Ground-Water Resources of Kyle and Lee Canyons, Spring Mountains, Clark County, Nevada

By Russell W. Plume

U.S. GEOLOGICAL SURVEY

Open-File Report 84-438

Prepared in cooperation with the

U.S. FOREST SERVICE

Carson City, Nevada

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

U.S. Geological Survey
Room 227, Federal Building
705 North Plaza Street
Carson City, NV 89701

Copies of this report may be
purchased from:

Open-File Services Section
U.S. Geological Survey
Box 25425, Federal Center
Denver, CO 80225

Call (303) 236-7476 for
ordering information

CONTENTS

ILLUSTRATIONS

[All plates in pocket at back of report]

TABLES

CONVERSION FACTORS

Except for water-quality units of measure, only the "inch-pound" system is used in this report. Abbreviations and conversion factors from inch-pound to International System (SI) units are listed below.

Multiply	*By*	*To obtain*
Acres	0.4047	Square hectometers (hm^2)
Acre-feet (acre-ft)	0.001233	Cubic hectometers (hm^3)
Acre-feet per year (acre-ft/yr)	0.001233	Cubic hectometers per year (hm^3/yr)
Feet (ft)	0.3048	Meters (m)
Feet per day (ft/d)	0.3048	Meters/day (m/d)
Feet per mile (ft/mi)	0.1894	Meters per kilometer (m/km)
Feet squared per day (ft^2/d)	0.09290	Meters squared per day (m^2/d)
Gallons (gal)	3.785	Liters (L)
Gallons per minute (gal/min)	0.06309	Liters per second (L/s)
Miles (mi)	1.609	Kilometers (km)
Pounds per square inch ($lb/in.^2$)	0.07031	Kilograms per square centimeter (kg/cm^2)

ALTITUDE DATUM

The term "National Geodetic Vertical Datum of 1929" (abbreviation, NGVD of 1929) replaces the formerly used term "mean sea level" to describe the datum for altitude measurements. The NGVD of 1929 is derived from a general adjustment of the first-order leveling networks of both the United States and Canada. For convenience in this report, the datum also is referred to as "sea level."

GROUND-WATER RESOURCES OF KYLE AND LEE CANYONS,

SPRING MOUNTAINS, CLARK COUNTY, NEVADA

By Russell W. Plume

ABSTRACT

Kyle and Lee Canyons are in the Spring Mountains of southern Nevada about 25 miles northwest of Las Vegas. There is concern that septic-tank effluent may be affecting ground-water quality in both canyons. This study evaluates the ground-water system and the quality of ground water in each canyon.

The bedrock of the study area consists of Paleozoic limestone, dolomite, and minor clastic rocks that have been offset by thrust and high-angle faults. The bedrock is overlain by Pliocene and Pleistocene alluvial and colluvial fill that is at least 150 feet thick in Lee Canyon and 400 feet thick in Kyle Canyon.

The estimated hydraulic conductivity of Paleozoic carbonate rocks ranges from 0.04 to 5 feet per day. However, these estimates may be low by as much as several orders of magnitude. The estimated hydraulic conductivity of alluvium in Kyle Canyon is 50 feet per day on the basis of drillers' well tests. The estimated specific yield of the alluvium is 12 percent.

Ground water occurs in the carbonate rocks and alluvium of Kyle Canyon and the carbonate rocks of Lee Canyon (the alluvium of Lee Canyon is rarely, if ever, saturated). Most ground water moves generally eastward toward Las Vegas Valley, although flow to other adjacent basins is also possible. Estimated average velocities of ground-water movement are about 30 feet per day in the alluvium of Kyle Canyon and range from 0.2 to 3,000 feet per day in the carbonate rocks of both canyons.

Each year, ground-water levels in both canyons rise during the spring and early summer in response to the snowmelt, then decline to a base level by late fall or early winter. During 1980, measured water levels fluctuated 41 to 134 feet in Kyle Canyon and 8 to 27 feet in Lee Canyon. Water-level changes appear to be due to changes in pressure head in the carbonate rocks, rather than to a slug of snowmelt moving downgradient through the system.

Snowmelt is the primary source of recharge to the ground-water reservoir of each canyon. Discharge occurs as underflow to Las Vegas Valley and possibly to other adjacent basins. Kyle and Lee Canyons receive about 5,000 and 3,000 acre-feet per year of recharge, respectively. Discharge from the two systems by way of carbonate rocks cannot be estimated because the saturated thicknesses are not known.

The alluvium of Kyle Canyon receives recharge as snowmelt on the canyon floor and as inflow from carbonate rocks. Discharge from the alluvium occurs as underflow at the canyon mouth and as outflow to the carbonate rocks. Recharge in 1980 was an estimated 2,000-3,000 acre-feet, and discharge was an estimated 5,000 acre-feet. The upper part of Kyle Canyon is an area of net inflow to alluvium and the middle and lower parts of the canyon are areas of net outflow to bedrock.

The ground water of Kyle and Lee Canyons is similar in quality. Principal cations are calcium and magnesium, and the principal anion is bicarbonate. Analysis of water-quality data indicates that septic-tank effluent is present in the ground water of Kyle Canyon. The data are not sufficient to make such a determination for Lee Canyon. Ground-water quality in both canyons presently (1981) meets established State drinking-water standards for all determined constituents.

INTRODUCTION

Kyle and Lee Canyons are located on the eastern slope of the Spring Mountains in southern Nevada, about 25 miles northwest of Las Vegas (figure 1). The U.S. Forest Service is concerned that residential and recreational development in each of the canyons may be affecting the quality of ground-water supplies. Ground water from both canyons is used to serve the needs of residents and short-term recreational visitors. Once used, most of the water returns to the ground-water reservoirs of each canyon through septic systems.

Purpose and Scope

The purpose of this study was to evaluate the hydrology of the ground-water systems in Kyle and Lee Canyons in terms of the occurrence, movement, and quality of the water. Specific objectives were to: (1) Define the chemical quality of the ground water, (2) evaluate the occurrence and movement of ground water in both the alluvial fill and underlying consolidated rocks, (3) develop ground-water budgets for both canyons, and (4) develop a water-resources data base for the area.

The study was originally intended to be an evaluation of the hydrology and quality of ground water in the alluvial fill in Kyle and Lee Canyons, because the fill underlies developed and heavily used areas. However, an understanding of the alluvial-fill hydrology requires an understanding of the geology and hydraulic properties of the surrounding bedrock because the alluvium and bedrock are hydraulically connected. Therefore, this study also evaluates (to the extent possible) the hydrology of bedrock.

Data Collection

The geology of the study area has been mapped and studied in three separate investigations (Maxey and Jameson, 1948; Dolliver, 1968; and Burchfiel and others, 1974). Therefore, data collection during the current study was concentrated on measuring depths to water in wells, collecting samples for evaluation of water quality, collecting seismic data to be used for determining the thickness of alluvial fill measuring discharge at a spring in Kyle Canyon, and performing aquifer tests where possible. Water levels were measured monthly from April through July 1980 and every other month from September 1980 through March 1981. Water-quality samples were collected concurrent with the water-level measurements. Seismic refraction data were collected during the fall of 1980. Spring discharge was measured during the spring of 1980 and an aquifer test (in Lee Canyon) was performed during the summer of that year.

Features of the Study Area

The study area consists of the drainage areas of Kyle and Lee Canyons as far downstream as the canyon mouths (figure 1 and plate 1). Kyle Canyon is V-shaped and relatively narrow along its floor, whereas Lee Canyon is U-shaped and wider (plate 2). The two canyons are separated by a high ridge that crests more than 10,800 feet above sea level. The main ridge of the Spring Mountains ranges in altitude from nearly 10,000 feet in Lee Canyon to 11,918 feet at Charleston Peak in Kyle Canyon.

Lee Canyon is generally higher in altitude than Kyle Canyon. The floor of Lee Canyon ranges in altitude from 7,600 to 8,600 feet. The floor of Kyle Canyon ranges in altitude from 6,800 to 8,200 feet.

Population and Water Use

Residential, recreational, and commercial activities in Kyle and Lee Canyons are the three main sources of septic-tank effluent in the study area. The residential population of Kyle Canyon in 1976 was estimated at 790, of which 425 were permanent and 365 were part-time, and the residential population of Lee Canyon in 1976 was estimated at 90, of which about 50 were permanent and 40 were part-time (Brown and Caldwell, 1978, page 4-19). The estimate for permanent residents in Lee Canyon seems high; in July 1980, the total was about 20.

Noncommercial recreational activities in the canyons consist of overnight campers and sightseers; in addition, a Girl Scout Camp and the Clark County Youth Camp are in Lee Canyon. Recreational activities accounted for 62,000 visitor-days in Kyle Canyon and 83,000 visitor-days in Lee Canyon during 1977 (Brown and Caldwell, 1978, page 4-20). Not all recreational activities contribute wastewater to the ground-water reservoir. Toilet facilities at the U.S. Forest Service campgrounds and picnic grounds use vaults that are regularly pumped; the waste is disposed of outside the study area. Except for the Youth and Girl Scout Camps in Lee Canyon, recreational uses in the study area have little potential for contributing wastewater to the ground-water reservoirs.

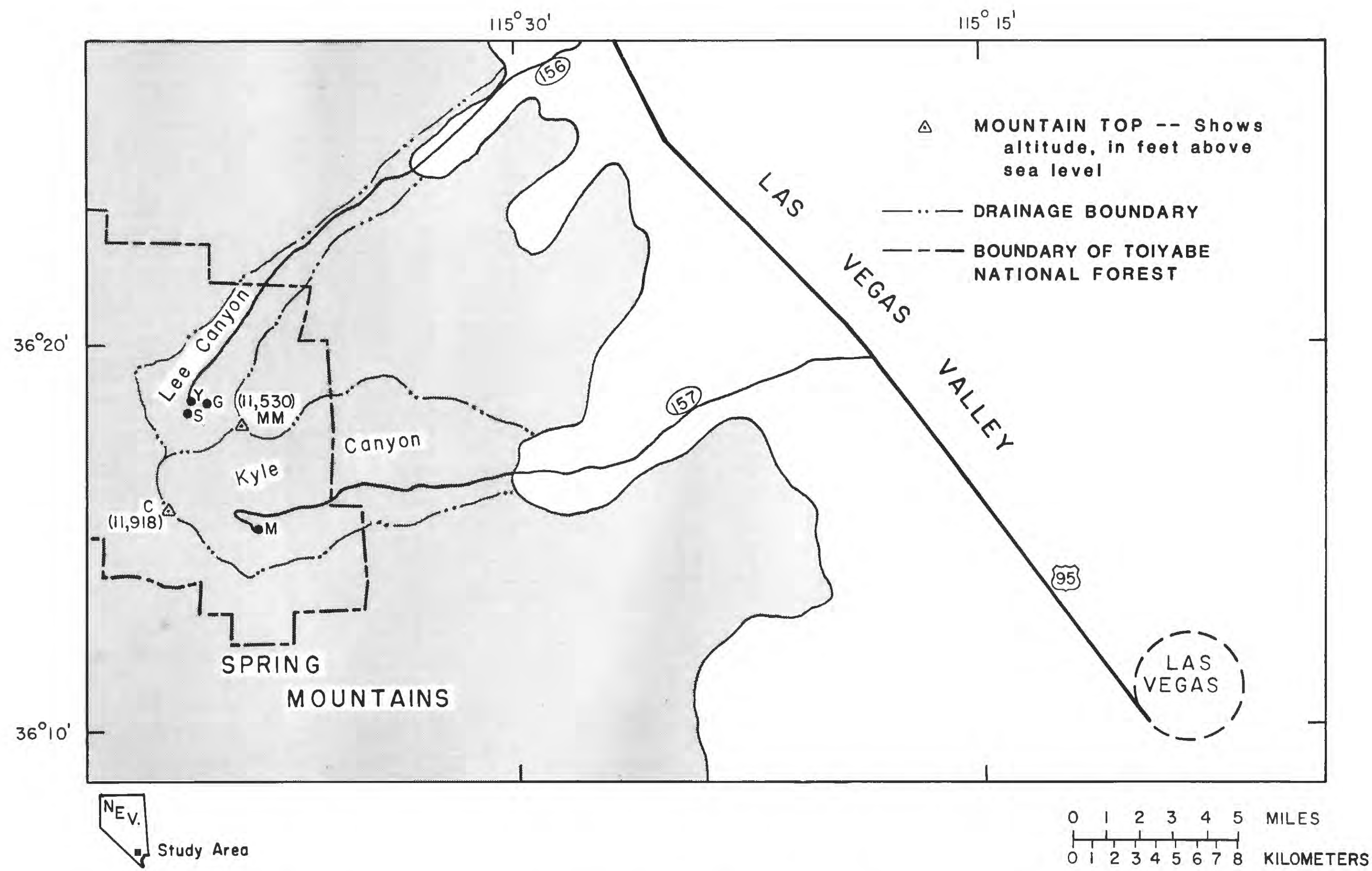

Figure 1.--Location and features of study area and vicinity. Shading indicates mountainous areas. C, Charleston Peak; G, Girl Scout Camp; M, Mount Charleston Lodge; MM, Mummy Mountain; S, Ski Lodge; Y, Clark County Youth Camp.

Commercial activities in the study area consist of a restaurant (Mount Charleston Lodge) in Kyle Canyon and a ski area in Lee Canyon. The restaurant had an estimated 61,000 visitor-days and the ski area 12,000 visitor-days during 1977 (Brown and Caldwell, 1978, page 4-20).

Total water use in 1977 for the above activities was 22 million gallons (68 acre-feet) in Kyle Canyon and 6.2 million gallons (19 acre-feet) in Lee Canyon, of which an estimated 90 percent became wastewater (Brown and Caldwell, 1978, pages 4-29 and 4-31). Therefore, an estimated 20 million gallons (61 acre-feet) of septic-tank effluent were generated in Kyle Canyon and an estimated 5.6 million gallons (17 acre-feet) were generated in Lee Canyon during 1977.

Acknowledgments

Many individuals and organizations contributed to the completion of this study. The author is grateful to the residents of the study area and employees of the Las Vegas Valley Water District who made their wells available for measurement, sampling, and aquifer tests. The U.S. Forest Service provided assistance and space for living quarters during part of the study. The State Engineer's Offices in Las Vegas and Carson City provided well logs used in the study.

U.S. Geological Survey personnel involved in the study were Terry Katzer, who helped during the Lee's Crest aquifer test, and Douglas K. Maurer and James M. Thomas, who helped collect seismic data.

Well Location System

The location system used in this report is based on a hydrographic-area number and the rectangular subdivision of lands referenced to the Mount Diablo baseline and meridian. Each well designation ("location" in table 4) includes a hydrographic-area number, as defined by Rush (1968), and the township, range, section, subdivision of the section, and sequence number. For instance, in well designation 212 S19 E56 27AACA1, the first part (212) indicates that the well is in the Las Vegas Valley hydrographic area (Rush, 1968, page 26). Subsequent numbers indicate that the well is in section 27 of township 19 south, range 56 east. The letters following the section number indicate specifically where the well is in section 27. The northeast quarter is represented by the letter "A," and the other three quarters in a counterclockwise direction are designated "B," "C," and "D," respectively. Each quarter can be similarly subdivided and so on, the usual limit being four letters (which define an area of 2½ acres) when the location is precisely known. The first letter in the sequence indicates the largest subdivision in the section and the last letter the smallest. Thus, the well described above is in the northeast quarter of the southwest quarter of the northeast quarter of the northeast quarter of section 27. Well designations include a sequence number following the letters. This is useful when two wells are so close together that they would otherwise have the same designation. All wells referred to in this report are in the Las Vegas Valley hydrographic area. Therefore, the hydrographic-area number (212) for each well location is omitted.

Each well listed in table 4 also has a site identification number that consists of the latitude and longitude of the well, and a sequence number. These numbers are necessary for retrieving water-quality data that is stored in the U.S. Geological Survey WATSTORE database. The latitude (in degrees, minutes, and seconds) is represented by the first six digits of the number. The longitude (in degrees, minutes, and seconds) is represented by the next seven digits. The sequence number, which has the same function as in the well designation, is the last two digits. As an example, well 361612115353301 is at latitude 36° 16' 12" north and longitude 115° 35' 33" west.

HYDROGEOLOGY

Geologic Features

Two general rock types are found in the study area: (1) Paleozoic sedimentary rocks that consist mostly of limestone and dolomite, with minor amounts of sandstone, quartzite, and shale, and (2) Cenozoic alluvium and colluvium. These are separated into four hydrogeologic units that are shown on plate 1.

Paleozoic Rocks

Paleozoic rocks are exposed throughout the study area except where they are overlain by Cenozoic alluvium, mostly along the bottoms of Kyle and Lee Canyons (plate 1). The Paleozoic rocks are divided into three hydrogeologic units: (1) A lower unit that consists of limestone and dolomite and minor amounts of sandstone, shale, and quartzite; (2) a middle unit that consists of limestone and dolomite; and (3) an upper unit that consists of limestone and dolomite and minor amounts of sandstone and shale (plate 1). Although these three units are lithologically similar, they may differ in their ability to store and transmit water (Maxey and Jameson, 1948, pages 42-50).

The lower unit is exposed on the entire north side and parts of the south side of Lee Canyon and on Mummy Mountain in the middle part of Kyle Canyon (plate 1). Its thickness is not accurately known but is at least several thousand feet. The geologic formations that constitute this unit (see plate 1) are of Cambrian, Ordovician, and Silurian age.

The middle unit consists of the Sultan and the Monte Cristo Limestones, and is found on both sides of Kyle Canyon and on the south side of Lee Canyon (plate 1). The unit is about 2,000 feet thick and is of Devonian and Mississippian age. It is thought to provide the primary avenues for the transmission of ground water from the Spring Mountains to the Las Vegas Valley ground-water reservoir (Maxey and Jameson, 1948, page 47).

The upper unit consists of the Bird Spring Formation, which is found on both sides of Kyle Canyon and at the head of Lee Canyon. Estimates of its thickness range from 5,000 to 7,000 feet (Longwell and others, 1965, page 32), and it is of Pennsylvanian and Permian age.

Cenozoic Deposits

Cenozoic deposits in the study area consist of alluvium and colluvium of Pliocene and Pleistocene age (Dolliver, 1968, page 57). The deposits comprise colluvium on the sides of Kyle and Lee Canyons, alluvium filling the canyons to depths as great as 400 feet, and isolated outcrops of older alluvium above canyon floors (plate 1). The deposits are poorly sorted, range in grain size from clay to boulders, and are unconsolidated to consolidated. The deposits form prominent cliffs at the mouths of both canyons and discontinuous terraces along their sides. The terraces are remnants of older canyon surfaces that were downcut by erosion to present canyon floors.

The hydrogeologic sections on plate 2 show the thickness of alluvium at selected sites in Kyle and Lee Canyons. Thicknesses were determined from well logs at all sections except at D-D', where the thickness is based on seismic-refraction data. The sections show that the thickness of alluvium in each canyon ranges from a feather edge on canyon walls to a maximum, presumably near the center of the canyon floor. However, sections B-B' and D-D' show that the maximum thickness may be offset relative to the center of the canyon floor.

The alluvium of Kyle Canyon is as thick as 210 feet at section A-A', 400 feet at section B-B', and 300 feet at section C-C' (plate 2). The alluvium of Lee Canyon is as much as 150 feet thick at section D-D' and 100 feet thick at section E-E' (plate 2). The estimated thickness of alluvium in Kyle Canyon was at least 740 feet prior to partial erosion of the fill (Dolliver, 1968, page 24).

Structure

The rocks of the Spring Mountains have been subjected to two periods of deformation. The first was dominated by thrust faulting and folding and some coincident high-angle faulting, and the second was dominated by normal faulting. The timing of the first period is very uncertain (Burchfiel and others, 1974, page 1013). Normal faulting occurred in southern Nevada from the Miocene through the Pliocene and possibly through the Pleistocene (Hamilton and Myers, 1966, pages 510-513).

Three zones of thrust faulting have been identified in the study area (plate 1). They are named the Kyle Canyon Thrust, the Deer Creek Thrust, and the Lee Canyon Thrust (Burchfiel and others, 1974). These zones offset each of the three Paleozoic hydrogeologic units in the study area. From north to south the zones offset progressively younger units (plate 1). Normal faults occur throughout the study area. They generally trend in a north-northeast to northwest direction, with most downthrown to the west (Longwell and others, 1965, page 66).

Hydraulic Properties

The hydraulic properties of Paleozoic carbonate rocks in the Spring Mountains were first estimated by Maxey and Jameson (1948, pages 46-50 and 64). They concluded that the Sultan and Monte Cristo Limestones are the only rocks of Paleozoic age in the study area capable of storing and transmitting more than small quantities of water. They believed that solution channels developed mostly in these two formations, and that faults in the other Paleozoic rocks are cemented and therefore act as barriers to ground-water movement. Winograd and Thordarson (1975, pages 14-22) have found that secondary permeability in Paleozoic carbonate rocks at the Nevada Test Site (50 miles north of the study area) is due mostly to fractures and joints, some of which may be solution-widened.

The hydraulic properties of Paleozoic carbonate rocks in the study area were estimated from the results of two single-well aquifer tests. The results of a U.S. Geological Survey aquifer test at the Lee's Crest[1] well in Lee Canyon are shown in figure 3. Pump discharge was measured three times during the test and water levels were measured at closely spaced intervals, especially early in the test. The results of a similar aquifer test done by a pump-service company at the Ski Lodge well are shown in figure 4. The only difference between this test and the one illustrated in figure 3 is that water levels were measured at 5-minute intervals at the Ski Lodge well. This lengthy interval makes the early part of the test difficult to interpret. Aquifer tests such as those depicted in figures 3 and 4 may produce low estimates of aquifer properties if the well is not properly constructed or fully developed. In addition, the results of these tests only represent a small volume of aquifer near the well bore.

Aquifer properties that were determined from the two tests are hydraulic conductivity and transmissivity. Hydraulic conductivity is defined as the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area of the aquifer measured at right angles to the direction of flow (Lohman and others, 1972, page 4). The units of measure for hydraulic conductivity are feet per day. Transmissivity is defined by Lohman and others (1972, page 13) as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The units of measure are feet squared per day. Mathematically, the transmissivity of a water-table aquifer equals its total saturated thickness (the distance between the static water level and the base of the aquifer) times its hydraulic conductivity. For a well that only partly penetrates an aquifer, the value of transmissivity represents only that part of the aquifer that yields water to the well (usually the length of open-hole or perforated casing between the static water level and the pump). Both the Ski Lodge and Lee's Crest wells penetrate about 200 feet of aquifer. The total thickness of the aquifer is not known.

---

[1] For convenience, wells are hereafter referred to by informal name (table 4). See figure 2 for well names and locations.

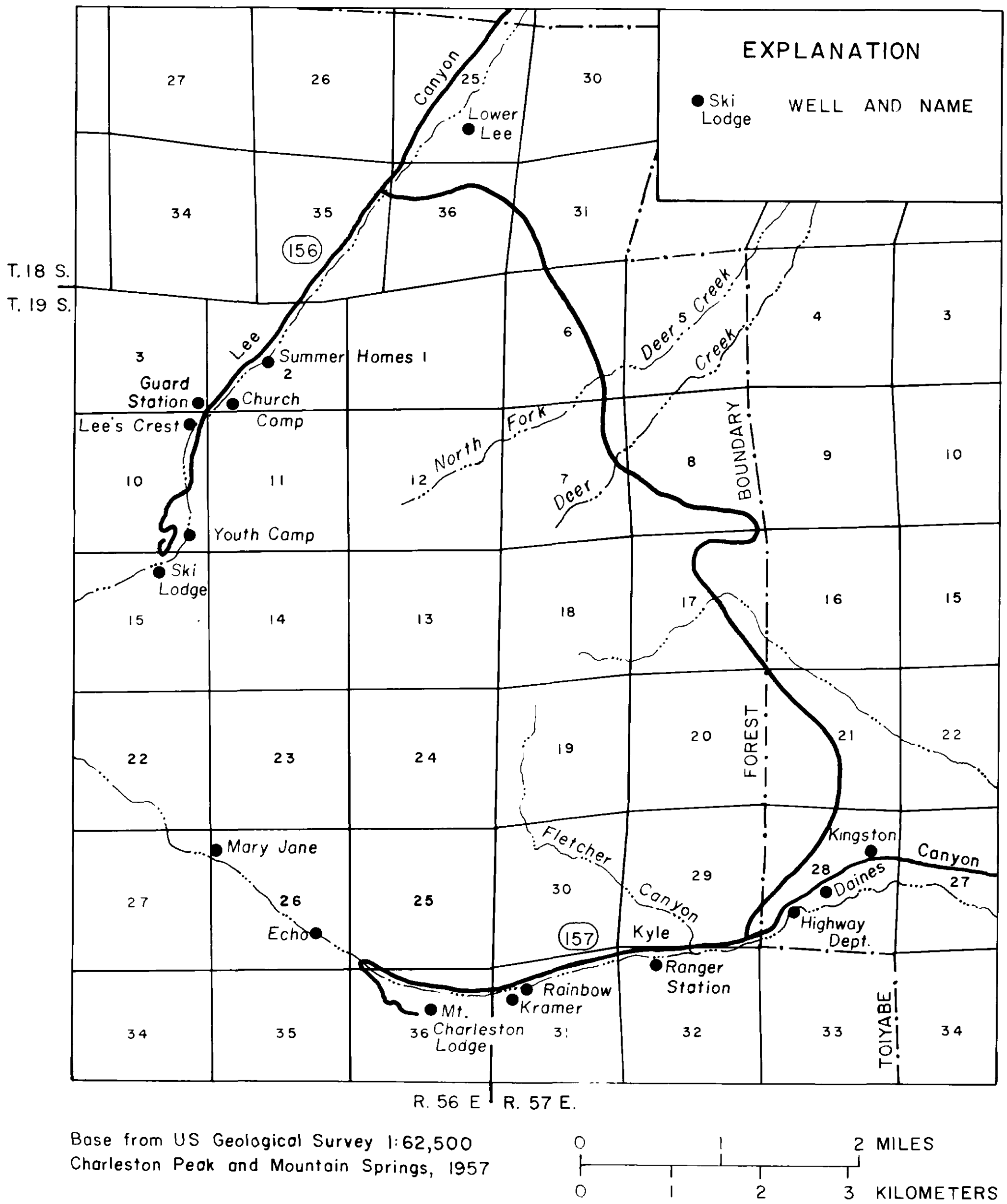

Figure 2.--Locations of wells in study area.

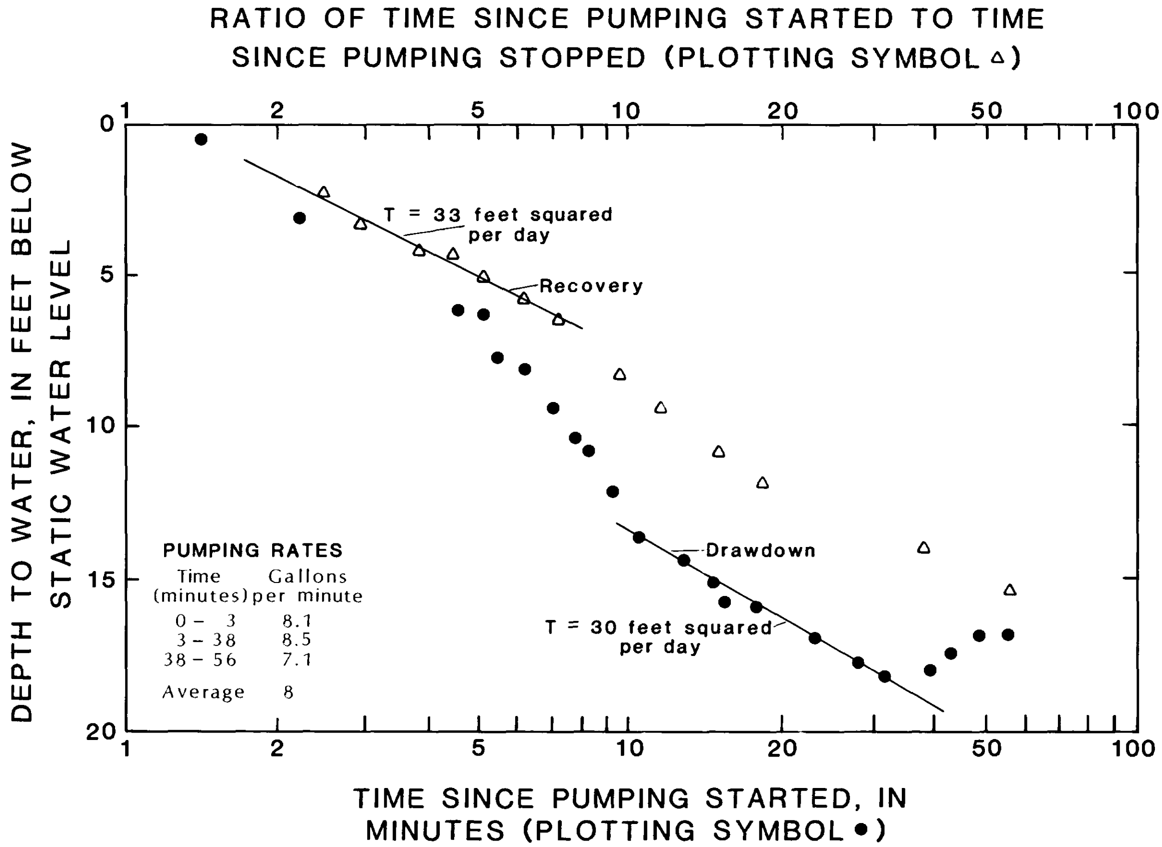

Figure 3.--Water-level drawdown and recovery, and estimates of T (transmissivity) for a pumping test of Lee's Crest well, July 21, 1980.

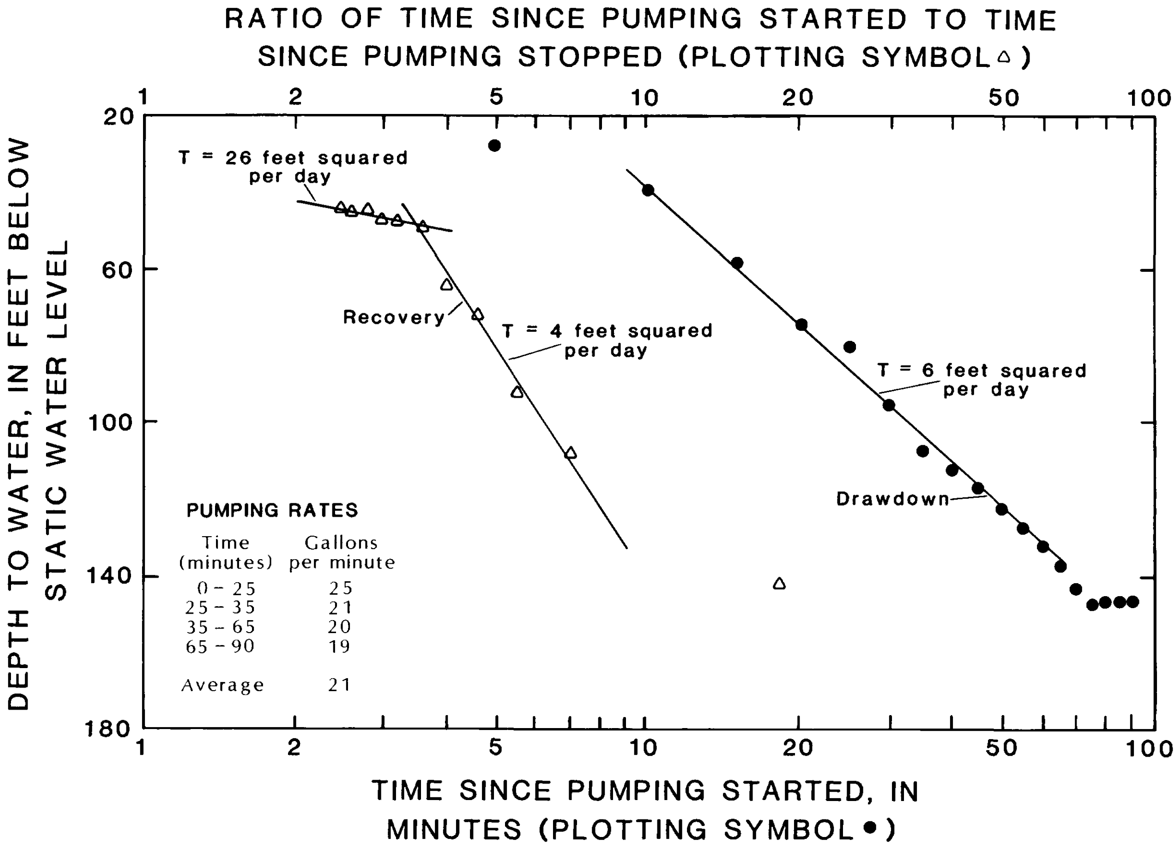

Figure 4.--Water-level drawdown and recovery, and estimates of T (transmissivity) for a pumping test of Ski Lodge well. Test performed by Water Well Services, Las Vegas, October 15, 1976.

The results of aquifer tests at the Lee's Crest and Ski Lodge wells are shown in figures 3 and 4 as semilogarithmic plots of (1) water-level drawdown caused by pumping and (2) water-level recovery after pumping ceased.[1] The initial segments of both drawdown curves are relatively flat and reflect water stored within the well bore. After this water was removed by pumping, drawdown proceeded at a faster rate. The drawdowns in figures 3 and 4 have straight-line segments that are followed by deviations from those linear trends. At the Lee's Crest well, the drawdown curve rises and then flattens out after about 40 minutes of pumping. At the Ski Lodge well the drawdown curve flattens after about 75 minutes of pumping. These deviations may be due to: (1) a delayed yield caused by lowering of the water table; (2) a moderate decrease in pumping rate at the Lee's Crest well; or (3) a recharge boundary such as a fracture.

The linear middle segment of each drawdown curve was used to determine transmissivity, on the basis of the following formula (Ferris and others, 1962, pages 100, 101):

$$T = 35.3Q/s \ ,$$

where T = transmissivity in (ft^2/d) feet squared per day;
Q = pumping rate, in gallons per minute; and
s = the water-level change, in feet, determined from one log cycle of that part of the drawdown or recovery curve being analyzed.

The calculated values are 6 and 30 ft^2/d for the Ski Lodge and Lee's Crest wells, respectively (figures 3 and 4).

The recovery of the water level in a well after pumping ceases tends to produce a smoother curve than that of drawdown. Ferris and others (1962, page 101) note that after a sufficient period of water-level recovery, the subsequent data should describe a straight line on a semilogarithmic plot. They caution, however, that boundary conditions that affect the drawdown during pumping may also affect the recovery, resulting in an erroneous transmissivity value.

For the Lee's Crest well, the last part of the recovery curve constitutes a relatively straight line. The transmissivity computed from this segment is 33 ft^2/d, which is in close agreement with the value computed from the drawdown curve. Although the recovery curve of the Ski Lodge well may be affected by a recharge boundary, the last several points on the curve fall close to a straight line that indicates a transmissivity of 26 ft^2/d. This does not agree with the transmissivity computed from the drawdown curve, but it agrees with values of transmissivity determined at Lee's Crest well. An earlier part of the recovery curve for the Ski Lodge well describes a relatively straight

---

[1] The method used to analyze these data (Ferris and others, 1962, pages 98-103) assumes that the aquifer is confined, homogeneous, isotropic, and of infinite areal extent. Although these conditions are not fully met, the data are satisfactory for making rough estimates of aquifer properites.

line that indicates a transmissivity of 4 ft^2/d. This agrees with the value computed from the drawdown curve. Thus, transmissivity estimates for the intervals of aquifer tested range from 4 ft^2/d at the Ski Lodge well to 33 ft^2/d at the Lee's Crest well.

The Ski Lodge and Lee's Crest wells both penetrate carbonate rocks of the Nopah Formation (Burchfiel and others, 1974, figure 4) of the lower unit (plate 1). The transmissivities indicated for these rocks can be converted to the approximate hydraulic conductivity by dividing by the distance between the static water level at the beginning of the test and the pump (160 feet at the Ski Lodge well and about 40 feet at the Lee's Crest well according to the owner). The two aquifer tests indicate that the hydraulic conductivity of the Nopah Formation may be on the order of 0.04 to 0.8 ft/d in the vicinity of the two wells. However, these values could be low because of reasons stated earlier.

Transmissivity and hydraulic conductivity can also be estimated from driller's well tests, which usually record a pumping rate (in gallons per minute) and a water-level drawdown at the end of the test (in feet). Thomasson and others (1960, page 222) give the following empirical relation-between transmissivity (T) and specific capacity (SC): $T = (270)(SC)$. The specific capacity of a well is the rate of discharge of water from the well divided by the water-level drawdown (Lohman and others, 1972, page 11). This method was used for the Mary Jane well in Kyle Canyon and the Guard Station well in Lee Canyon--the only test-pumped wells in the study area that produce only from carbonate rocks. Estimated transmissivities are 170 and 200 ft^2/d, respectively. Corresponding hydraulic conductivities are 5 and 2 ft/d. The Mary Jane well produces from the Monte Cristo Limestone (middle unit) and the Guard Station well produces from the Nopah Formation (lower unit).

Aquifer tests at the Nevada Test Site (50 miles north of the study area) yielded values of transmissivity that range from 80 to 120,000 ft^2/d for carbonate rocks that are equivalent to parts of the lower and middle units of the study area (Winograd and Thordarson, 1975, page 22). For the Nopah Formation these tests yielded values of 1,500 to 3,600 ft^2/d. Corresponding values of hydraulic conductivity range from 1 to 750 ft/d for all carbonate rocks tested and from 20 to 48 ft/d for the Nopah Formation at the test site. Such a large range in hydraulic conductivity (from 0.04 ft/d in the current study area to 750 ft/d at the Test Site) might be due to variations in the development of fracture permeability; but the differences also suggest the possibility that aquifer properties are underestimated in the study area.

Estimates of the hydraulic properties of the alluvium of Kyle Canyon were made because all of the wells in the canyon pump, at least partly, from the alluvium.[1] Aquifer properties that are estimated for the alluvium are specific yield and hydraulic conductivity. Specific yield is defined by Lohman and others (1972, page 12) as the ratio of (1) the volume of water which rock or soil, after being saturated, will yield by gravity to (2) the volume of rock

---

[1] The alluvium of Lee Canyon was above the water table throughout the current study.

or soil. For example, a 10-cubic-foot volume of soil that is saturated with water will yield 1 cubic foot of water by gravity flow if its specific yield is 10 percent.

The specific yield of alluvium in Kyle Canyon was estimated by computing the weighted average specific yield at each of seven wells in the canyon. This was done by first assigning a specific yield to each lithologic interval recorded on the driller's log. Values of specific yield were obtained from Todd (1959, page 25). The sum of the products of specific yield and thickness for each interval, divided by the total thickness of alluvium penetrated by the well, produces a weighted average value of specific yield for alluvium at that well. The values range from 8 to 16 percent at the seven wells in Kyle Canyon, and their average is 12 percent. At any point in the canyon, however, the specific yield of alluvium might differ significantly from the range of values shown.

The hydraulic conductivity of alluvium in Kyle Canyon was estimated from drillers' well tests. This method could be used for only the Echo well (log prior to deepening) and Ranger Station well because they are the only ones that (1) penetrate little or no bedrock and (2) have well-test data. The hydraulic conductivities determined from these tests were 4 and 30 ft/d, respectively. Because these estimates might be low, the value used for this report is 50 ft/d.

GROUND WATER

Occurrence and Movement

Ground water occupies fractures and solution channels in the Paleozoic carbonate rocks underlying Kyle and Lee Canyons, and it occupies the interstitial pore space of part of the alluvium of Kyle Canyon. Water levels are deepest at the mouths of both canyons--usually from 400 to over 500 feet below land surface. In higher parts of the canyons, water levels usually range from 130 to over 300 feet below land surface, although in Kyle Canyon the water level at Echo well was at or above land surface during late spring 1980 and within 100 feet of land surface through March 1981. Depths to water shown in table 4 indicate that the alluvium of Kyle Canyon is saturated in part throughout the year. However, the alluvium of Lee Canyon probably is never saturated except for possible perched water bodies of limited aerial and vertical extent.

Plate 3 shows the altitude of ground-water levels in Kyle and Lee Canyons in the summer of 1980 and in November 1980. Water-table contours are shown as being straight, indicating that water, whether it is in bedrock or alluvium, generally moves eastward in Kyle Canyon and northeastward in Lee Canyon, without first moving toward the axis of each canyon as might be expected. This is probably an oversimplification of a complex system. However, wells are situated in each canyon such that only a general idea of the direction of ground-water movement can be determined from water levels.

Water-table gradients are variable in both canyons. In Kyle Canyon, gradients between pairs of wells range from 320 to 340 ft/mi in the upper part of the canyon and from 260 to 270 ft/mi in the lower part. At the mouth of Kyle Canyon between the Highway Department and Kingston wells, the gradient steepens to about 480 ft/mi. Water-table gradients in Lee Canyon range from 240 to 280 ft/mi between the Ski Lodge well and Church Camp well. The gradient steepens in the lower part of the canyon to about 430 ft/mi between the Church Camp and Lower Lee wells.

The average velocity of ground-water movement through an aquifer can be estimated by using the following equation:

$$\overline{V} = Ki/\theta ,$$

where $\overline{V}$ = average velocity, in feet per day;
K = hydraulic conductivity, in feet per day;
i = gradient, in feet per foot; and
θ = effective porosity, as a decimal fraction.

Effective porosity refers to the amount of interconnected pore space that is available for fluid transmission (Lohman and others, 1972, page 10). Using values of 50 ft/d for hydraulic conductivity, 0.06 ft/ft (300 ft/mi) for gradient, and 0.1 for effective porosity, the average velocity of ground-water movement in the alluvium of Kyle Canyon would be 30 ft/d (about 2 mi/yr). However, the uncertainty of estimated values for the hydraulic conductivity of the alluvium make any estimate of average velocity very uncertain.

The average velocity of ground-water movement through carbonate rocks in the study area can also be estimated using the above equation. Estimates of hydraulic conductivity of carbonate rocks, on the basis of aquifer and well tests in the study area, range from 0.04 to 5 ft/d. Estimates of effective fracture porosity of carbonate rocks at the Nevada Test site range from 0.0001 to 0.01 (Winograd and Thordarson, 1975, pages 114-115). Using these ranges of values and a gradient of 0.06 ft/ft, the average velocity of ground-water movement in carbonate rocks could range from 0.2 to 3,000 ft/d. This wide range reflects both the possible variations in the hydraulic properties of the aquifer and the uncertainty of methods used to estimate the hydraulic properties.

Water-Level Fluctuations

Ground-water levels in the study area rise each spring in response to the snowmelt and then decline through early winter (figures 5 and 6). During the study (April 1980-March 1981), measured water levels fluctuated as much as 134 feet in Kyle Canyon and 28 feet in Lee Canyon.

Figure 5 shows that water levels at the Mary Jane and Echo wells began to rise as early as late January or early February 1981. This occurred late in the study, but suggests that in the upper part of Kyle Canyon, water levels may begin to rise each year in late winter, although the timing may vary from year to year depending on late winter weather. The figure also shows that water levels at the Mary Jane and Echo Wells were highest prior to mid-May. The water levels then declined from late spring through the following winter. The decline was relatively rapid until late July, but continued at a lesser rate through January.

The water level at the Echo well was above land surface in late April and early May. The well flowed daily during this period, and a pressure reading of 15 pounds per square inch at the top of the casing in late April (Kurt Kramer, Las Vegas Valley Water District, oral communication, 1980) indicated the head to be about 34 feet above land surface (2.3 feet of head per 1 pound per square inch). The flow is apparently due to pressure head in the carbonate rocks. This well penetrates alluvium and almost 100 feet of bedrock, and is cased throughout its entire depth. The actual head in the carbonate rocks could have been more than 34 feet above land surface because some water may have been moving through perforations into alluvium. Flow at the Echo well indicates that the alluvium in this part of Kyle Canyon receives substantial ground-water inflow from bedrock during spring and early summer, and possibly to a lesser degree during the rest of the year.

Figure 5 also shows that water levels rose from late April to late June 1980 and then declined through the following winter in the middle to lower part of Kyle Canyon (area between Mt. Charleston Lodge and Highway Department wells). Water levels rose 83 feet at the Mt. Charleston Lodge well and 56 feet at the Ranger Station well, and then declined 116 and 58 feet, respectively, between June and November 1980.

At the mouth of Kyle Canyon, the water level at the Kingston well fluctuated 134 feet during the study. From mid-April to late July 1980, the water level rose 126 feet; it then declined 134 feet through the late winter of 1981.

In summary, water levels are highest during April and May in the upper part of Kyle Canyon, during June in the middle to lower part, and during late July at the mouth. Figure 5 suggests that pressure head in the carbonate rocks begins to increase in late winter in the upper part of the canyon and in the spring in the lower part. However, the timing of this could vary from year to year.

Ground-water levels in Lee Canyon also fluctuate in response to the spring snowmelt (figure 6), but the fluctuations are not as great as those in Kyle Canyon. The records for the Ski Lodge and Youth Camp wells are incomplete and show only that water levels declined 8 and 16 feet, respectively, from July 1980 through the following winter.

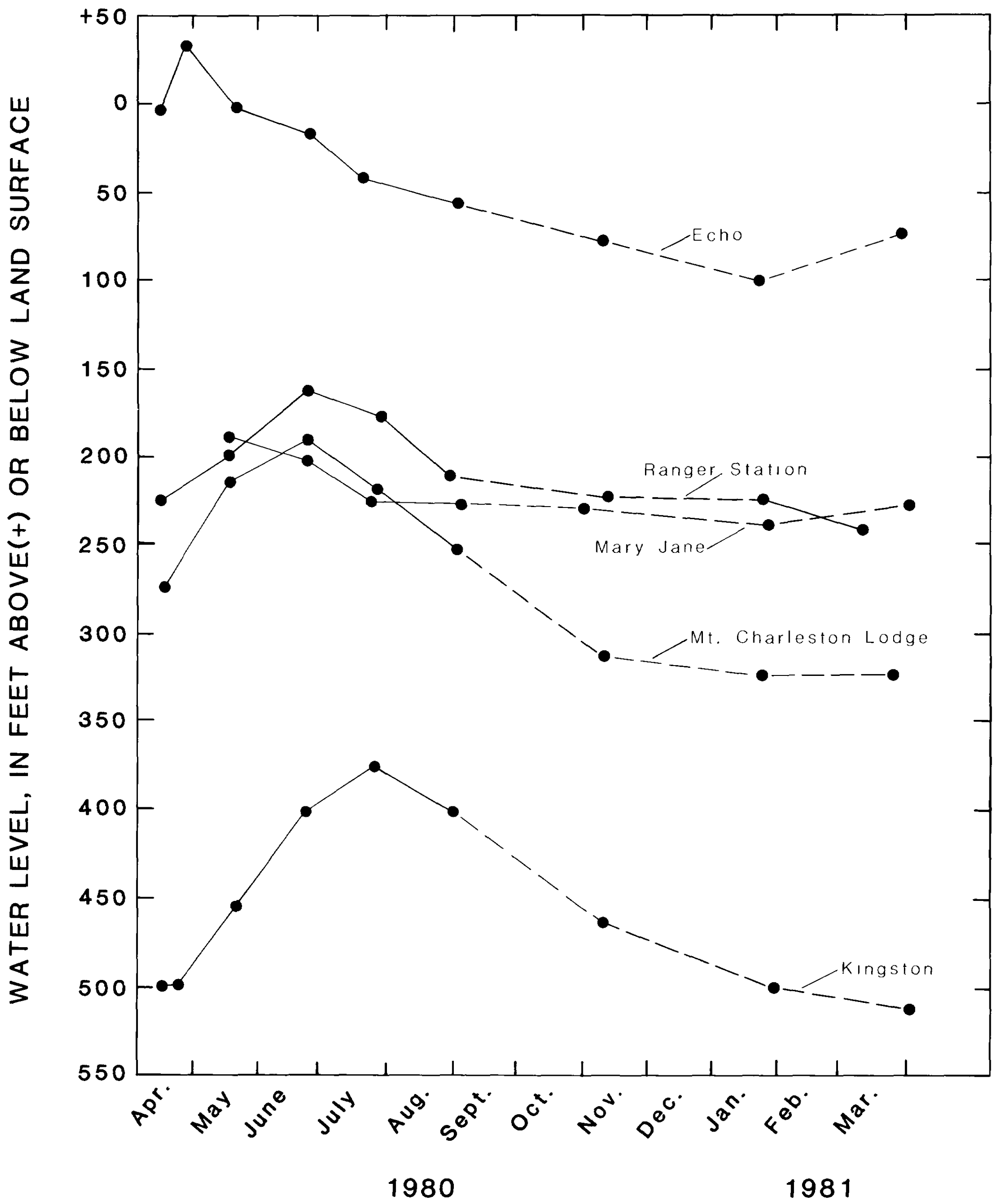

Figure 5.--Hydrographs for selected wells in Kyle Canyon, April 1980-March 1981. (Dashed where frequency of measurements exceeds two months.)

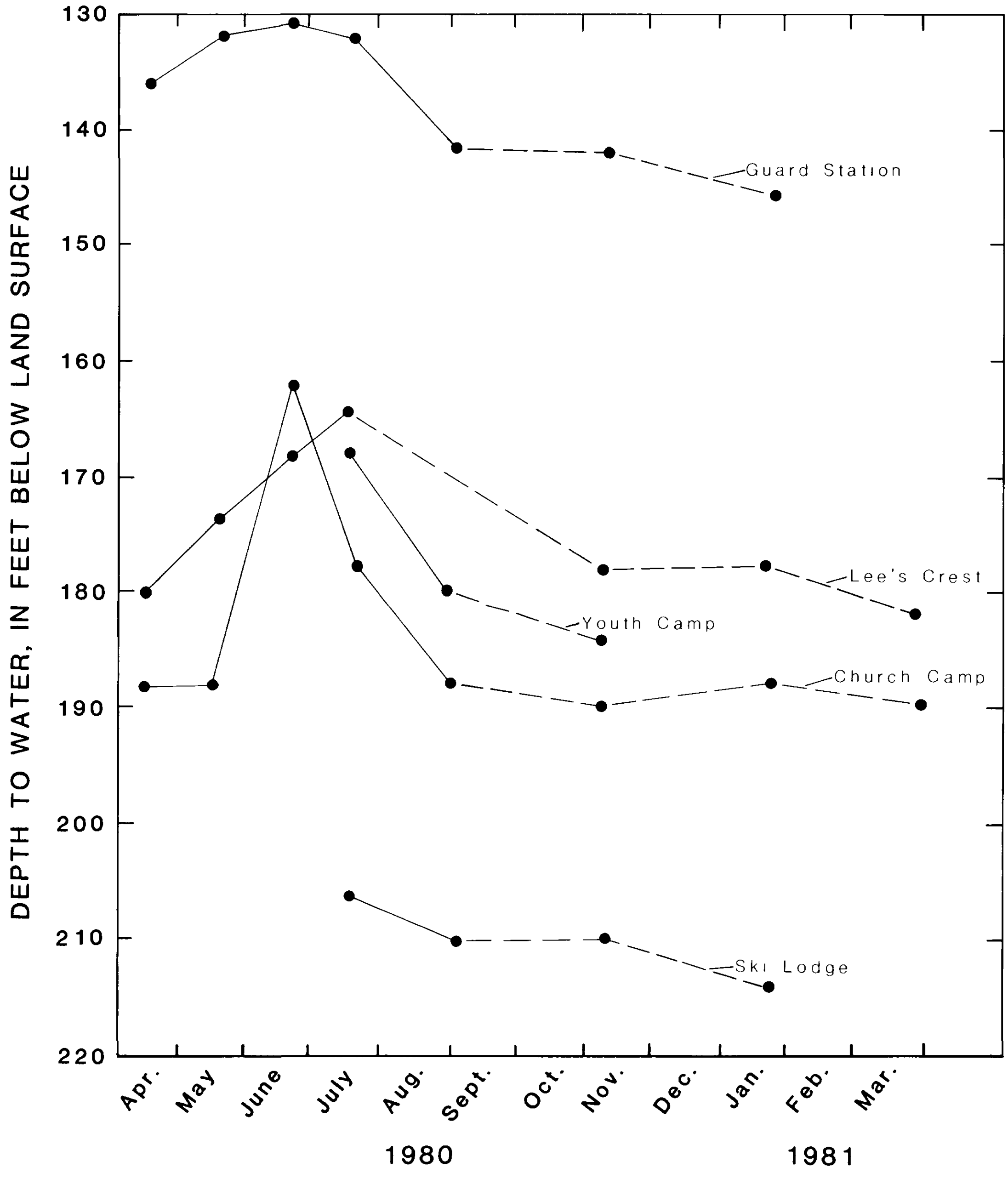

Figure 6.--Hydrographs for selected wells in Lee Canyon, April 1980-March 1981. (Dashed where frequency of measurements exceeds two months.)

The Lee's Crest, Guard Station, and Church Camp wells are within 0.3 mile of each other, but their hydrographs show different fluctuations in water level (figure 6). The water level at the Guard Station well rose 4 feet from April to May 1980, then rose at a slower rate through June or early July, and then had declined 9 feet by early September. The water level at the Lee's Crest well rose 15 feet from April to mid-July 1980 and then declined nearly 13 feet at a relatively constant rate through early November. The water level at the Church Camp well fluctuated more than any other measured water level in Lee Canyon. It began to rise in mid-May 1980, and by late June had risen 26 feet. The water level then declined 27 feet through early September.

The hydrographs for the Lee's Crest, Guard Station, and Church Camp wells are difficult to interpret in terms of the movement of ground water through the carbonate rocks. For instance, the water level rose to its highest point at the Church Camp well nearly a month before it did at the Lee's Crest well (figure 6), even though the latter is upgradient from the former (figure 2). In addition, there is a 30-40 foot difference in water level between the Lee's Crest and Guard Station wells, even though the two are close together and at about the same altitude. A possible explanation is that the wells intercept fracture systems that are not interconnected.

In summary, water levels in the middle part of Lee Canyon (Lee's Crest, Guard Station, and Church Camp well, see figure 2) rose through June and July and then declined through the following winter. In other parts of the canyon, the data are not sufficient to estimate timing of highest water levels.

Recharge

The method most commonly used to estimate recharge in the Great Basin is an empirical one based on altitude and precipitation. The method assumes that precipitation increases with increasing altitude and that the effects of evaporation and sublimation decrease. Maxey and Jameson (1948, pages 107-109) first used the method in the Great Basin in the mountains that surround Las Vegas Valley. More recently, Quiring (1965) refined precipitation-altitude relationships, and Rush (1970, page 13) refined estimates of the proportion of total precipitation that becomes recharge (table 1). Even with these refinements, however, the uncertainty of recharge estimates may be on the order of 50 percent (Isaac J. Winograd, U.S. Geological Survey, written communication, 1982).

Recharge in the study area comes mostly from the spring snowmelt, which generally begins in late March or April[1] and lasts through mid-June. Summer thunderstorms may contribute minor amounts of recharge. The estimated recharge is 5,000 acre-ft/yr in Kyle Canyon and 3,000 acre-ft/yr in Lee Canyon (table 1). These estimates are based on the average annual amount of precipitation that falls within the drainage areas of Kyle and Lee Canyons. Because of the complex geology of the area, interbasin flow may affect the disposition of some of this recharge.

---

[1] Figure 5 indicates that in 1981 the snowmelt began as early as January or February.

TABLE 1.--*Relationships between altitude, precipitation, and recharge*

Altitude zone (feet above sea level)	Precipitation: Average[1] (inches per year)	Precipitation: Percentage as recharge[2]	Kyle Canyon: Area (acres)	Kyle Canyon: Recharge acre-feet per year)	Lee Canyon: Area (acres)	Lee Canyon: Recharge (acre-feet per year)
Over 11,000	36	25	200	150	72	54
10,000-11,000	32	25	1,500	1,000	780	520
9,000-10,000	26	25	3,000	1,600	2,500	1,400
8,000-9,000	21	25	3,400	1,500	3,200	1,400
7,000-8,000	17	15	3,000	640	440	94
6,000-7,000	14	7	450	37	0	0
TOTALS (rounded)	--	--	12,000	5,000	7,000	3,000

[1] From Quiring (1965, figure 1).
[2] From Rush (1970, page 13).

The alluvium of Kyle Canyon is recharged by snowmelt on the canyon floor and by ground-water inflow from bedrock. Surface flow was negligible from April 1980 to March 1981. Using methods described above, snowmelt that directly enters the alluvium along the canyon floor is estimated at 500 acre-ft/yr (see tabulation below). This estimate was computed from the area (in acres) of each of the three altitude zones included in the outcrop area of alluvium along the canyon floor. However, the snow pack in April 1980 was about 200 percent of normal (R. E. Moreland, U.S. Soil Conservation Service, oral communication, 1981), so this part of recharge to the alluvium in 1980 may have been more than 500 acre-feet.

Altitude zone (feet above sea level)	Area (acres)	Recharge (acre-feet per year)
6,000-7,000	358	29
7,000-8,000	1,780	380
8,000-9,000	226	99
Total (rounded)	2,400	500

The interchange of ground water between alluvium and carbonate rocks involves both inflow to and outflow from the alluvium, and both processes may operate simultaneously in any part of the canyon. Underflow through the alluvium in Kyle Canyon can be used to identify areas of net inflow and outflow. Although underflow is a discharge process, it can indicate areas where alluvium receives recharge as inflow from bedrock. Underflow is estimated at sections A-A', B-B', and C-C' (plate 2) using Darcy's Law ($Q = KiA$), where discharge (Q) equals the product of hydraulic conductivity (K), the gradient (i) of the water table, and the area (A) across which flow occurs. The cross-sectional area of flow (A) was computed from the saturated thickness of alluvium shown on plate 2. The saturated thickness and the water-table gradient (i) at each section are based on mean water levels shown in table 4. Pairs of wells used to compute gradients were: Mary Jane and Echo for section A-A'; Kramer and Ranger Station for section B-B'; and Ranger Station and Highway Department for section C-C'. The hydraulic conductivity (K) of the alluvium is assumed to be 50 ft/d (see earlier section of this report). Underflow during 1980 is an estimated 2,000 acre-feet at section A-A', 500 acre-feet at section B-B', and 400 acre-feet at section C-C'. Underflow at section A-A' (2,000 acre-feet) is due mostly to inflow from carbonate rocks because snowmelt on the canyon floor was probably no more than 100 acre-feet in this part of the canyon (see previous tabulation).[1] These estimates of underflow show that the upper part of the canyon is an area of net inflow to alluvium and the middle and lower parts of the canyon are areas of net outflow. The part of the canyon where the predominance of net inflow changes to a predominance of net outflow is uncertain, but is somewhere between sections A-A' and B-B'. Because of this uncertainty, more inflow than that indicated at section A-A' may enter the alluvium.

Thus, estimated recharge to the alluvium of Kyle Canyon during 1980 (a wetter-than-average year) consisted of at least 500 acre-feet of snowmelt that directly entered alluvium and at least 2,000 acre-feet of ground-water inflow from carbonate rock, for a total of 2,000-3,000 acre-feet. In a year of average precipitation, however, recharge to the alluvium might be significantly less.

Discharge

Discharge from the ground-water systems of Kyle and Lee Canyons is due to pumpage, springs, underflow, and evapotranspiration. Most water used in Kyle Canyon is pumped from the Echo, Mt. Charleston Lodge, Rainbow, Highway Department, and Daines wells, although springs provide water to a few residences and a picnic ground. Most residences in Lee Canyon depend on well water. The ski lodge, Youth Camp, and Girl Scout Camp use water from springs, with additional water needs at the Youth Camp supplied by a well. Water use for 1977 is an estimated 68 acre-feet in Kyle Canyon and 19 acre-feet in Lee Canyon (Brown and Caldwell, 1978, page 4-31). Both estimates include water from springs and therefore are not true pumpage figures; however, when

---

[1] This part of the canyon floor is within the 8,000-9,000-foot altitude zone and a very small part of the 7,000- to 8,000-foot zone.

compared with total recharge, the figures illustrate the insignificance of discharge due to pumping. Spring discharge in Kyle and Lee Canyons is also relatively small. Nichols and Davis (1979, page 7) showed that springs in the study area were discharging as much as 260 acre-ft/yr in August 1978; however, they also noted that spring flow infiltrates the stream bed within a few hundred feet of the orifice (Nichols and Davis, 1978, page 14). Discharge by evapotranspiration (combined effects of evaporation and use of ground water by vegetation) is small because ground water is not normally near enough to land surface except at springs.

Underflow is the most important form of discharge from the ground-water reservoirs of the study area. This water moves through the alluvium and carbonate rocks of Kyle Canyon and the carbonate rocks of Lee Canyon toward Las Vegas Valley. Although there may be some interbasin flow between the two canyons or to adjacent basins other than Las Vegas Valley. Underflow for either canyon cannot be computed because the saturated thickness of the carbonate rocks is not known.

Discharge from the alluvium of Kyle Canyon occurs as underflow at the canyon mouth and as outflow to bedrock. Discharge during the study can be estimated by computing the change in volume of saturated alluvium between April 1980 and March 1981. The amount of water that drained from the alluvium can then be computed by multiplying this volume by the estimated specific yield of alluvium in the canyon (12 percent). However, this change in storage may not represent total discharge from the alluvium because inflow from carbonate rocks probably continues even as water levels decline. Therefore, the total discharge may have been greater. The change in volume of saturated alluvium was computed from: (1) the saturated width of alluvium at each of the cross sections in the canyon (plate 2); (2) changes in water levels (difference between maximum and minimum water levels in table 4) at each well between April 1980 and March 1981; and (3) the length of saturated aquifer measured along the axis of the canyon from a point midway between the Mary Jane and Echo wells to the Highway Department well. The point between the Echo and Mary Jane wells was chosen because alluvium was never saturated during the study at the Mary Jane well and some was always saturated at the Echo well. Cross section B-B' (plate 1) was used to separate the alluvium into two segments. The upper segment is 16,000 feet long and the lower one 5,000 feet long. Saturated widths based on mean water levels for April 1980-March 1981 are 1,000 feet at section A-A', 900 feet at B-B', and 600 feet at C-C' (plate 2). Mean water-level changes were 94 feet for wells in the upper segment (Echo, Mt. Charleston Lodge, Kramer, and Ranger Station wells) and 70 feet for wells in the lower segment (Ranger Station and Highway Department wells). These data indicate that at least 5,000 acre-feet of ground water was discharged from the alluvium during April 1980-March 1981.

Alluvial underflow from the study area at section C-C' was an estimated 400 acre-feet in 1980 (see previous section). Therefore, the remaining discharge, 4,600 acre-feet, would, of necessity, constitute ground water moving from the alluvium into the underlying bedrock between sections A-A' and C-C'.

Ground-Water Budgets

The ground-water budgets for the Kyle Canyon and Lee Canyon drainage basins within the study area are summarized in table 2. Kyle Canyon receives an estimated 5,000 acre-ft/yr of recharge, which subsequently discharges as underflow in carbonate rocks and alluvium. Lee Canyon receives an estimated 3,000 acre-ft/yr of recharge, which discharges as underflow in carbonate rocks. Discharge is assumed to move eastward to the Las Vegas Valley ground-water reservoir; however, flow to other adjacent basins is also possible.

The water budget for the alluvium in Kyle Canyon (table 2) is complex and doubtless varies from year to year depending on precipitation quantities. Recharge enters the alluvium as snowmelt on the canyon floor and as inflow from adjacent bedrock. Snowmelt recharge to the alluvium is an estimated 500 acre-feet for a normal year. Inflow from carbonate rocks to the alluvium occurs in the upper part of Kyle Canyon, and is estimated to have been 2,000 acre-feet from April 1980 to March 1981 in the area upgradient from section A-A' (plate 2). Total recharge to the alluvium during this period was 2,000-3,000 acre-feet, and may have been greater depending on the amount of inflow between sections A-A' and B-B'.

Ground water in the alluvium of Kyle Canyon discharges as underflow at the canyon mouth and as outflow to carbonate rocks. Total discharge from the alluvium was at least 5,000 acre-feet in 1980, of which 400 acre-feet was alluvial underflow at the canyon mouth and the remainder outflow to bedrock in the area upgradient from the mouth.

The water budget for the alluvium of Kyle Canyon (table 2) is based on data collected during 1980--a year in which the snowpack was about 200 percent of normal. The several components of recharge and discharge presumably would be different in magnitude during a year of average snowpack. Nonetheless, the data for 1980 indicate that much of the total recharge for Kyle Canyon enters the alluvium in the upper part of the canyon, and yet most of the discharge in the canyon is through the carbonate rocks.

The complexity of the ground-water systems of Kyle and Lee Canyons adds to the imprecision of the water budgets. Even if the uncertainties of the method used to estimate recharge could be eliminated, other uncertanties would remain because the hydrogeology of the area is not well understood. Two major problems are discharge and interbasin flow. Total discharge for alluvium plus bedrock cannot be computed because the saturated thickness of bedrock is not known. Regarding interbasin flow, recharge in Kyle and Lee Canyons was computed using the topographic boundaries of each canyon. However, the ground-water divides between the canyons and adjacent basins may not everywhere coincide with the topographic divides; as a result, part of the percolating snowmelt in either canyon could move to an adjacent basin.

TABLE 2.--*Ground-water budgets for drainage basins of Kyle and Lee Canyons in an average year and for alluvium of Kyle Canyon in 1980*

Budget item		Acre-feet per year
Kyle Canyon: entire drainage basin, average year		
Estimated annual recharge (table 1)		5,000
Estimated annual discharge (underflow in bedrock and alluvium)		(*a*)
Kyle Canyon: alluvium only, 1980[b]		
Estimated recharge		
Snowmelt on canyon bottom	500	
Inflow from bedrock	2,000+	
Total recharge		2,000-3,000
Estimated discharge		5,000
Lee Canyon: entire drainage basin, average year		
Estimated annual recharge (table 1)		3,000
Estimated annual discharge (underflow in bedrock only)		(*a*)

[a] Could not be determined because saturated thickness of the carbonate rocks is not known.

[b] According to R. E. Moreland (U.S. Soil Conservation Service, oral communication, 1981), the 1980 snowpack was 200 percent of normal. Therefore, quantities might be greater than normal.

Ground-Water Quality

Physical and Chemical Character

Water-quality information presented in this report consists of data collected in August 1978 (Nichols and Davis, 1979, table 4) and from April 1980 to March 1981 during the current study. Tables 5 and 6 (at back of report) show the physical and chemical character of ground water in Kyle and Lee Canyons. Table 3 is a statistical summary of some constituents listed in tables 5 and 6. The tables are arranged to permit a comparison of water quality from well to well in a downgradient direction. Physical determinations that are shown on the tables are water temperature[1] and specific conductance, both of which were measured onsite. Chemical constituents include those that show general chemical quality of the water and those that might indicate the presence of septic-tank effluent.

[1] Temperature in tables 5 and 6 is reported in degrees Celsius (°C), which may be converted to degrees Fahrenheit (°F) by using the formula °F = [(1.8)(°C)] + 32.

Specific conductance is a measure of the ability of a solution to conduct an electrical current. The units used are micromhos per centimeter at 25°C (hereafter abbreviated "micromhos"). Specific conductance can be used to estimate the dissolved-solids concentration of water. The concentration of dissolved solids in water from Kyle and Lee Canyons, in milligrams per liter, is characteristically about 60 percent of the specific-conductance value.

The data in figure 7 and tables 5 and 6 show that ground water in Kyle Canyon differs slightly from ground water in Lee Canyon. The dominant cations in ground water of both canyons are calcium and magnesium. Ratios of calcium to magnesium are higher in Kyle Canyon than in Lee Canyon and are lower at the mouth of each canyon than in the upper part. These ratios suggest that there may be more dolomite in the carbonate rocks of Lee Canyon than in those of Kyle Canyon. Alkalinity values in tables 5 and 6 show that the dominant anions in the sampled ground water of Kyle and Lee Canyons are bicarbonate plus carbonate (expressed as alkalinity, and presumably dominated by bicarbonate). Chloride and sulfate are far less abundant; however, sulfate values at the Highway Department well in Kyle Canyon and at the Lee's Crest well in Lee Canyon are significantly higher than at other wells in either canyon. In addition, measured sulfate values are characteristically greater in Lee Canyon than in Kyle Canyon.

The hardness of water is the result of calcium and magnesium ions, and is expressed as milligrams per liter (mg/L) of calcium carbonate. During the study, hardness ranged from 150 mg/L at the Mt. Charleston Lodge well to 240 mg/L at the Highway Department well in Kyle Canyon (table 5). In Lee Canyon, hardness ranged from 180 mg/L at the Ski Lodge well to 240 mg/L at the Lee's Crest well (table 6).

Concentrations of cations and anions generally change in two respects in the study area. Concentrations generally increase downgradient, reflecting an increasing residence time of ground water in the rocks. At individual wells, especially in Kyle Canyon, concentrations decrease in the spring and early summer, and usually reach their lowest values as much as a month after the water level is highest in the well. This supports the conclusion made earlier in this report that water-level changes in Kyle Canyon are due to a pressure head in the carbonate rocks because the dilution effect of snowmelt usually does not become apparent until after water levels have begun to decline.

Some of the constituents of ground water listed in tables 5 and 6 can be used as possible indicators of contamination by septic-tank effluent. These constituents are phosphorus, MBAS (methylene blue active substances), organic carbon, chloride, sodium, and the several forms of nitrogen. Septic-tank effluent would be expected to increase the concentrations of these constituents in ground water downgradient from the septic systems. Sampling sites that are downgradient from septic systems are the Rainbow, Highway Department, and Daines wells in Kyle Canyon, and the Youth Camp, Lee's Crest, and Summer Homes wells in Lee Canyon.

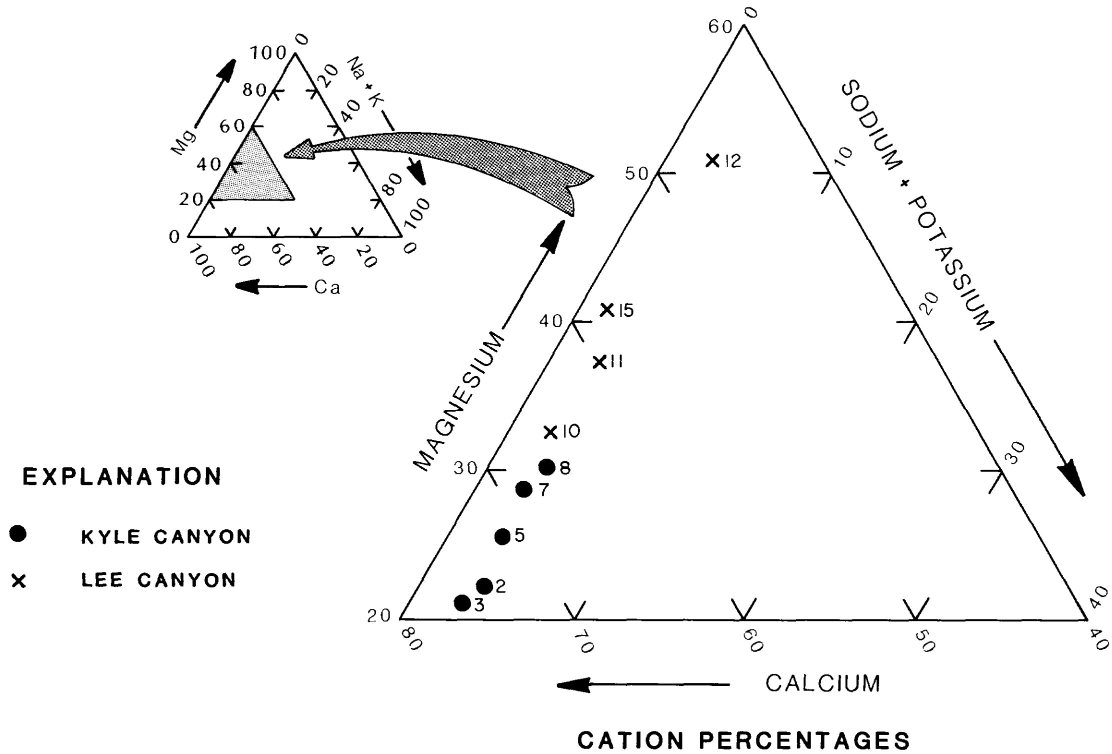

Figure 7.--Proportions of major cations in water from wells. [Percentages are based on milliequivalents per liter (see Hem, 1970, pages 81-84 and 268-270). Well numbers refer to table 3.]

Phosphorus and MBAS are constituents that can indicate the presence of detergents in water. Concentrations of both constituents were near the limits of detection in the ground water of Kyle and Lee Canyons (tables 5 and 6), suggesting that little if any detergent residue was present in the sampled well water. However, phosphorus is readily adsorbed in most soils and MBAS is rapidly degraded by soil micro-organisms. The absence of either of these constituents in the ground water of Kyle and Lee Canyons does not imply that septic tank effluent is not present in the water.

The several forms of nitrogen found in ground water--nitrate, nitrite, ammonia, and organic--can come from different sources. Primary sources in Kyle and Lee Canyons presumably are organic matter in soils and, possibly, septic-tank effluent. In both Kyle and Lee Canyons, the predominant form of nitrogen is organic nitrogen. Nitrate plus nitrite constitutes a significant proportion of the dissolved nitrogen in Kyle Canyon but is relatively minor in Lee Canyon except at the Summer Homes well. In both canyons, ammonia constitutes a very small proportion of the dissolved nitrogen.

In Kyle Canyon, mean values of nitrate plus nitrite increase gradually in a downgradient direction (table 3). Values of the other forms of nitrogen, however, do not change in a similar manner. In Lee Canyon, maximum values of nitrate plus nitrite and dissolved nitrogen (table 3) increase downgradient. However, the number of samples ranges from one at the Ski Lodge well to seven at the Youth Camp well.

Concentrations of total organic carbon in Kyle Canyon vary seasonally, with maximum concentrations in fall and winter and minimum concentrations in spring and summer. Concentrations at the Rainbow well were more than twice those at the Echo and Mt. Charleston Lodge wells (tables 3 and 5). Concentrations at the Highway Department and Daines wells were lower than at the Rainbow well, but still exceeded values at the Echo and Mt. Charleston Lodge wells. The range in values at all wells in the canyon during the fall and winter (November-February) was from 4.3 to 18 mg/L (table 5). During spring and summer, values of total organic carbon ranged from 0.6 to 4.0 mg/L (table 5), but did not systematically increase downgradient. In Lee Canyon, values of total organic carbon did not show seasonal variation, but the Lee's Crest and Summer Homes wells generally had the highest concentrations.

Organic carbon has been used as an indicator of septic-tank effluent in ground water. Leenheer and others (1974, page 369) have shown that concentrations of dissolved organic carbon in 17 unpolluted limestone aquifers in the United States range from 0.2 to 5.0 mg/L, with a median of 0.7 mg/L. Although median values of total organic carbon[1] in Kyle Canyon are higher (2.4-3.6 mg/L), the range of values at all wells in the spring and summer (time of minimum concentrations) falls within the range determined for other limestone aquifers (Leenheer and others, 1974, page 369).

---

[1] The difference between concentrations of total organic carbon and dissolved organic carbon is generally small in ground water.

TABLE 3.--*Statistical summary of selected water-quality data, 1980-81*

[Values in milligrams per liter]

	Kyle Canyon wells				
Constituent	Echo	Mt. Charleston Lodge	Rainbow	Highway Dept.	Daines
Total organic carbon					
No. of determinations	6	7	7	6	6
Mean/median	3.9/3.6	2.9/3.2	6.1/3.6	4.0/3.6	3.7/2.4
Maximum (date)	6.5(1/81)	5.2(11/80)	18(11/80)	9.4(1/81)	11(11/80)
Minimum (date)	1.1(5/80)	0.7(4/80)	0.7(5/80)	0.6(*a*)	0.6(6/80)
Dissolved nitrogen					
No. of determinations	7	7	7	6	6
Mean/median	0.71/0.68	0.53/0.48	0.68/0.69	0.66/0.55	0.87/0.69
Maximum (date)	1.3(6/80)	0.95(3/81)	0.84(7/80)	1.2(4/80)	2.0(6/80)
Minimum (date)	0.30(11/80)	0.27(5/80)	0.49(11/80)	0.37(11/80)	0.29(11/80)
Nitrate plus nitrite					
No. of determinations	8	8	8	7	7
Mean/median	0.16/0.14	0.09/0.10	0.21/0.21	0.23/0.22	0.30/0.26
Maximum (date)	0.25(3/81)	0.16(3/81)	0.28(3/81)	0.34(3/81)	0.49(3/81)
Minimum (date)	0.09(7/80)	0.01(5/80)	0.14(7/80)	0.19(9/80)	0.24(7/80)
Sodium					
No. of determinations	3	4	3	3	4
Mean/median	--	--	--	--	--
Maximum (date)	1.8(1/81)	1.4(1/81)	1.8(1/81)	1.9(*a*)	2.8(1/81)
Minimum (date)	1.2(11/80)	0.9(*a*)	1.3(11/80)	1.6(11/80)	1.9(11/80)
Chloride					
No. of determinations	8	8	8	7	7
Mean/median	0.7/0.7	0.6/0.6	1.5/1.4	1.1/1.1	1.5/1.6
Maximum (date)	0.8(*a*)	0.8(5/80)	2.4(11/80)	1.4(3/81)	1.9(9/80)
Minimum (date)	0.5(*a*)	0.5(*a*)	0.7(9/80)	0.9(*a*)	1.2(*a*)

[a] Value occurred more than once during study.

Furthermore, maximum values of total organic carbon at the Echo and Mt. Charleston Lodge wells do not greatly exceed the range for other limestone aquifers; in contrast, maximum values at the Rainbow, Highway Department, and Daines wells (9.4-18 mg/L) exceed that range. In Lee Canyon, maximum concentrations of total organic carbon exceed values of dissolved organic carbon in other limestone aquifers. However, maximum and minimum values are not restricted to a particular time of year.

An effective way of analyzing water-quality data is to plot concentrations of constituents on arithmetic probability paper (Nowlin, 1982, pages 34-40); such a plot indicates the "frequency of occurrence" of the concentration for a specific constituent. For instance, figure 9 is a probability plot of sodium concentrations in ground water in Kyle Canyon. The plot shows that for all values of sodium, 90 percent will be less than 2.4 mg/L and 5 percent will be less than 0.8 mg/L.

TABLE 3.--*Statistical summary of selected water-quality data, 1980-81*--Continued

[Values in milligrams per liter]

Constituent	Lee Canyon Wells			
	Ski Lodge	Youth Camp	Lee's Crest	Summer Homes
Total organic carbon				
No. of determinations	1	6	6	2
Mean/median	--	6.0/5.8	5.5/2.8	--
Maximum (date)	12(7/80)	11(6/80)	19(1/81)	11(11/80)
Minimum (date)	--	1.6(*a*)	0.0(5/80)	7.4(7/80)
Dissolved nitrogen				
No. of determinations	1	6	6	2
Mean/median	--	0.40/0.38	0.47/0.39	--
Maximum (date)	0.43(7/80)	0.67(3/81)	0.99(1/81)	1.1(7/80)
Minimum (date)	--	0.24(11/80)	0.27(3/81)	0.70(11/80)
Nitrate plus nitrite				
No. of determinations	1	7	6	3
Mean/median	--	0.02/0.00	0.01/0.02	--
Maximum (date)	0.00(6/80)	0.10(3/81)	0.03(6/80)	0.27(11/80)
Minimum (date)	--	0.00(*a*)	0.00(*a*)	0.19(7/80)
Sodium				
No. of determinations	0	3	2	1
Mean/median	--	--	--	--
Maximum (date)	--	2.0(1/81)	2.3(1/81)	1.6(11/80)
Minimum (date)	--	1.4(11/80)	2.1(3/81)	--
Chloride				
No. of determinations	1	6	6	3
Mean/median	--	0.8/0.8	1.1/1.2	--
Maximum (date)	0.6(6/80)	0.9(1/81)	1.2(*a*)	2.7(7/80)
Minimum (date)	--	0.7(*a*)	0.9(6/80)	1.1(*a*)

[a] Value occurred more than once during study.

A group of values such as those for sodium in Kyle Canyon will plot near a straight line if all the values have a statistically normal distribution about some mean. This indicates that variations may be due to random errors in sampling or analysis, or to gradual changes in the chemistry of the water. In contrast, a probability plot that consists of two straight-line segments with different slopes (for example, figures 10 and 11), suggests two groups of values, each representing water of different chemistry.

Ground-water constituents in Kyle Canyon that were analyzed with probability plots were calcium, magnesium, sodium, sulfate, chloride, and nitrate plus nitrite (figures 8-11). Of these, calcium, magnesium, and sulfate are least sensitive to contamination by septic-tank effluent. Except for sulfate, values of these three constituents generally plot along straight lines (figure 8), with data for the Echo and Mt. Charleston Lodge wells in the lower range of values and data for the Rainbow, Highway Department, and Daines wells in the upper range. The probability plot of sodium (figure 9) also approximates a straight line, showing a gradual increase in concentration in a downgradient direction.

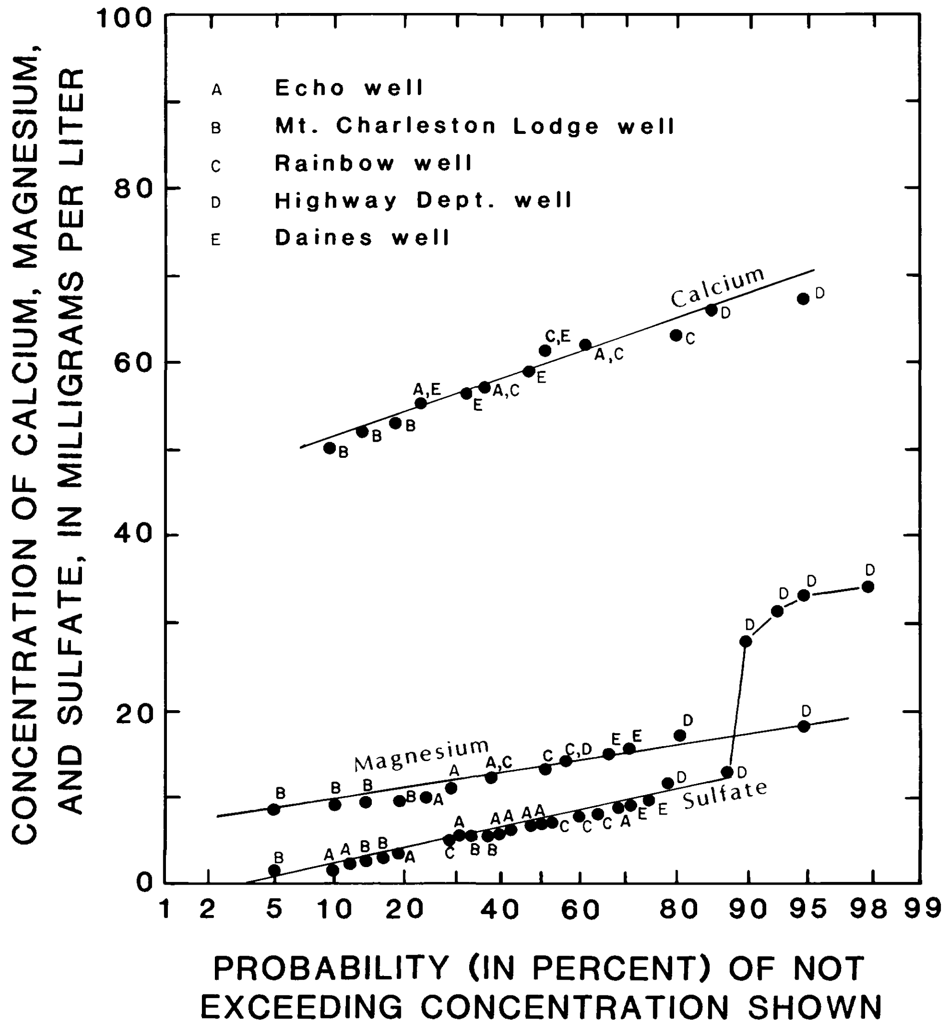

Figure 8.--Frequency distributions of calcium, magnesium, and sulfate in ground water from Kyle Canyon.

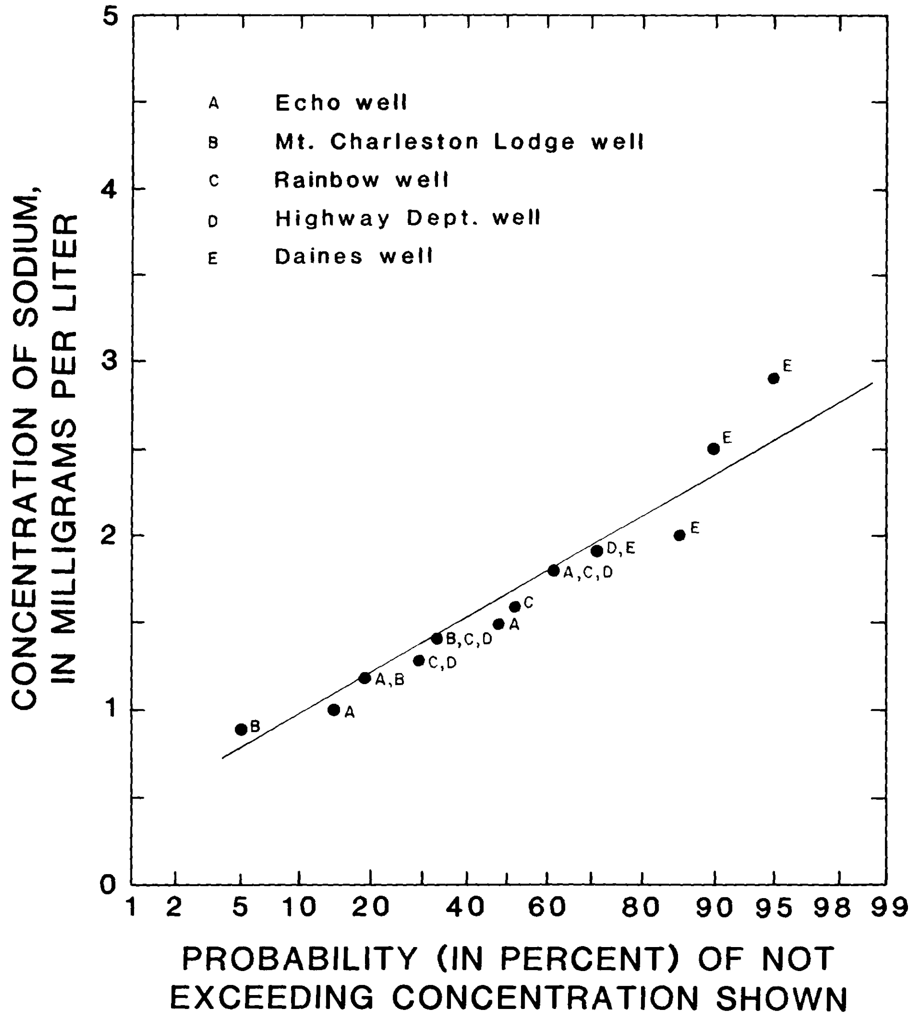

Figure 9.--Frequency distribution of sodium in ground water from Kyle Canyon.

In figure 8, sulfate data plot near a straight line, except for the highest concentrations at the Highway Department well. These high concentrations, which are for samples collected in the fall, winter, and early spring, result in a range of values for the Highway Department well that exceeds the range for any other well in Kyle Canyon, including the nearby Daines well (figure 2 and plate 3). This suggests that water of different chemistry, at least with respect to sulfate, enters the ground water in Kyle Canyon near its mouth. However, this water has not affected sulfate concentrations at the Daines well, possibly because different rocks or fracture systems yield water to each of the wells.

Figure 10 is a probability plot for chloride in the ground water of Kyle Canyon. It shows that chloride values comprise two discrete groups. One group, defined by values less than 1.0 mg/L, represents water from the Echo and Mt. Charleston Lodge wells. The other, for values greater than or equal to 1.0 mg/L, represents water from the Rainbow, Highway Department, and Daines wells. One value for chloride plots far from the other points, suggesting a sampling or analytical error.

Nitrate plus nitrite data also show two groups of values when plotted on probability paper (figure 11); however, the distinction between the two groups is not as obvious as for chloride. The two populations represent concentrations less than and greater than 0.17 mg/L. An outlying point on this plot also may reflect sampling or analytical error.

The probability plots of chloride and nitrate plus nitrite (figures 10 and 11) and some of the data in table 3 (especially total organic carbon) indicate that septic-tank effluent has affected ground-water quality in the middle and lower parts of Kyle Canyon. These changes do not appear to be due to natural causes; if they were, the two probability plots (figures 10 and 11) presumably would resemble those for cations (figures 8 and 9). In addition, the groups of higher chloride and nitrate plus nitrite values (figures 10, 11) and the increase in maximum concentrations of total organic carbon (table 3) represent samples from the Rainbow, Highway Department, and Daines wells, where ground water presumably would be most affected by septic-tank effluent.

A similar analysis of ground-water quality in Lee Canyon with respect to the possible effects of septic-tank effluent is not possible for two reasons. First, the Ski Lodge well (the only well in Lee Canyon that is not downgradient from septic systems) could be sampled only once during the study. Second, the downgradient changes in the values of constituents in table 3 are not always systematic from well to well. For instance, maximum values of dissolved nitrogen were not restricted to one sampling period, but instead occurred at different times of the year at different wells. The data suggest that ground water near the Summer Homes well and possibly at the Lee's Crest well is contaminated, although the observed changes might also be due to natural causes.

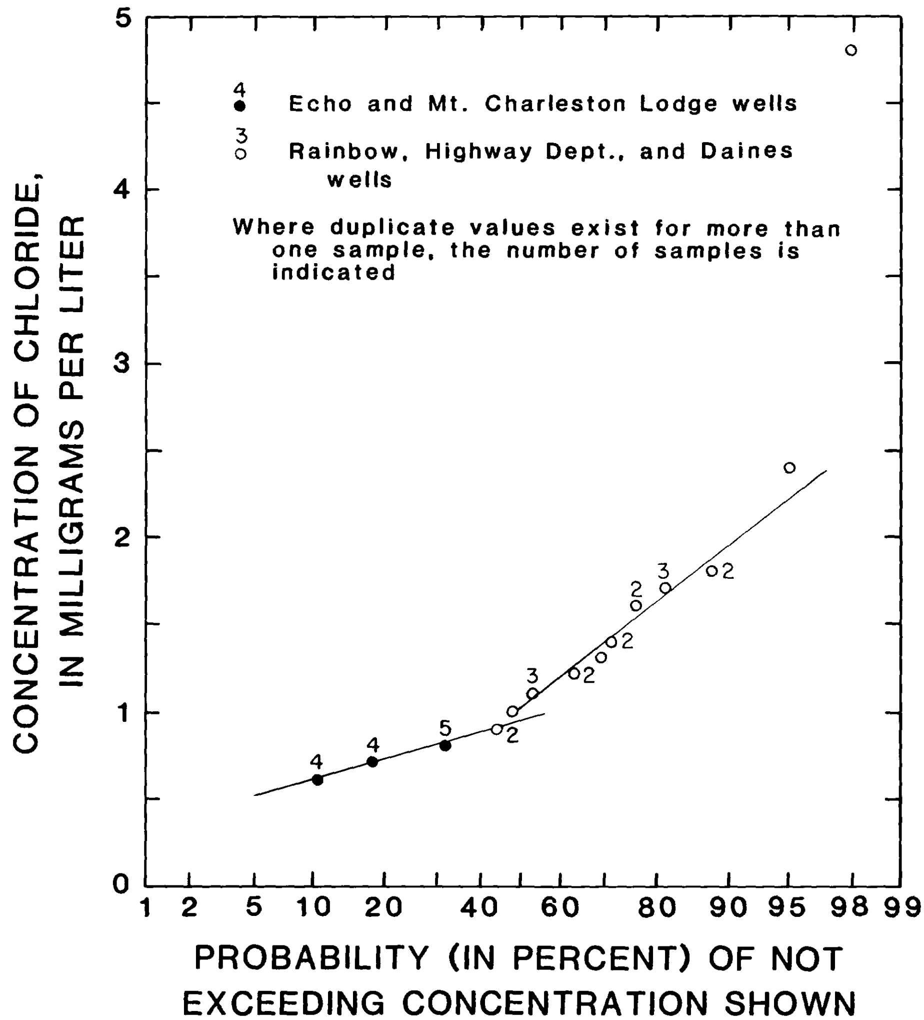

Figure 10.--Frequency distribution of chloride in ground water from Kyle Canyon.

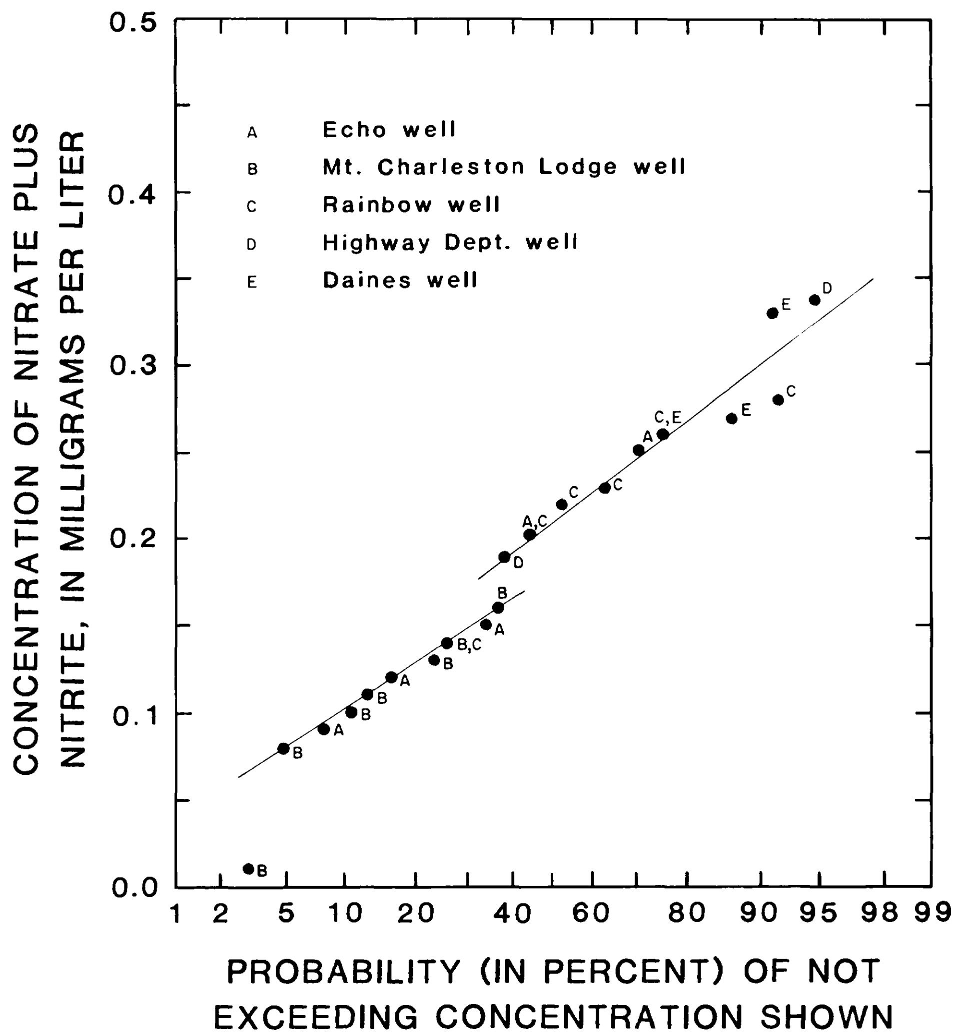

Figure 11.--Frequency distribution of nitrate plus nitrite (as N) in ground water from Kyle Canyon.

Suitability for Use

Water-quality standards used for this report are those adopted by the Nevada Division of Health (Nevada Bureau of Consumer Health Protection Services, 1980, page 8, and Appendix A, page 2). The upper limits or permissible range for constituents listed in tables 5 and 6 are as follows:

Chloride	400 mg/L
Fluoride	1.4-2.4 mg/L
Magnesium	150 mg/L
Nitrate	10 mg/L
Sulfate	500 mg/L
Total dissolved solids (residue at 103-105°C)	1,000 mg/L

Comparison of these standards with data in tables 5 and 6 shows that the water in both canyons easily meets water-quality standards. Ground water in part of Kyle Canyon (and possibly Lee Canyon) has been affected by low levels of septic-tank effluent. The effects are as yet slight, and concentrations of possible contaminants such as nitrate and chloride were well below the limits for drinking water as of 1981.

The hardness of a water is of concern to many users. Therefore, the U.S. Geological Survey has informally adopted the following rating:

Hardness, as $CaCO_3$ (milligrams per liter)	Rating and remarks
0-60	Soft (suitable for most uses without artificial softening)
61-120	Moderately hard (usable except in some industrial applications; softening profitable for laundries)
121-180	Hard (softening required by laundries and some other industries)
More than 180	Very hard (softening desirable for most purposes)

The hardness of ground water in Kyle and Lee Canyons ranges from 150 to 240 mg/L of $CaCO_3$, and is therefore classified as hard to very hard.

Ground water in Kyle and Lee Canyons is suitable for human use with respect to constituents listed in tables 5 and 6. However, the data suggest that a potential water-quality problem may exist in both canyons. The data are not sufficient to fully define the problem (especially in Lee Canyon) or to predict the potential effects of future development. A program to monitor water quality in each canyon over the long term would help define future trends.

SUMMARY

Residential and recreational development have created a situation in which septic-tank effluent could be affecting the quality of ground water in Kyle and Lee Canyons in the Spring Mountains of southern Nevada. This study was undertaken to gain an understanding of the hydrology and quality of ground water in both canyons.

Paleozoic limestone, dolomite, and minor clastic rocks are exposed throughout the study area except in the bottoms of Kyle and Lee Canyons, which are filled by Pliocene and Pleistocene alluvium. The alluvium is unconsolidated to consolidated and at least 400 feet thick in Kyle Canyon and 150 feet thick in Lee Canyon. Thrust and high-angle faults offset the Paleozoic rocks and have greatly complicated an understanding of the hydrogeology of the study area.

The hydraulic properties of the Paleozoic carbonate rocks in the study area are not accurately known. Aquifer tests evaluated for two shallow wells (Ski Lodge and Lee's Crest wells) in Lee Canyon produced hydraulic conductivities of 0.04 and 0.8 ft/d for the Nopah formation. Analysis of drillers' well tests done on the Mary Jane and Guard Station wells produced conductivities of 2 and 5 ft/d for the Monte Cristo Limestone and Nopah Formation, respectively. In contrast, aquifer tests done on wells tapping similar carbonate rocks at the Nevada Test Site yielded conductivities that range from 1 to 750 ft/d (Winograd and Thordarson, 1975, page 22). The hydraulic conductivity of Paleozoic carbonate rocks in the study area should be comparable to that of similar carbonate rocks at the Test Site. The tests done in the study area were relatively short and the wells may not have been fully efficient. Thus, the hydraulic conductivity of Paleozoic carbonate rocks in the study area could be several orders of magnitude greater than the range of values indicated by the four aquifer tests.

Hydraulic properties estimated for the alluvium of Kyle Canyon were specific yield and hydraulic conductivity. Average specific yield (estimated from drillers' logs) is 12 percent. Hydraulic conductivity computed from the results of drillers' well tests are 4 ft/d at the Echo well and 30 ft/d at the Ranger Station well. However, such estimates commonly are low, and the average hydraulic conductivity of alluvium in Kyle Canyon is considered to be on the order of 50 ft/d.

Ground water occurs in the alluvium and carbonate rocks of Kyle Canyon and in the carbonate rocks of Lee Canyon. Water levels in Lee Canyon indicate that the alluvium is rarely, if ever, saturated. Ground water moves through carbonate rock (and alluvium in Kyle Canyon) generally eastward toward Las Vegas Valley along gradients that range from 240 to 480 ft/mi. However, this may be an oversimplification of a complex ground-water system. Some water may also move to adjacent basins. The velocity of ground-water movement in the alluvium of Kyle Canyon is an estimated 30 ft/d and in carbonate rocks in the two canyons is estimated to range from 0.2 to 3,000 ft/d.

Water levels in Kyle and Lee Canyons rise each spring and early summer in response to snowmelt, and then decline through early winter. Measured water levels in Kyle Canyon (in alluvium and carbonate rocks) fluctuated 41-134 feet from April 1980 to March 1981. Measured water levels in Lee Canyon (in carbonate rocks only) fluctuated 8-27 feet during the same period. Water-level fluctuations, especially those in Kyle Canyon, appear to be caused by pressure head in carbonate rocks, rather than by a slug of water moving downgradient.

The water budgets of Kyle and Lee Canyons are summarized in table 2. Recharge, which consists mostly of snowmelt, is estimated to average 5,000 acre-ft/yr in the Kyle Canyon drainage area and 3,000 acre-ft/yr in the Lee Canyon drainage area. Discharge, which consists of underflow to Las Vegas Valley and possibly to adjacent basins, cannot be estimated because the saturated thickness of carbonate rocks is not known.

Recharge to the alluvium of Kyle Canyon in 1980 (April 1980-March 1981) was 2,000-3,000 acre-feet, of which 500 acre-feet directly infiltrated alluvium as snowmelt and at least 2,000 acre-feet entered alluvium as inflow from bedrock. Discharge from the alluvium of Kyle Canyon is comprised of underflow at the canyon mouth and outflow to bedrock mostly in the middle to lower parts of the canyon. Total discharge from the alluvium (5,000 acre-feet) was estimated from the change in storage that occurred from April 1980 to March 1981 as a result of water-level fluctuations. The water budget for the alluvium of Kyle Canyon during 1980 is based on a year when the snowpack was 200 percent of normal (R. E. Moreland, U.S. Soil Conservation Service, oral communication, 1981) and may not represent the water budget for a normal year.

Ground water in Kyle Canyon is generally similar in quality to that in Lee Canyon. The principal cations are calcium and magnesium, and the principal anion is bicarbonate. Ratios of calcium to magnesium are higher in Kyle Canyon than in Lee Canyon, possibly reflecting a greater proportion of dolomite in the rocks of Lee Canyon. Concentrations of dissolved constituents increase downgradient in each canyon because of increased residence time of water in the rocks. Concentrations of dissolved constituents decrease at individual wells during the snowmelt period and reach a minimum as much as a month after water levels are highest. This supports the conclusion that water-level changes in Kyle Canyon are a result of changes in pressure head in carbonate rocks.

Frequency distributions of cation and anion concentrations (figures 8 and 9) indicate that natural changes in water quality in Kyle Canyon constitute gradual increases in concentration in a downgradient direction. Mixing with other natural water of different chemistry generally is not indicated.

Concentrations of total organic carbon during winter (table 3) and frequency distributions of chloride and nitrate plus nitrite concentrations (figures 10 and 11) indicate that septic-tank effluent has affected ground-water quality in Kyle Canyon at and downgradient from the Rainbow well.

In Lee Canyon, concentrations of some ground-water constituents suggest that septic-tank effluent has affected water quality there too, but the data are not sufficient to identify sources of possible contaminants. Thus, the changes in Lee Canyon could be due to natural causes instead.

The ground water of Kyle and Lee Canyons easily meets State of Nevada water-quality standards as they pertain to constituents in tables 5 and 6. Continued monitoring of water quality in the study area could help identify future trends.

BASIC DATA

This section is comprised of compilations of the principal data used in the preparation of this report. Table 4 lists well data, including limited water-level information. Tables 5 and 6 list water-quality data for Kyle and Lee Canyons, respectively. Information on water levels, and other data, are available from the U.S. Geological Survey in Carson City, Nev.

(p. 41 follows)

TABLE 4.--*Well data*

[Use: C, commercial; D, domestic; PS, public supply; U, unused]

	Well name[a]	Location and site ID[b]	Year drilled	Use	Depth (feet)	Hole diameter (inches)	Land-surface altitude (feet above sea level)	Water level[c] (feet below land surface)		
								Maximum	Minimum	Mean
	Kyle Canyon									
1.	Mary Jane	S19 E56 26BBC1 361625115402601	1965	U	261	[d]10	8,240	234	193	219
2.	Echo	S19 E56 26DAC1 361555115392901	[e]1964	PS	350	[d]8	7,740	94	1	44
3.	Mt. Charleston Lodge	S19 E56 36ACB1 361524115384501	1961	C	377	8	7,600	323	193	272
4.	Kramer	S19 E57 31BB1 361525115374001	1957	U	290	[d]8	7,360	248	164	213
5.	Rainbow	S19 E57 31BB2 361534115374701	1960	PS	245	[d]10	7,280	--	--	[f]147
6.	Ranger Station	S19 E57 32BAB1 361544115365101	1965	U	274	[d]10	7,030	232	164	209
7.	Highway Dept.	S19 E57 28CBD1 361617115353801	1968	D	297	[d]6	6,800	251	179	224
8.	Daines	S19 E57 28CAA1 361612115353301	1979	D	405	12	6,760	--	--	[g]355
9.	Kingston	S19 E57 28ADB1 361622115350001	1977	U	650	10	6,700	514	380	458
	Lee Canyon									
10.	Ski Lodge	S19 E56 15ABA1 361811115404401	1967	U	400	10	8,660	214	206	210
11.	Youth Camp	S19 E56 10DDB1 361826115402801	1978	D	400	12	8,550	184	168	(*h*)
12.	Lee's Crest	S19 E56 10AAA1 361907115402201	[i]1967	D	[i]400	—	8,320	182	164	174
13.	Guard Station	S19 E56 3DDD1 361911115402001	1979	D	370	10	8,320	145	131	137
14.	Church Camp	S19 E56 2CCD1 361934115394201	1956	U	386	10	8,300	189	161	183
15.	Summer Homes	S19 E56 2CA1 362006115391801	1962	D	440	12	8,200	--	--	[g]152
16.	Lower Lee	S18 E56 25DC1 362056115381801	--	U	--	--	7,570	533	526	(*h*)

[a] Wells are listed in downgradient sequence for each canyon. The number to the left of each well name is used to identify that well on plate 3.
[b] See text for discussion of well-location and site-identification numbers.
[c] Measurements made during period April 1980-March 1981 by author, except as noted.
[d] Diameter of deepest part of hole.
[e] Deepened in 1966.
[f] Well measurable only once during study.
[g] Well not accessible for measurement. Water level reported by driller.
[h] Not enough measurements to justify calculation of mean.
[i] Driller's log not available; information from owner.

TABLE 5.--Physical and chemical character of ground water in Kyle Canyon, 1978-81

[Sites are listed in down-canyon order. MG/L, milligrsms per liter. "--" indicates measurement not made]

DATE	TEMPERATURE, WATER (DEG C)	SPECIFIC CONDUCTANCE (MICROMHOS)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)
					ECHO WELL						
1978											
AUG 21	8.5	342	180	57	10	1.0	0.4	170	6.7	1.0	0.1
1980											
APR 16	8.5	350	--	--	--	--	--	--	5.2	.8	--
MAY 20	8.5	336	--	--	--	--	--	--	1.5	.6	--
JUN 25	8.0	317	--	--	--	--	--	--	2.2	.8	--
JUL 23	9.0	325	--	--	--	--	--	--	3.5	.5	--
SEP 01	9.0	343	--	--	--	--	--	--	8.9	.6	--
NOV 10	9.0	341	180	55	11	1.2	.4	190	5.9	.7	.1
1981											
JAN 27	8.5	356	200	62	12	1.8	.4	190	6.8	.8	.1
MAR 30	8.5	362	200	62	11	1.5	.5	190	6.2	.7	.2
					ECHO SPRING						
1980											
APR 16	8.0	360	200	60	11	1.3	0.5	190	6.5	1.2	0.2
MAY 21	8.0	341	--	--	--	--	--	--	1.8	.7	--
					MT. CHARLESTON LODGE WELL						
1978											
AUG 21	--	282	160	48	8.6	0.8	0.3	140	5.7	0.8	0.1
1980											
APR 15	--	288	160	50	8.7	.9	.4	150	3.2	.7	.1
MAY 20	--	276	--	--	--	--	--	--	1.3	.8	--
JUN 24	--	269	--	--	--	--	--	--	.6	.6	--
JUL 22	--	270	--	--	--	--	--	--	.2	.5	--
SEP 01	--	279	--	--	--	--	--	--	2.8	.5	--
NOV 10	--	278	150	48	8.1	.9	.4	150	1.3	.5	.1
1981											
JAN 26	--	304	170	52	9.1	1.4	.4	160	5.4	.6	.1
MAR 30	--	307	170	53	9.6	1.2	.4	160	3.5	.7	.1
					RAINBOW WELL						
1978											
AUG 21	9.0	361	200	61	12	1.4	0.6	180	7.7	4.8	0.1
1980											
APR 16	--	390	--	--	--	--	--	--	7.2	1.7	--
MAY 20	9.0	386	--	--	--	--	--	--	5.1	1.1	--
JUN 25	9.0	364	--	--	--	--	--	--	5.6	1.9	--
JUL 23	9.5	356	--	--	--	--	--	--	6.4	1.8	--
SEP 01	9.0	352	--	--	--	--	--	--	4.8	.7	--
NOV 10	9.0	353	190	57	12	1.3	.4	190	4.7	2.4	.1
1981											
JAN 26	8.5	379	210	63	13	1.8	.4	200	7.3	1.1	.1
MAR 30	8.5	383	210	62	14	1.6	.5	200	7.8	1.2	.2
					HIGHWAY DEPARTMENT WELL						
1978											
AUG 21	--	397	210	62	14	1.4	0.5	200	12	1.7	0.2
1980											
APR 15	10.0	434	--	--	--	--	--	--	31	1.1	--
MAY 20	--	391	--	--	--	--	--	--	13	1.4	--
JUN 24	9.5	384	--	--	--	--	--	--	12	.9	--
SEP 01	10.0	378	--	--	--	--	--	--	12	.9	--
NOV 10	--	415	240	67	17	1.6	.5	210	28	1.0	.2
1981											
JAN 26	10.0	413	230	66	17	1.9	.4	200	34	1.1	.2
MAR 31	--	428	240	66	18	1.9	.5	190	33	1.4	.2
					DAINES WELL						
1980											
MAY 20	--	392	210	56	16	2.0	0.5	200	9.0	1.3	0.1
JUN 25	--	383	--	--	--	--	--	--	9.3	1.2	--
JUL 22	--	374	--	--	--	--	--	--	8.0	1.7	--
SEP 02	--	390	--	--	--	--	--	--	7.7	1.9	--
NOV 10	--	378	200	55	15	1.9	.5	200	7.7	1.2	.1
1981											
JAN 26	--	382	220	61	16	2.8	.4	200	12	1.6	.1
MAR 30	--	396	220	59	17	2.5	.5	200	11	1.6	.2

DATE	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, RESIDUE AT 180 DEG C DISSOLVED (MG/L)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)[1]	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, DISSOLVED (MG/L AS N)[2]	PHOSPHORUS, DISSOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	METHYLENE BLUE ACTIVE SUBSTANCE (MG/L)
					ECHO WELL					
1978										
AUG 21	5.4	184	--	--	--	--	--	--	--	--
1980										
APR 16	--	--	--	0.12	0.02	0.51	0.65	0.03	3.3	0.1
MAY 20	--	--	--	.12	.01	.26	.39	.02	1.1	--
JUN 25	--	--	--	.15	.04	1.1	1.3	.02	2.5	.0
JUL 23	--	--	--	.09	.00	.86	.95	.02	4.0	.0
SEP 01	--	--	--	.12	--	--	--	.01	--	--
NOV 10	5.4	195	204	.22	.00	.08	.30	.03	--	.0
1981										
JAN 27	6.0	205	203	.20	.04	.45	.69	.02	6.5	.0
MAR 30	5.8	203	211	.25	.07	.36	.68	.03	6.0	.0
					ECHO SPRING					
1980										
APR 16	6.3	202	206	0.13	0.02	2.0	2.1	0.02	1.9	0.1
MAY 21	--	--	--	.11	.01	.63	.75	.02	1.0	.1
					MT. CHARLESTON LODGE WELL					
1978										
AUG 21	4.5	153	--	--	--	--	--	--	--	--
1980										
APR 15	4.7	159	168	0.13	0.02	0.31	0.46	0.02	0.7	0.1
MAY 20	--	--	--	.01	.01	.25	.27	.01	3.2	.0
JUN 24	--	--	--	.10	.01	.37	.48	.01	3.3	.0
JUL 22	--	--	--	.11	.00	.53	.64	.04	2.4	.0
SEP 01	--	--	--	.02	--	--	--	.01	--	--
NOV 10	4.6	155	160	.14	.00	.14	.28	.04	5.2	.0
1981										
JAN 26	5.0	171	166	.08	.06	.49	.63	.02	4.3	.0
MAR 30	5.0	170	176	.16	.03	.76	.95	.03	1.0	.0
					RAINBOW WELL					
1978										
AUG 21	5.6	201	--	--	--	--	--	--	--	--
1980										
APR 16	--	--	--	0.22	0.00	0.35	0.57	0.02	3.8	0.1
MAY 20	--	--	--	.26	.01	.33	.60	.01	.7	.0
JUN 25	--	--	--	.23	.03	.43	.69	.02	1.7	.0
JUL 23	--	--	--	.14	.00	.70	.84	.04	2.2	.0
SEP 01	--	--	--	.14	--	--	--	.02	--	--
NOV 10	5.6	199	202	.20	.00	.29	.49	.03	18	.0
1981										
JAN 26	5.8	214	215	.20	.05	.46	.71	.02	13	.0
MAR 30	5.7	214	225	.28	.07	.48	.83	.03	3.6	.0
					HIGHWAY DEPARTMENT WELL					
1978										
AUG 21	5.7	218	--	--	--	--	--	--	--	--
1980										
APR 15	--	--	--	0.22	0.02	0.95	1.2	0.02	3.8	0.1
MAY 20	--	--	--	.23	.01	.31	.55	.01	.6	.1
JUN 24	--	--	--	.25	.01	.28	.54	.01	3.4	.1
SEP 01	--	--	--	.19	--	--	--	.01	--	--
NOV 10	6.2	249	248	.22	.00	.15	.37	.01	6.5	.0
1981										
JAN 26	6.2	248	257	.19	.06	.53	.78	.05	9.4	.0
MAR 31	6.3	243	246	.34	.05	.16	.55	.02	.6	.0
					DAINES WELL					
1980										
MAY 20	6.6	213	217	0.33	0.01	0.27	0.61	0.01	1.2	0.1
JUN 25	--	--	--	.27	.01	1.7	2.0	.01	.6	.0
JUL 22	--	--	--	.24	.00	.40	.64	.01	1.5	.0
SEP 02	--	--	--	.26	--	--	--	.01	--	--
NOV 10	6.3	209	218	.26	.00	.03	.29	.02	11	.0
1981										
JAN 16	6.7	222	224	.26	.06	.42	.74	.01	4.3	.0
MAR 30	6.6	221	225	.49	.05	.40	.94	.03	3.4	.0

[1] Chemical symbols: NO_2, nitrite; NO_3 nitrate.
[2] Dissolved nitrogen is the mathematical sum of the dissolved nitrate, nitrite, ammonia, and organic forms of nitrogen, all expressed as N.

TABLE 6.—*Physical and chemical character of ground water in Lee Canyon, 1978-81*

[Sites are listed in down-canyon order. MG/L, milligrams per liter. "--" indicates measurement not made]

DATE	TEMPER-ATURE, WATER (DEG C)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)
					SKI LODGE WELL						
1978											
AUG 23	8.0	336	180	47	14	0.9	0.4	170	9.9	1.4	0.1
1980											
JUL 24	--	357	--	--	--	--	--	--	18	.6	--
					YOUTH CAMP WELL						
1980											
MAY 21	7.5	392	220	52	21	1.3	0.5	210	11	1.1	0.1
JUN 24	8.0	413	--	--	--	--	--	--	13	.7	--
JUL 22	8.0	409	--	--	--	--	--	--	11	.8	--
SEP 01	8.0	438	--	--	--	--	--	--	11	.8	--
NOV 10	7.0	380	220	55	21	1.4	.4	210	12	.7	.1
1981											
JAN 27	7.5	411	230	59	21	2.0	.4	220	12	.9	.1
MAR 30	--	421	230	58	21	1.6	.6	220	10	.7	.1
					LEE'S CREST WELL						
1978											
AUG 22	10.0	442	240	46	31	1.9	0.7	220	23	1.9	0.1
1980											
APR 15	--	408	--	--	--	--	--	--	22	1.1	--
MAY 21	9.0	410	--	--	--	--	--	--	19	1.0	--
JUN 24	9.0	408	--	--	--	--	--	--	19	.9	--
JUL 21	9.0	411	--	--	--	--	--	--	20	1.1	--
1981											
JAN 26	8.5	413	240	45	30	2.3	.6	210	21	1.2	.1
MAR 30	8.0	--	230	43	30	2.1	.8	210	21	1.2	.1
					SUMMER HOMES WELL						
1978											
AUG 22	--	407	230	54	23	1.4	0.8	210	14	1.6	0.1
1980											
JUL 23	--	417	--	--	--	--	--	--	13	2.7	--
SEP 02	--	446	--	--	--	--	--	--	11	1.1	--
NOV 10	--	378	210	48	21	1.6	1.0	210	8.2	1.1	.0

TABLE 6.—*Physical and chemical character of ground water in Lee Canyon, 1978-81*—Continued

DATE	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, RESIDUE AT 180 DEG C DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)[1]	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN, DIS-SOLVED (MG/L AS N)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)
					SKI LODGE WELL					
1978										
AUG 23	4.9	181	--	--	--	--	--	--	--	--
1980										
JUL 24	--	--	--	0.00	0.00	0.43	0.43	0.00	12	0.0
					YOUTH CAMP WELL					
1980										
MAY 21	6.1	219	230	0.01	0.01	0.24	0.26	0.01	4.1	0.1
JUN 24	--	--	--	.06	.01	.31	.38	.01	11	.0
JUL 22	--	--	--	.00	.00	.39	.39	.00	1.6	.0
SEP 01	--	--	--	.00	-	--	--	.01	--	--
NOV 10	4.6	221	216	.00	.00	.24	.24	.01	10	.0
1981										
JAN 27	6.8	234	232	.00	.08	.38	.46	.03	7.5	.0
MAR 30	6.9	232	238	.10	.05	.52	.67	.03	1.6	.0
					LEE'S CREST WELL					
1978										
AUG 22	7.9	245	--	--	--	--	--	--	--	--
1980										
APR 15	--	--	--	0.01	0.04	0.40	0.45	0.01	7.7	0.1
MAY 21	--	--	--	.02	.01	.44	.47	.01	.0	.1
JUN 24	--	--	--	.03	.04	.26	.33	.00	3.3	.0
JUL 21	--	--	--	.00	.00	.31	.31	.01	2.4	.0
1981										
JAN 26	8.0	234	225	.00	.07	.92	.99	.01	19	.0
MAR 30	7.9	232	230	.02	.05	.20	.27	.02	.8	.0
					SUMMER HOMES WELL					
1978										
AUG 22	6.3	228	--	--	--	--	--	--	--	--
1980										
JUL 23	--	--	--	0.19	0.00	0.88	1.1	0.00	7.4	0.0
SEP 02	--	--	--	.00	--	--	--	.01	--	--
NOV 10	6.4	215	211	.27	.00	.43	.70	.01	11	.0

[1] Chemical symbols. NO_2, nitrite; NO_3 nitrate.
[2] Dissolved nitrogen is the mathematical sum of the dissolved nitrate, nitrite, ammonia, and organic forms of nitrogen, all expressed as N.

REFERENCES CITED

Brown and Caldwell, 1978, Wastewater management--Mt. Charleston area: Pasadena, Calif., Consultant report, 249 p.

Burchfiel, B. C., Fleck, R. J. Secor, D. T., Vincelette, R. R., and Davis, G. A., 1974, Geology of the Spring Mountains, Nevada: Geological Society of America Bulletin, v. 85, no. 7, p. 1013-1022.

Davis, S. N., and DeWiest, R. J. M., 1966, Hydrogeology: New York, John Wiley, 463 p.

Dolliver, C. V., 1968, Late Tertiary and Quaternary geomorphic history of Kyle Canyon, Spring Mountains, (southwestern) Nevada: University Park, Pennsylvania State University, unpublished Ph. D. thesis, 140 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geological Survey Water-Supply Paper 1536-E, p. 69-174.

Hamilton, Warren, and Myers, W. B., 1966, Cenozoic tectonics of the western United States: Reviews of Geophysics, v. 4, no. 4, p. 509-549.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Leenheer, J. A., Malcolm, R. L., McKinley, P. W., and Eccles, L. A., 1974, Occurrence of dissolved organic carbon in selected ground-water samples in the Unites States: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 361-369.

Lohman, S. W., and others, 1972, Definition of selected ground-water terms--revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, 218 p.

Maxey, G. B., and Jameson, C. H., 1948, Geology and water resources of Las Vegas, Pahrump, and Indian Springs Valleys, Clark and Nye Counties, Nevada: Nevada State Engineer, Water Resources Bulletin 5, 121 p.; app. 1, 128 p.; app. 2, 43 p.

Nevada Bureau of Consumer Health Protection Services, 1980, Water supply regulations--part 1, water quality standards--monitoring, recordkeeping, and reporting: Nevada Division of Health, 16 p.; app. A, 11 p.

Nichols, W. D., and Davis, L. E., 1979, Data on ground-water resources of the Spring Mountains area, Toiyabe National Forest, Nevada: U.S. Geological Survey Open-File Report 79-1638, 16 p.

Nowlin, J. O., 1982, Ground-water levels and water quality in an area near Topaz Lake, Douglas County, Nevada: U.S. Geological Survey Open-File Report 80-2046, 76 p.

Quiring, R. F., 1965, Annual precipitation amount as a function of elevation in Nevada south of 38° degrees latitude: Las Vegas, Nev., U.S. Weather Bureau Research Station report, 8 p.

Rush, F. E., 1968, Index of hydrographic areas: Nevada Division of Water Resources Information Report 6, 38 p.

-----1970, Regional ground-water systems in the Nevada Test Site area, Nye, Lincoln, and Clark Counties, Nevada: Nevada Division of Water Resources Reconnaissance Report 54, 25 p.

Thomasson, H. G., Jr., Olmsted, F. H., and LeRoux, E. F., 1960, Geology, water resources, and usable ground-water storage capacity of part of Solano County, California: U.S. Geological Survey Water-Supply Paper 1464, 693 p.

Todd, D. K., 1959, Ground-water hydrology: New York, John Wiley, 336 p.

Winograd, I. J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712-C, 126 p.