | 7.06 | 6,300 | 6,140 | 520 | 380 | 720 | 59 | 310 | 3,100 | 600 | 84 |
| | 06-02-87 | 17.5 | 7.11 | 6,700 | 6,040 | 530 | 380 | 640 | 57 | 290 | 3,000 | 540 | 80 |
| WG053EN | 10-22-86 | 21.5 | 7.34 | 6,500 | 6,120 | 560 | 380 | 640 | 52 | 300 | 3,100 | 600 | 76 |
| | 01-15-87 | 16.0 | 7.18 | 6,300 | 6,070 | 520 | 380 | 700 | 54 | 300 | 3,100 | 590 | 81 |
| | 06-02-87 | 18.0 | 7.09 | 6,600 | 5,960 | 540 | 380 | 640 | 51 | 300 | 2,900 | 560 | 77 |
| WG055 | 05-01-86 | 18.5 | 6.90 | 4,100 | 3,430 | 480 | 160 | 230 | 30 | 210 | 1,800 | 270 | 88 |
| | 09-25-86 | 21.5 | 6.98 | 4,300 | 3,660 | 560 | 150 | 270 | 32 | 260 | 1,900 | 280 | 95 |
| | 01-17-87 | 15.0 | 7.34 | 3,800 | 3,760 | 550 | 190 | 240 | 38 | 140 | 2,200 | 140 | 69 |
| | 06-04-87 | 18.0 | 7.17 | 4,400 | 3,780 | 600 | 160 | 260 | 46 | 150 | 2,100 | 250 | 95 |
| WG062A | 03-03-87 | 10.0 | 7.65 | 5,200 | 4,910 | 560 | 300 | 420 | 36 | 440 | 2,400 | 450 | 71 |
| | 06-02-87 | 18.5 | 7.43 | 5,500 | 5,040 | 620 | 300 | 410 | 42 | 570 | 2,400 | 430 | 74 |
| WG062B | 03-04-87 | 10.0 | 7.56 | 4,600 | 3,880 | 430 | 230 | 330 | 28 | 360 | 2,100 | 430 | 61 |
| | 06-03-87 | 16.5 | 7.21 | 4,800 | 4,150 | 520 | 240 | 340 | 36 | 360 | 2,000 | 350 | 72 |
| WG062C | 03-04-87 | 11.0 | 7.52 | 4,700 | 3,960 | 460 | 230 | 340 | 28 | 330 | 2,100 | 250 | 63 |
| | 06-03-87 | 15.5 | 7.25 | 4,800 | 4,090 | 530 | 240 | 330 | 35 | 330 | 2,000 | 360 | 72 |
| WG062D | 03-04-87 | 11.0 | 7.50 | 5,100 | 4,540 | 530 | 250 | 420 | 33 | 310 | 2,300 | 370 | 67 |
| | 06-02-87 | 16.0 | 7.33 | 4,900 | 4,160 | 500 | 260 | 360 | 32 | 310 | 2,100 | 360 | 69 |
| WG062E | 03-05-87 | 11.0 | 7.46 | 5,000 | 4,520 | 490 | 250 | 440 | 33 | 300 | 2,300 | 410 | 57 |
| | 06-03-87 | 14.0 | 7.31 | 5,000 | 4,110 | 470 | 240 | 380 | 33 | 320 | 2,100 | 360 | 68 |
| WG064 | 05-01-86 | 18.7 | 7.10 | 3,700 | 3,160 | 610 | 110 | 190 | 24 | 210 | 1,700 | 250 | 77 |
| | 01-17-87 | 17.0 | 7.18 | 3,800 | 3,520 | 620 | 110 | 240 | 23 | 240 | 1,800 | 280 | 99 |
| | 06-04-87 | 19.5 | 7.22 | 4,000 | 3,360 | 650 | 100 | 210 | 21 | 230 | 1,800 | 240 | 72 |
| WG065 | 05-02-86 | 22.8 | 6.90 | 9,000 | 7,740 | 550 | 490 | 910 | 98 | 300 | 3,600 | 910 | 52 |
| | 09-26-86 | 23.0 | 7.05 | 8,000 | 7,520 | 540 | 500 | 800 | 100 | 310 | 3,600 | 810 | 61 |
| | 01-17-87 | 21.0 | 7.08 | 7,400 | 7,300 | 570 | 460 | 910 | 110 | 260 | 3,600 | 830 | 57 |
| WG072 | 05-02-86 | 20.0 | 7.10 | 5,300 | 4,720 | 620 | 230 | 430 | 45 | 270 | 2,200 | 630 | 110 |
| | 09-27-86 | 21.5 | 7.02 | 5,400 | 4,750 | 590 | 230 | 430 | 48 | 270 | 2,200 | 630 | 120 |
| | 01-18-87 | 20.0 | 7.09 | 5,600 | 5,150 | 620 | 250 | 560 | 56 | 310 | 2,400 | 730 | 59 |
| WG073 | 05-02-86 | 22.2 | 7.10 | 7,700 | 7,120 | 570 | 440 | 810 | 110 | 180 | 3,500 | 780 | 59 |
| | 09-27-86 | 21.0 | 7.12 | 7,500 | 7,350 | 570 | 420 | 860 | 110 | 190 | 3,600 | 870 | 62 |
| | 01-18-87 | 21.0 | 7.16 | 7,100 | 6,900 | 540 | 420 | 860 | 120 | 190 | 3,400 | 810 | 62 |
| WG074 | 05-02-86 | 21.8 | 7.30 | 8,900 | 7,880 | 590 | 430 | 1,100 | 85 | 180 | 3,600 | 1,200 | 40 |
| | 09-27-86 | 20.5 | 7.49 | 9,400 | 8,350 | 610 | 430 | 1,200 | 91 | 150 | 3,700 | 1,400 | 40 |
| | 01-17-87 | 21.0 | 7.49 | 8,500 | 8,200 | 570 | 420 | 1,300 | 110 | 130 | 3,800 | 1,300 | 38 |

TABLE 10.--*Data on ground-water quality for the period April 1986 through June 1987*--Continued

| Well name | Sample date | Water temperature (°C) | pH (units) | Specific conductance (microsiemens) | Dissolved solids[1] | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WG075 | 05-02-86 | 21.8 | 7.30 | 8,500 | 7,440 | 590 | 490 | 900 | 87 | 160 | 3,600 | 990 | 27 |
| | 09-27-86 | 20.0 | 7.43 | 6,600 | 6,340 | 560 | 400 | 640 | 74 | 120 | 3,200 | 690 | 21 |
| | 01-17-87 | 22.0 | 7.38 | 6,500 | 6,330 | 540 | 420 | 670 | 78 | 130 | 3,200 | 730 | 21 |
| WG123 | 04-29-86 | 22.5 | 7.10 | 6,300 | 5,500 | 700 | 280 | 470 | 58 | 200 | 2,400 | 860 | 74 |
| | 09-23-86 | 21.0 | 7.04 | 6,100 | 5,610 | 710 | 280 | 480 | 58 | 190 | 2,500 | 870 | 75 |
| | 01-12-87 | 20.0 | 7.03 | 6,100 | 5,480 | 700 | 280 | 540 | 62 | 190 | 2,600 | 900 | 74 |
| | 06-03-87 | 20.5 | 7.13 | 6,500 | 5,510 | 710 | 280 | 510 | 59 | 200 | 2,500 | 890 | 69 |
| WG126 | 04-29-86 | 20.5 | 7.10 | 6,300 | 5,560 | 520 | 290 | 640 | 43 | 240 | 2,600 | 630 | 70 |
| | 09-24-86 | 19.0 | 7.22 | 6,400 | 5,880 | 560 | 310 | 670 | 45 | 240 | 2,800 | 630 | 72 |
| | 01-16-87 | 18.5 | 7.25 | 6,200 | 5,580 | 500 | 300 | 700 | 49 | 240 | 2,700 | 700 | 65 |
| | 06-03-87 | 19.5 | 7.20 | 6,400 | 5,550 | 500 | 280 | 660 | 42 | 240 | 2,700 | 640 | 67 |
| WG129 | 04-30-86 | 18.7 | 7.00 | 6,500 | 5,300 | 450 | 310 | 590 | 36 | 210 | 2,500 | 630 | 67 |
| | 09-23-86 | 20.0 | 7.07 | 6,200 | 5,890 | 540 | 330 | 600 | 32 | 230 | 2,800 | 720 | 71 |
| | 01-16-87 | 18.5 | 6.97 | 6,500 | 6,060 | 500 | 380 | 700 | 53 | 240 | 3,000 | 750 | 71 |
| | 06-02-87 | 19.5 | 7.18 | 6,800 | 5,880 | 550 | 350 | 630 | 39 | 240 | 3,000 | 680 | 71 |
| WG131 | 01-16-87 | 18.0 | 7.19 | 7,700 | 7,520 | 630 | 510 | 830 | 69 | 260 | 3,600 | 1,000 | 70 |
| | 06-02-87 | 20.5 | 7.11 | 8,500 | 7,800 | 440 | 560 | 860 | 70 | 280 | 3,700 | 1,000 | 72 |
| WG132 | 05-03-86 | 20.0 | 7.20 | 7,900 | 7,830 | 580 | 560 | 790 | 65 | 340 | 3,600 | 820 | 72 |
| | 09-24-86 | 17.8 | 7.25 | 6,900 | 6,810 | 550 | 470 | 650 | 49 | 290 | 3,400 | 660 | 80 |
| PG263 | 05-03-86 | 19.0 | 6.90 | 4,500 | 4,100 | 540 | 170 | 340 | 34 | 240 | 1,900 | 370 | 72 |
| | 09-24-86 | 21.5 | 7.11 | 3,800 | 3,000 | 520 | 98 | 200 | 23 | 240 | 1,600 | 260 | 82 |
| | 01-16-87 | 17.0 | 6.91 | 5,100 | 4,600 | 620 | 190 | 430 | 34 | 220 | 2,200 | 490 | 82 |
| | 06-04-87 | 17.5 | 7.15 | 5,200 | 4,330 | 590 | 200 | 430 | 40 | 240 | 2,200 | 480 | 75 |
| PG264 | 05-03-86 | 19.0 | 6.95 | 4,000 | 4,200 | 420 | 220 | 490 | 45 | 250 | 2,200 | 470 | 36 |
| | 09-24-86 | 22.0 | 7.20 | 3,900 | 3,210 | 340 | 170 | 340 | 51 | 240 | 1,500 | 380 | 39 |
| | 01-16-87 | 17.0 | 7.20 | 3,100 | 2,370 | 320 | 110 | 220 | 30 | 240 | 1,200 | 260 | 31 |
| | 06-04-87 | 19.5 | 7.22 | 4,800 | 3,800 | 340 | 170 | 430 | 48 | 240 | 1,900 | 400 | 37 |
| PG269 | 05-03-86 | 14.5 | 7.10 | 5,800 | 5,120 | 530 | 250 | 560 | 34 | 320 | 2,500 | 540 | 71 |
| | 09-24-86 | 17.0 | 7.06 | 5,200 | 4,680 | 560 | 230 | 470 | 34 | 270 | 2,400 | 450 | 82 |
| PG270 | 05-03-86 | 14.0 | 7.30 | 2,500 | 1,840 | 190 | 93 | 210 | 24 | 270 | 800 | 200 | 34 |
| | 09-24-86 | 18.5 | 7.15 | 6,400 | 6,280 | 660 | 440 | 520 | 55 | 380 | 3,200 | 680 | 58 |
| | 01-16-87 | 10.0 | 7.21 | 6,700 | 6,410 | 650 | 410 | 600 | 41 | 440 | 3,000 | 740 | 49 |
| | 06-04-87 | 15.0 | 7.18 | 5,900 | 5,160 | 520 | 340 | 490 | 48 | 430 | 2,500 | 510 | 47 |
| PG271 | 05-03-86 | 14.0 | 7.10 | 4,500 | 3,850 | 460 | 220 | 330 | 38 | 400 | 1,900 | 280 | 89 |
| | 09-24-86 | 17.0 | 7.22 | 4,000 | 3,310 | 390 | 200 | 300 | 49 | 430 | 1,600 | 340 | 94 |
| | 01-16-87 | 9.0 | 7.17 | 4,500 | 3,900 | 460 | 220 | 320 | 34 | 340 | 1,800 | 370 | 78 |
| PG273 | 04-29-86 | 21.0 | 7.10 | 6,200 | 5,150 | 460 | 240 | 550 | 38 | 240 | 2,500 | 500 | 66 |
| | 09-25-86 | 23.0 | 7.19 | 6,200 | 5,640 | 540 | 280 | 670 | 41 | 240 | 2,800 | 650 | 72 |
| | 01-14-87 | 20.0 | 7.37 | 6,100 | 5,680 | 540 | 280 | 680 | 39 | 240 | 2,700 | 630 | 70 |
| PG274 | 04-29-86 | 18.3 | 7.20 | 6,500 | 5,900 | 490 | 400 | 600 | 42 | 270 | 3,200 | 620 | 82 |
| | 09-25-86 | 18.5 | 7.26 | 6,500 | 5,990 | 470 | 420 | 630 | 43 | 280 | 3,000 | 680 | 80 |
| | 01-15-87 | 17.0 | 7.35 | 6,300 | 6,050 | 480 | 410 | 630 | 42 | 280 | 2,900 | 620 | 80 |
| | 06-02-87 | 19.5 | 7.28 | 6,700 | 5,960 | 480 | 420 | 650 | 47 | 280 | 3,600 | 640 | 72 |

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[1] Dissolved solids determined from residue at 180 degrees Celsius.

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