RESULTS OF A SHALLOW SEISMIC-REFRACTION SURVEY IN THE LITTLE VALLEY AREA NEAR HEMET, RIVERSIDE COUNTY, CALIFORNIA

By Lowell F.W. Duell, Jr.

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report Report 95-4138

Prepared in cooperation with the
EASTERN MUNICIPAL WATER DISTRICT

Sacramento, California
1995

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For sale by the U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286. MS 517
Denver Federal Center
Denver, CO 80225

For additional information write to:
District Chief
U.S. Geological Survey
Federal Building, Room W-2233
2800 Cottage Way
Sacramento, CA 95825

CONTENTS

FIGURES

TABLES

Conversion Factors, Vertical Datum, and Well-Numbering System

Multiply	By	To obtain
acre	0.4047	hectare
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
gallon (gal)	3.785	liter
inch (in.)	25.4	millimeter
million gallon per day (Mgal/d)	3,785	cubic meter per day
mile (mi)	1.609	kilometer

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

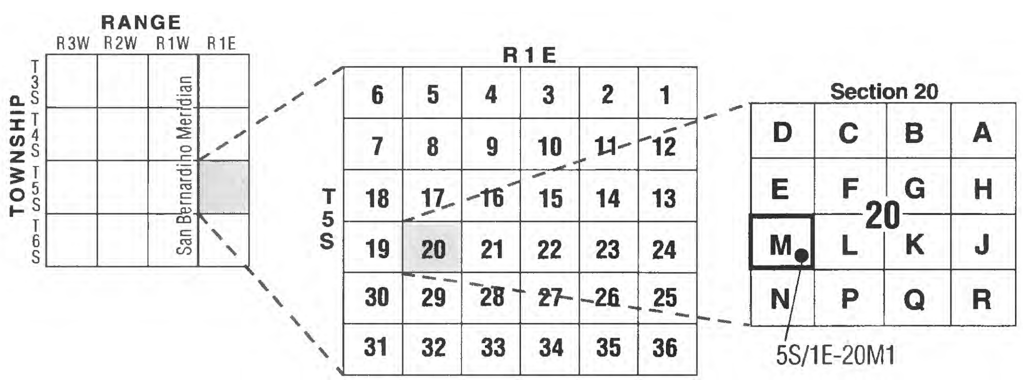
$$^{o}F = 1.8(^{o}C) + 32$$

Vertical Datum

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). All wells in the study area are referenced to the San Bernardino base line and meridian (S). Well numbers consist of 15 characters and follow the form 005S001E20M001S. In this report, well numbers are abbreviated and written 5S/1E-20M1. Wells in the same township and range are referred to by only their section designation, 20M1. The following diagram shows how the number for well 5S/1E-20M1 is derived.



BLANK PAGE

RESULTS OF A SHALLOW SEISMIC-REFRACTION SURVEY IN THE LITTLE VALLEY AREA NEAR HEMET, RIVERSIDE COUNTY, CALIFORNIA

By Lowell F.W. Duell, Jr.

Abstract

Little Valley, a small locally named valley southeast of the city of Hemet in Riverside County, California, is being evaluated for development of a constructed wetland and infiltration area as part of a water-resources management program in the area. The valley is a granitic basin filled with unconsolidated material. In August 1993 and June and July 1994, the U.S. Geological Survey conducted a seismic-refraction survey consisting of four lines northwest of the valley, eight lines in the valley, and six lines northeast of the valley. Two interpretations were made for the lines: a two-layer model yielded an estimate of the minimum depths to bedrock and a three-layer model yielded the most likely depths to bedrock.

Results of the interpretation of the three-layer model indicate that the unsaturated unconsolidated surface layer ranges in thickness from 12 to 83 feet in the valley and 24 to 131 feet northeast of the valley. The mean compressional velocity for this layer was about 1,660 feet per second. A saturated middle layer was detected in some parts of the study area, but not in others—probably because of insufficient thickness in some places; however, in order to determine the "most likely" depths to bedrock, it was assumed that the layer was present throughout the valley. Depths to this layer were verified on three seismic lines using the water level from the only well in the valley. Data for additional verification were not available for wells near Little Valley.

The bedrock slope from most of Little Valley is down toward the northeast. Bedrock profiles show that the bedrock surface is very uneven in the study area. The interpreted most likely depth to bedrock in the valley ranged from land surface (exposed) to a depth of 176 feet below land surface, and northeast of the valley it ranged from 118 to 331 feet below land surface. Bedrock depths were verified using lithologic logs from test holes drilled previously in the area. On the basis of a measured mean compressional velocity of about 12,000 feet per second, the bedrock was interpreted to be weathered granite.

INTRODUCTION

The Eastern Municipal Water District (EMWD), in southwestern Riverside County, California, provides water to an expanding population, which was about 350,000 in 1992 (Crother and Tewksbury, 1992, p. 1). Most of the water is imported. The local ground-water and imported-water supplies are relatively fixed, and as growth and development in the district increase, future shortages of potable water may occur. According to Crother and Tewksbury (1992, p. 1), EMWD operates five regional water-reclamation facilities that treat a combined flow of more than 24

Mgal/d. By the year 2010, development projections indicate that the amount of effluent water generated could increase to approximately 104 Mgal/d. Because of this, EMWD is interested in using more reclaimed water to replenish its ground water and to augment its other water supplies.

Little Valley, a small locally named valley about 3 mi southeast of Hemet, California (fig. 1), is being considered by EMWD as the site for a constructed wetland or as a ground-water recharge site. Hydrologic data from wells in the area are inadequate to produce water-table maps that are sufficiently detailed to provide determinations of directions and rates of ground-water flow. Previous surface geophysical studies have been conducted near, but not in, the valley. Available data on depth to bedrock and on bedrock gradients in Little Valley are scant. The need

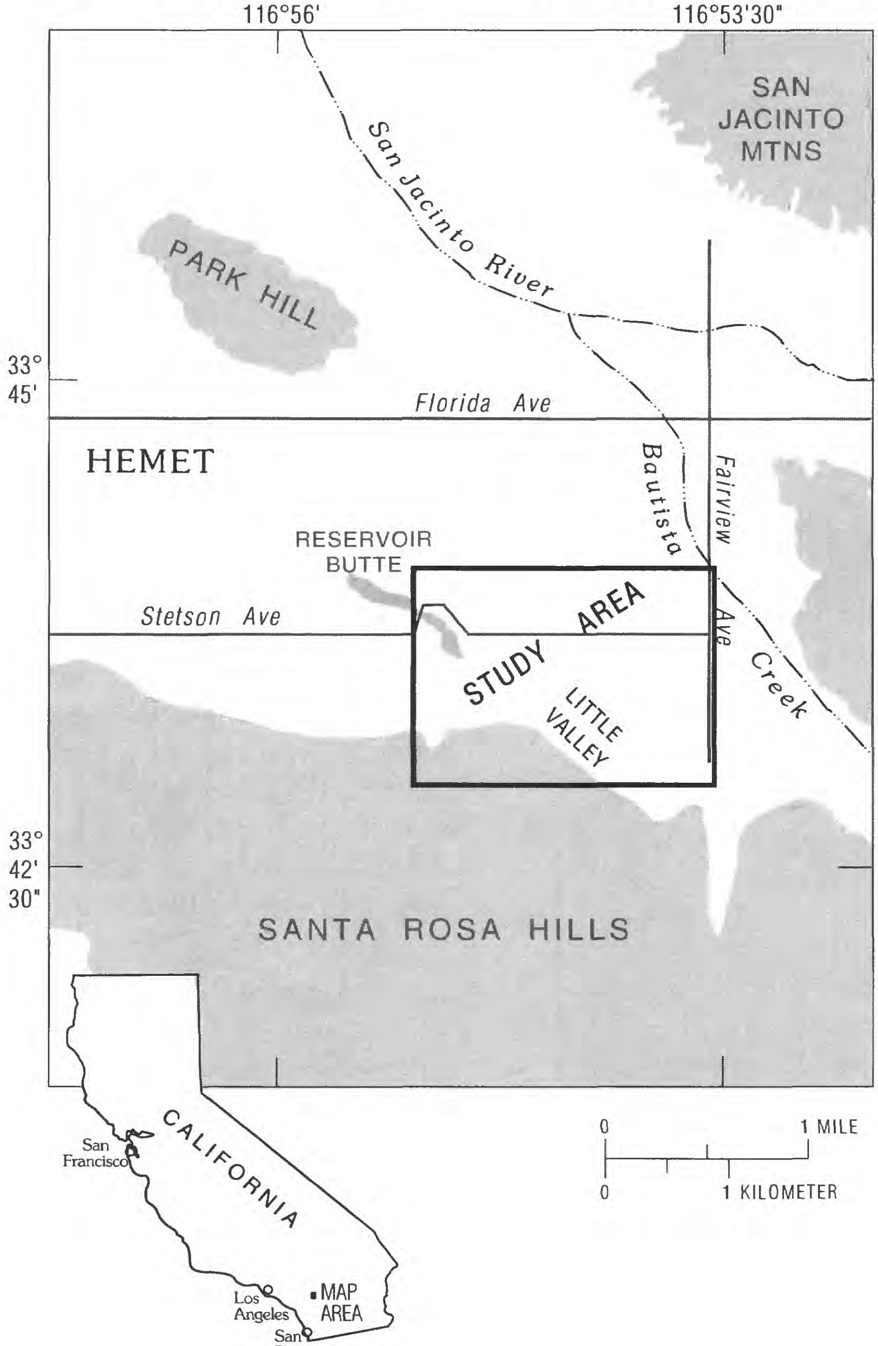


Figure 1. Location of the study area.

for information on bedrock in Little Valley prompted a geophysical investigation by the U.S. Geological Survey in cooperation with EMWD.

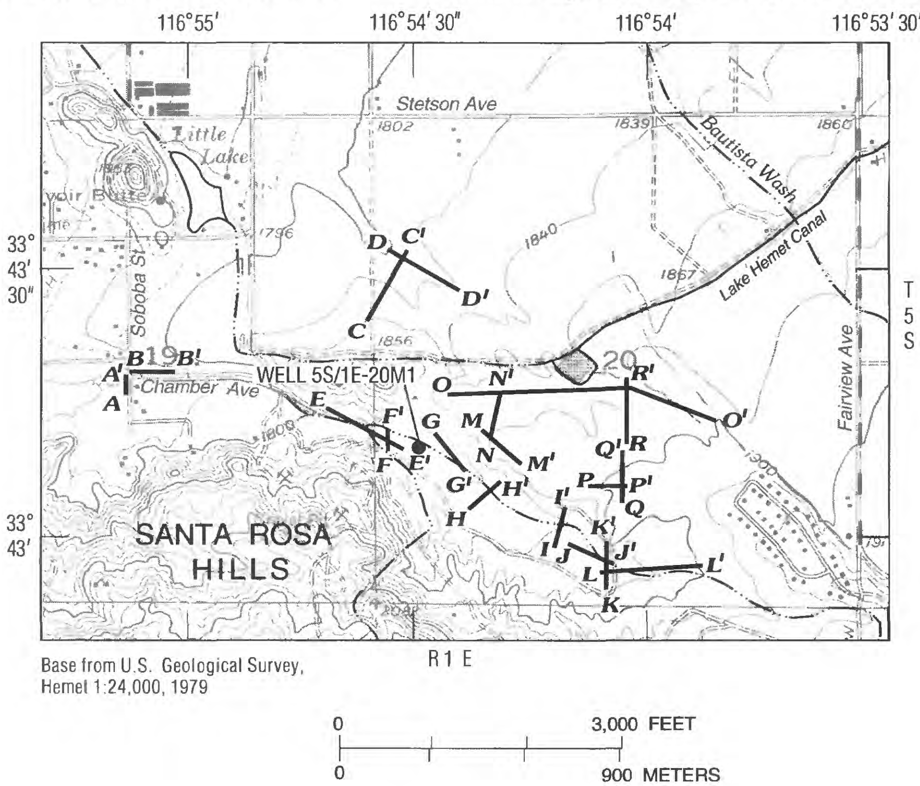
Purpose and Scope

This report presents the results of seismic-refraction surveys that were conducted by the U.S. Geological Survey to obtain subsurface data in and adjacent to Little Valley near Hemet, California. All data were collected in August 1993 and June and July 1994. Presented in this report are a description of the seismic-refraction methods used, selected records of the data that were collected, and a discussion of the results of the survey.

Description of the Study Area

The approximately 100-acre Little Valley is northeast of the Santa Rosa Hills (fig. 2) near Hemet in Riverside County, California. The altitude of the valley floor ranges from about 1,800 to 1,900 ft, and the valley trends southeast-northwest. An unnamed ephemeral stream passes northwestward through the valley, but it rarely flows—even during periods of normal precipitation. Mean annual rainfall is about 12 in. in Hemet. About 80 percent of the precipitation occurs during November-March.

Little Valley is underlain by decomposed granite, which is formed by the in-place weathering of the granitic basement rocks. The decomposed granite represents a transition zone between the overlying unconsolidated deposits and the underlying basement rocks. Test-hole data from a previous study (Crandall, Leroy and Associates, 1960) indicate that the bedrock is weathered and that depth to weathered bedrock ranges from land surface in the northwest to greater than 60 ft in the southeast. In some of the test holes, water was present in the unconsolidated deposits. Six distinct soil types have been identified in the Little Valley area: (1) granite and decomposed granite in the mountainous parts of the area; (2) cemented hardpan and weathered granodiorite or granite bedrock underlying the fan deposits; (3) generally coarse-textured soil in the numerous fans that border the main valley; (4) heavy sandy-loam surface soil and



EXPLANATION

L ——— *L'* Line of section

Figure 2. Little Valley, California, and location of the seismic-refraction profile lines *A* through *R*.

sandy-clay loam subsoil in the uplands bordering the valley; (5) fine sandy loam that has no underlying confining clay zones and is well drained in the main valley; and (6) coarse-textured, well-drained soil in the western part of the valley.

Previous Seismic Studies

Biehler and Lee (1993, p. 11) conducted a seismic-refraction survey in the Hemet area approximately 10 mi west of Little Valley. Their results show a near-surface layer that has a velocity of about 1,500 ft/s overlying a layer with a velocity of 5,000 to 7,000 ft/s overlying, in turn, a high-velocity, 14,000 to 20,000 ft/s, layer. They interpreted the layers as unsaturated alluvium (unconsolidated material) overlying saturated sediment (unconsolidated material) on top of variously weathered crystalline basement (bedrock).

Fett and Associates (1967, p. 36-37) also conducted a seismic-refraction survey in the Hemet area. One of their seismic lines originated about one-fourth mi north of Little Valley and extended more than a mile to the northeast. Their interpretations, which were based on three spreads and one shot per spread, indicated bedrock near Little Valley at a depth of 150 ft dipping 10 degrees to the northeast to a depth of 300 ft in a few hundred feet. Bedrock is exposed at land surface southwest of their seismic line and north of Little Valley. They measured the apparent surface-layer velocity at 1,750 ft/s and the apparent bedrock velocity at 28,200 ft/s; however, they assumed that the true bedrock velocity was 16,000 ft/s. They found what they interpreted to be a sedimentary layer with a velocity of about 11,000 ft/s northeast of Bautista Creek (fig. 1) at a depth of 500 ft and crystalline bedrock at a minimum depth of 1,350 ft. They found no evidence of the sedimentary layer near Little Valley.

Well 5S/1E-20M1 is the only well in Little Valley (fig. 2) and it is not used. The construction of the well is not documented; therefore, the perforation of the well casing is not known. Total depth of the well was measured at 224 ft below land surface on April 22, 1993, and the water level was 21.92 ft below land surface. The water level was 29.77 ft below land surface on July 27, 1993, prior to the use of a portable pump to collect a water-quality sample from the well. The pump was lowered to a depth of 180 ft below land surface, and water in the well was extracted for 40 minutes; the pump then was turned off for 20 minutes when the water level fell below the pump. This cycle was repeated three times. The well casing contained about 1,000 gal of water prior to pumping, and approximately 2,500 gal was pumped prior to sampling. The seismic-refraction surveys of lines *F* and *G* were conducted near the well on August 11, 1993, and the water level in the well, 15 days after pumping, was 28.96 ft below land surface. The water level on September 10, 1993, was 34.87 ft below land surface. When the seismic-refraction survey of line *E* was conducted near the well on June 23, 1994, the water level was 44.58 ft below land surface.

Acknowledgments

Appreciation is expressed to Gary L. McMillan and John Gliss for allowing access to their property. In addition, appreciation is expressed to the following U.S. Geological Survey personnel who assisted in collecting the seismic data: Carmen A. Burton, Nickolas J. Taranik, Charles A. Kaehler, Allen H. Christensen, Sean M. Lawlor, and Michael T. Land.

SEISMIC-REFRACTION METHOD

The seismic-refraction method allows for economical collection of subsurface data and generally is used early in a hydrologic investigation to help understand the subsurface geologic structure. The results of this method can provide the basis for more efficient collection of hydrologic data by means of test drilling or aquifer tests. Hydrogeologic cross sections interpreted from seismic-refraction data can improve hydrologic interpretations and help solve hydrologic problems; however, the method can be used only where all geologic layers have seismic velocities that increase with depth. Furthermore, each layer must be sufficiently thick that a refraction can be observed at the surface.

The seismic-refraction method measures the time it takes for a compressional sound wave generated by a point sound source near land surface to travel down through the layers of the Earth and refract back up to detectors called geophones placed on land surface (Haeni, 1988, p. 3). The direct and refracted sound waves are received by the geophones and converted into electrical impulses. The geophones are connected to a seismograph to amplify and record the seismogram, the recording of which begins the instant the sound source is generated. The seismogram includes the electrical signal from each geophone. Sound waves are refracted at any interface at which a velocity change occurs. As sound propagates through a layer having faster seismic velocities, part of the energy is refracted, or bent, and part is reflected back to the surface through the first layer. By measuring the traveltime of the first arrival of the sound wave and applying the laws of physics that govern the propagation of sound, one can infer the subsurface geologic structure. Traveltimes depend on the physical properties of the subsurface materials; velocities are greatest in bedrock and least in dry unconsolidated material. The field data consist of measured distances and seismic traveltimes. From this information, velocity variations and depths to individual layers can be calculated and modeled. For this study all interpretations were made using an inverse modeling program, SIPT2 (Rimrock Geophysics, Inc., 1988-93).

Seismic-refraction surveys were done in and around Little Valley to estimate depth to bedrock. Three layers were assumed to be present in the valley: unsaturated unconsolidated material, saturated unconsolidated material, and weathered bedrock. Eighteen seismic-refraction lines (see fig. 2) were implemented by placing 12 geophones spaced at 20- to 100-foot intervals. Lines *A-D* were located northwest of the valley, lines *E-L* were located in the valley, and lines *M-R* were located northeast of the valley. The seismic-refraction surveys of lines *F-K*, *M*, *P*, and *Q* were done in August 1993. All other lines were done in June and July 1994.

The sound source used for this study was created by exploding one to eight 8-gauge shotgun shells sealed inside plastic capsules and buried at depths of 1.4 to 7.1 ft. Typically, a minimum of three shot locations were used per line, one in the center and one on each end, with the end-spacing (from shot to nearest geophone) ranging from 5 to 400 ft. For seismic lines *F* and *I*, only two shots were made, one on each end. All shot points and geophones were surveyed to determine relative differences in land-surface altitudes.

One limitation of the seismic-refraction method is the possible existence of a geologic layer that cannot be detected (Soske, 1959, and Sander, 1978). In the study area, the presence of a saturated layer was expected on the basis of (1) the results of a previous seismic survey conducted by Fett and Associates (1967, p. 37), (2) pumpage from the two agricultural production wells located in the study area, (3) water-level measurements for well 5S/1E-20M1, and (4) the encountering of water by Crandall, Leroy and Associates (1960) in four of their test holes. This layer was detected beneath only two to three geophones for lines *B*, *D*, *N*, *O*, *P*, and *R*. The layer was not detected beneath the other 12 lines—including line *F*, which had the shortest geophone spacing used in the study (20 ft) and was located less than 400 ft from well 5S/1E-20M1. This layer was assumed to have insufficient thickness or seismic-velocity contrast to return first-arrival energy. According to Haeni (1988, p. 13), an intermediate layer such as this cannot be defined by any alternative location of the geophones. To resolve this problem, it was necessary to interpret the data in two ways: (1) The minimum depth to bedrock was determined using a two-layer-model interpretation in which there was assumed to be no saturated unconsolidated material in the geologic section; and (2) The most likely depth to bedrock was determined using a three-layer-model interpretation in which a layer of saturated unconsolidated material was assumed to be located between the unsaturated unconsolidated material and bedrock. These two interpretations were made for each seismic profile to determine the minimum and most likely depths to the bedrock and the range in thickness of the unsaturated layer.

The interpretation of a three-layer model required assigning a velocity, if a saturated middle layer is not detected, to the assumed hidden layer at the single point where the measured seismic-velocity contrast between the unsaturated layer and bedrock was first encountered. The velocity assigned to the undetected saturated layer was 5,000 ft/s, which is an estimate of the average velocity of saturated unconsolidated material (Clark, 1966, p. 204). The velocities measured for the saturated layer beneath lines *B*, *D*, *N*, *O*, *P*, and *R* ranged from 4,100 to 5,400 ft/s.

RESULTS OF THE SURVEY

The field-determined compressional velocities for the unsaturated layer and bedrock using the two methods of interpretation are given in table 1. The minimum and maximum values are average modeled

Table 1. Field-determined compressional velocity of sound in the subsurface material for Little Valley and the adjacent area

Geologic material	Average compressional velocity, in feet per second[1]					
	Two-layer model			Three-layer model		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Unsaturated unconsolidated material	1,100	2,110	1,690	1,110	2,070	1,660
Bedrock	8,300	16,200	11,500	9,100	18,100	12,000

[1]Table does not include the saturated unconsolidated material because of lack of data on that layer.

velocities for an entire line rather than the velocity for individual shots of a line. The mean of these data is the average of all 18 lines. The compressional velocity for the saturated layer, when it was not determined, was assigned a value of 5,000 ft/s. This layer was assumed to be a thin layer of saturated unconsolidated material that was nearly undetectable. Haeni (1988, p. 41) compiled and presented compressional velocities for common geologic materials determined in other studies. These data were used to estimate the type of subsurface material found in the unsaturated layer and the bedrock. The mean velocities determined in this study for the unsaturated layer averaged 1,690 ft/s (two-layer interpretation) and 1,660 ft/s (three-layer interpretation). These velocities are similar to the speed of sound in unsaturated unconsolidated material. Fett and Associates (1967, p. 37) found the surface-layer velocity near Little Valley to be 1,750 ft/s. The mean velocities of bedrock for the current study were found to be 11,500 ft/s (two-layer interpretation) and 12,000 ft/s (three-layer interpretation). Although these velocities are lower than the ones found by Fett and Associates (1967), they are interpreted as indicative of weathered granite.

Thickness of the unsaturated layer and depths to bedrock beneath each line are given in table 2. The unsaturated unconsolidated material for the three-layer model ranged in thickness from 12 ft (line *E*) to 83 ft (line *I*) in the valley and from 24 ft (line *O*) to 131 ft (line *Q*) northeast of the valley. For the two-layer model, this thickness was the depth to bedrock, which ranged from 27 ft (line *F*) to 99 ft (line *I*) in the valley and from 41 ft (line *O*) to 171 ft (line *R*) northeast of the valley. The assumed saturated unconsolidated material ranged in thickness from 22 ft (line *E*) to 106 ft (line *L*) in the valley and from 52 ft

Table 2. Thickness of the unsaturated unconsolidated layer and depth to bedrock

Seismic profile line designation	Two-layer interpretation	Three-layer interpretation	
	Range in depth to bedrock, in feet	Range in thickness of unsaturated unconsolidated material, in feet	Range in depth to bedrock, in feet
A	51-57	47-50	69-101
B	27-59	20-50	29-93
C	61-163	44-123	84-190
D	120-147	87-93	162-255
E	35-57	12-46	51-113
F	27-42	19-26	61-77
G	40-56	28-53	84-106
H	42-62	32-48	64-107
I	64-99	54-83	111-158
J	63-70	53-55	93-111
K	74-86	59-65	104-135
L	58-85	49-70	97-176
M	114-121	87-112	149-163
N	68-80	47-57	118-146
O	41-167	24-118	126-331
P	122-157	102-126	165-215
Q	142-165	128-131	187-235
R	153-171	99-108	233-269

(line *M*) to 214 ft (line *O*) northeast of the valley. These data, which are not shown in table 2, were calculated from the three-layer model using the difference between the depth to the top of the saturated layer and the depth to bedrock. The top of the saturated layer for lines *E, F,* and *G* near well 5S/1E-20M1 was at a depth similar to that of the water levels found in the well. The most likely depth to bedrock in the valley interpreted from the three-layer model was found to range from land surface (exposed) to 176 ft below land surface (line *L*). The most likely depth to bedrock northeast of the valley was found to range from 118 ft below land surface (line *N*) to 331 ft below land surface (line *O*). The interpreted depths of all the layers show good agreement between lines that cross each other or are close to each other.

The interpreted seismic sections extend to the ends of the geophone spread and are shown in figure 3 (line locations are shown in fig. 2). Extrapolation of sections beyond the end of the spread can give unpredictable results (Rimrock Geophysics, Inc., 1988-93, p. 12). Lines *A-D* (fig. 3*A*) were shot northwest of Little Valley in order to determine the altitude and gradient of the bedrock in those areas. Line *C*, which crosses an ephemeral stream, and line *D*, which parallels the stream, served an additional purpose: These lines were used to determine what erosional effect, if any, the stream had on the profile of the bedrock. Lines *F, H, I,* and *K* (fig. 3*B*) were laid out in a general north-south direction bisecting the valley's ephemeral stream. The purpose of these lines was to determine if an ancestral stream had eroded the bedrock prior to deposition of the valley's unconsolidated material, leaving channels that could act as flow paths in the bedrock. Lines *E, G, J,* and *L* (fig. 3*C*) were shot on the floor of the valley, in a general east-west direction, to determine if bedrock channels are present opposite lines *F, H, I,* and *K*. The purpose of lines *M-R* (fig. 3*D* and 3*E*) was to determine the altitude and gradient of the bedrock north of the valley.

The minimum and most likely depths to bedrock shown for lines *A* and *B* are at a lower altitude than those for line *F*, which indicates that the bedrock gradient westward from line *F* is descending. Line *A* shows the profiles of the minimum and most likely depths to bedrock to be uneven. Line *B* shows the minimum depth to bedrock to decrease by nearly 50 ft and the most likely depth to bedrock to decrease by about 75 ft from east to west. Line *C* shows the minimum and most likely depths to bedrock to decrease by almost 125 ft from southwest to northeast. In addition, these profiles show little evidence of ancestral stream erosion in the bedrock. Line *D* shows the profile of the minimum depth to bedrock to be almost flat and the profile of the most likely depth to bedrock to be uneven.

The profiles of the minimum and most likely depths to bedrock in Little Valley show little evidence of ancestral channels eroded in bedrock prior to deposition of the valley-fill material. Line *F* is located in Little Valley where the valley floor is at its lowest altitude. The line is the shortest in length and bisects the outlet of the valley's ephemeral stream. The profiles of the minimum and most likely depths to bedrock show an unevenness and a possible ancestral stream channel in the bedrock, about 100 ft wide and 10 ft deep, south of the current location of the stream. Bedrock under this line generally slopes upward to the north as expected because bedrock is exposed north of the line. Lines *H* and *I* are west of line *K*, which extends along the east end of the valley where the valley floor is at its highest altitude. Lines *H* and *I* show the minimum depth to bedrock to be even and the most likely depth to bedrock to be uneven. Lines *H* and *K* show that the altitudes of the most likely depths to bedrock decrease by as much as 30 ft from south to north, but the lines show no evidence of channels in the bedrock. The altitudes of the minimum and most likely depths to bedrock for lines *F* and *H* are about the same. The minimum and most likely depths to bedrock for line *I* are at lower altitudes than for line *H*, thus indicating that the gradient of bedrock between these lines is downward to the east. The minimum and most likely depths to bedrock for line *K* are generally at higher altitudes than for line *I*.

Lines *E, G, J,* and *L* generally transect the valley floor. The west end of line *E* shows a V-shaped notch in the profile of the most likely depth to bedrock. The notch in the profile is were the line has crossed over the valley's ephemeral stream and begins to climb up the hillside to were bedrock becomes exposed. Lines *E* and *J* generally show the altitude of the minimum and most likely depths to bedrock to increase from the west to the east. Lines *G* and *L* generally show the opposite: The altitude of the minimum and most likely depths to bedrock increases from the east to the west. The profiles of the most likely depth to bedrock

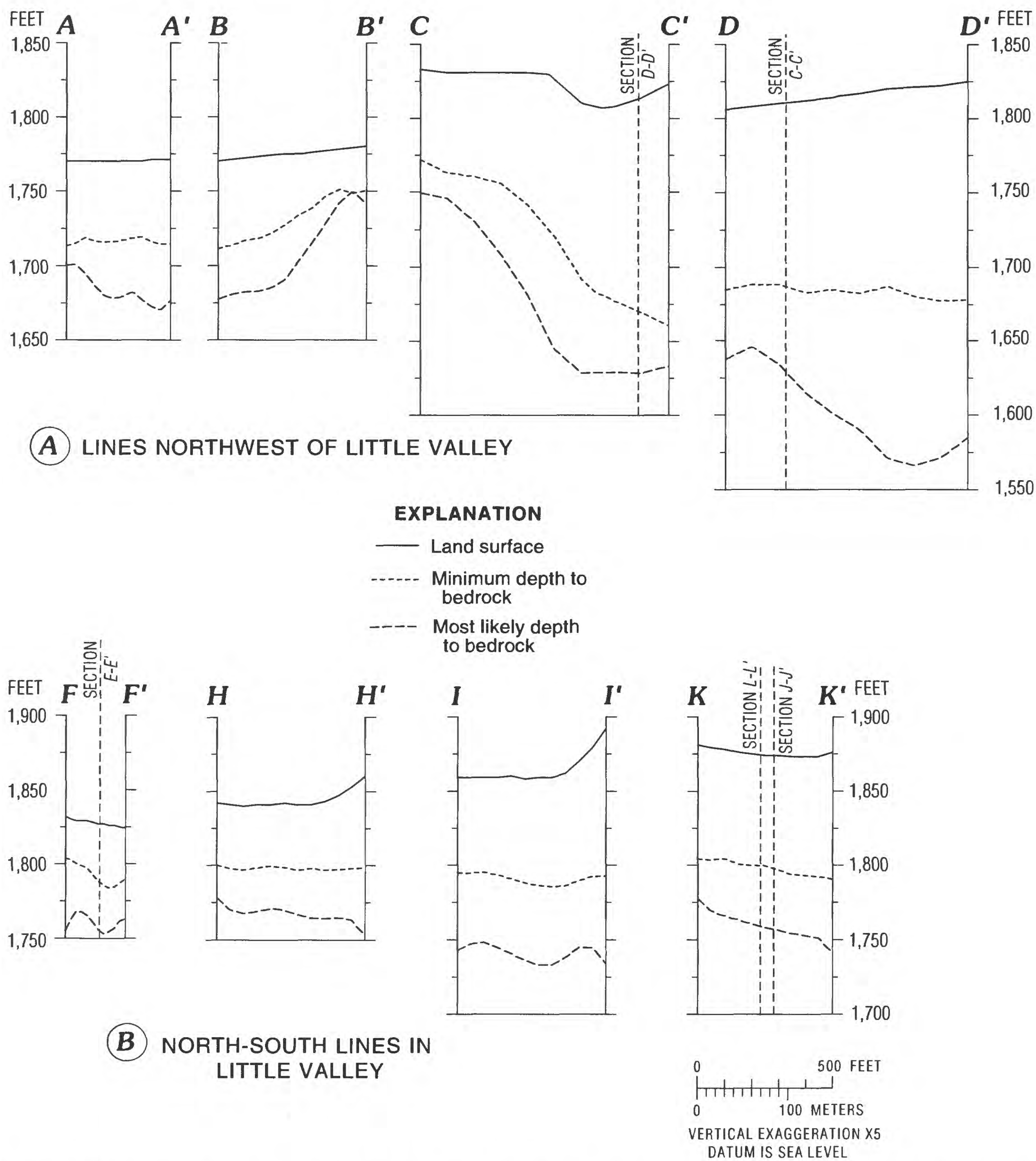


Figure 3. Interpreted seismic sections (*A-A'* through *R-R'*) for lines *A* through *R.* (Location of sections is shown in figure 2.)

for lines *G, J,* and *L* show the irregularity of the bedrock surface in those areas. The profile of the most likely depth to bedrock for line *L* shows a steep decrease in altitude on the east end of that line.

Lines *M, O,* and *P* were shot in the orange grove northeast of Little Valley in a general east-west direction. The surface altitudes of these lines are higher than the altitude of the valley floor. The profiles of the

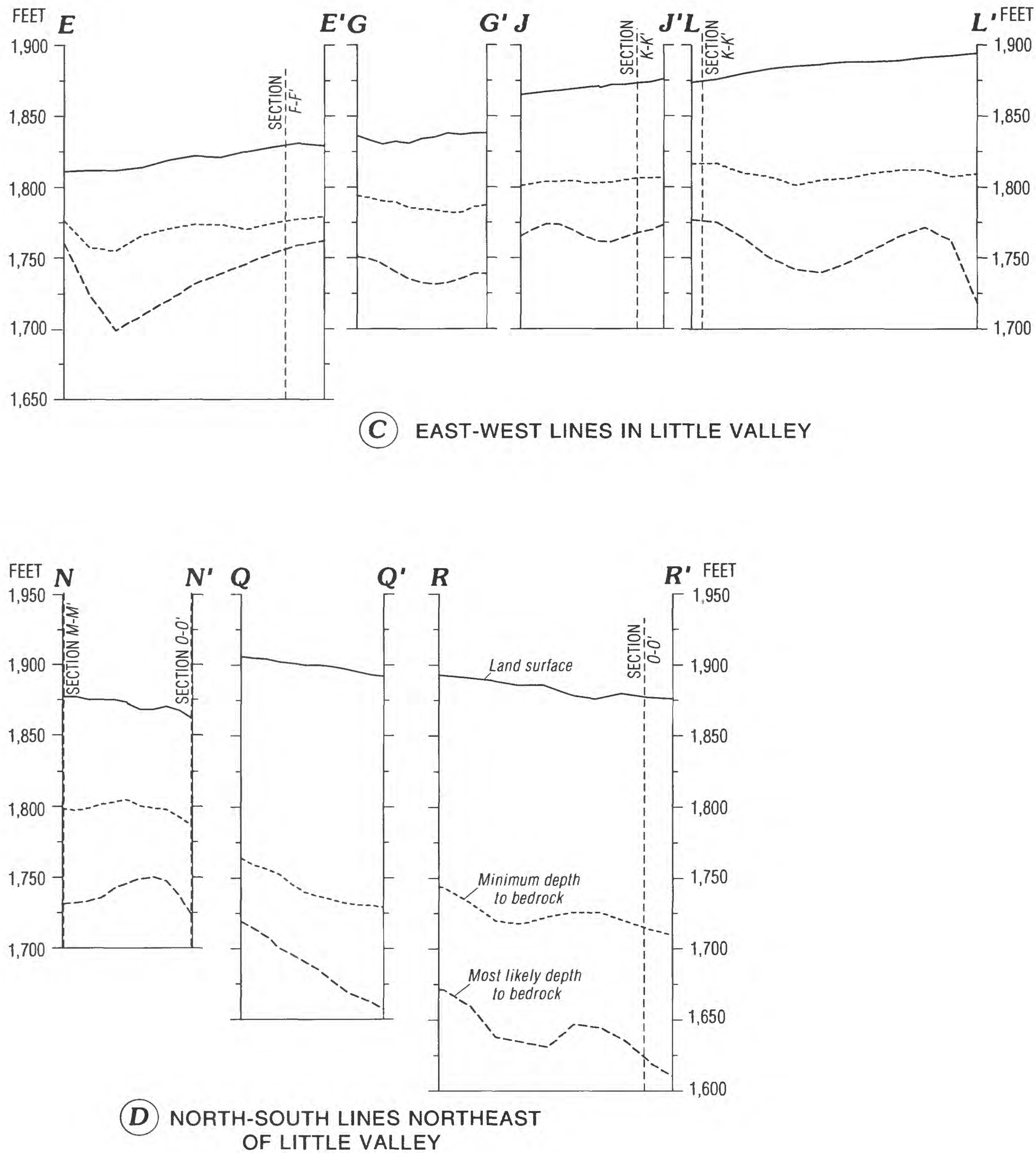


Figure 3. *Continued.*

most likely depth to bedrock for lines *M, O*, and *P* show that bedrock decreases in altitude from the west to the east. Line *O*, the longest line of the study, consisted of three spreads. The altitude of the minimum depth to bedrock for line *O* decreases by about 90 ft from the west to the east, and the altitude for the most likely depth to bedrock decreases by about 160 ft. The minimum depth to bedrock for line

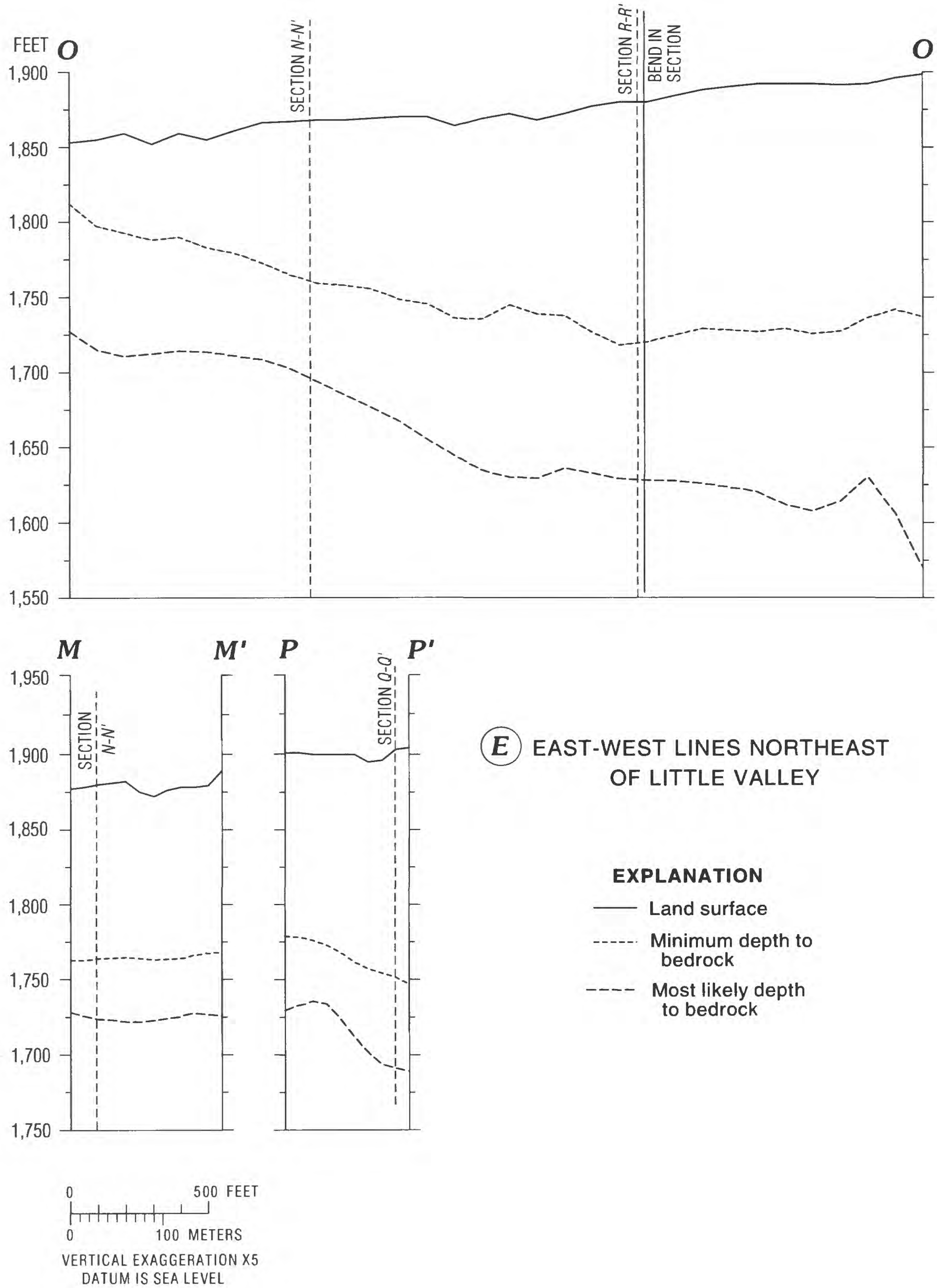


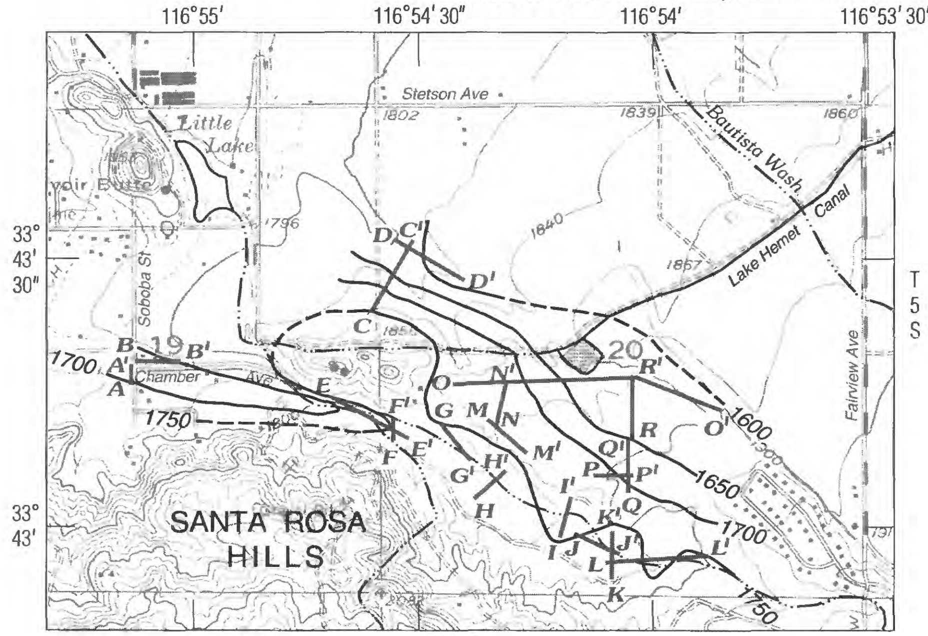
Figure 3. *Continued.*

M increases in altitude less than 25 ft from the west to the east, and the most likely depth to bedrock shows almost no change. The minimum and most likely depths to bedrock for line *P* show a decrease in altitude of about 30 and 40 ft, respectively, from the west to the east.

Line *N* shows that the minimum and most likely depths to bedrock decrease in altitude less than 25 ft from the south to the north. The profile of the most likely depth to bedrock for line *N* is uneven. Lines *R* and *Q* were shot in an orange grove in a general north-south direction north of line *K*. Line *R* shows that the minimum and most likely depths to bedrock are uneven in that area, decreasing in altitude from south to north more than 25 and 50 ft, respectively. Line *Q* shows a steady decrease in altitude from south to north of more than 25 ft in the minimum depth to bedrock and more than 50 ft in the most likely depth to bedrock.

The depths interpreted for bedrock beneath lines crossing or near one another show good agreement. Lines *C* and *D*; *E* and *F*; *J* and *K*; *K* and *L*; *M* and *N*; *O* and *N*; *O* and *R*; and *P* and *Q* crossed. One geophone was implanted in the same location for each line where the lines cross. The difference in the minimum depth to bedrock beneath where the lines cross ranged from 5 ft on lines *C* and *D* to 36 ft on lines *M* and *N*. The difference in the most likely depth to bedrock beneath where the lines cross ranged from 1 ft on lines *E* and *F* to 20 ft on lines *P* and *Q*.

The seismic-refraction profiles were used to construct contour lines (fig. 4) that show the altitude of the most likely depth to bedrock in the study area. The altitude of bedrock at the west end of Little Valley near lines *E* and *F* is about 1,750 ft. Bedrock is estimated to decrease in altitude by about 50 ft between these lines and lines *A* and *B*. From the lines located in Little Valley, the altitude of bedrock



Base from U.S. Geological Survey, Hemet 1:24,000, 1979

R 1 E

0 — 3,000 FEET
0 — 900 METERS

EXPLANATION

L ——— *L'* **Line of section**

1750 ——— — — **Bedrock contour**- Shows most likely altitude of bedrock surface. Contour interval 50 feet. Dashed where approximate. Datum is sea level

Figure 4. Altitude of the most likely depth to bedrock surface on the basis of three-layer model interpretations.

generally decreases to the northeast. Therefore, the bedrock slope from Little Valley, east of line *F*, is downward toward the northeast.

The direction of ground-water flow in the study area cannot be determined from the available data, which are limited to the water-level measurements in one well located in Little Valley and the interpreted data on bedrock depth. Although there are other wells within the study area near seismic lines *C, R,* and *O*, one was dry and the other two were in use and continuously pumped during the study.

VERIFICATION OF RESULTS

The interpreted depths to bedrock were verified using lithologic logs of test holes (Crandall, Leroy and Associates, 1960). The interpreted depths to the saturated layer at the ends of lines *E, F,* and *G* were verified using the water level from well 5S/1E-20M1 in the valley.

Crandall, Leroy and Associates (1960) drilled 43 test holes, ranging in depth from 5 to 80 ft below land surface, in and near the valley in 1960. According to the lithologic logs, 18 holes in the west end of the valley reached weathered granite bedrock at depths ranging from land surface to 40 ft below land surface. Some of these holes are near seismic lines *E, F,* and *G* of the current study. Four other test holes in the west end of the valley that range in depth from 5 to 20 ft below land surface did not reach bedrock. At the locations of all other seismic lines, no depth to bedrock information was available. Twenty-one of the test holes drilled in 1960, ranging in depth from 5 to 60 ft below land surface, were near these lines; however, none reached bedrock.

The intersection of seismic lines *E* and *F* is near test holes 2 and 5 (not shown) drilled by Crandall, Leroy and Associates (1960). They found the altitude of bedrock to be 1,797 ft for test hole 2 and 1,785 ft for test hole 5. The interpreted altitudes of bedrock for line *E* near test holes 2 and 5 are 1,780 ft using the two-layer interpretation (minimum depth to bedrock) and 1,762 ft using the three-layer interpretation (most likely depth to bedrock). The interpreted altitudes of bedrock for the center of line *F* were 1,793 ft for the minimum depth and 1,760 ft for the most likely depth. Test hole 15 (not shown), which is near the south end of seismic line *F*, shows the altitude of bedrock to be 1,826 ft. The interpreted altitudes of bedrock near test hole 15 on the south end of line *F* are 1,804 ft for the minimum depth and 1,755 ft for the most likely depth. Test holes 37 and 40 (not shown), near seismic line *G*, show bedrock altitude to be 1,836 ft on the northwest end of this line and 1,800 ft on the southeast end. The interpreted altitudes of bedrock on the northwest end of line *G* are 1,794 ft for the minimum depth and 1,751 ft for the most likely depth. The interpreted altitudes of bedrock on the southeast end of line G are 1,787 ft for the minimum depth and 1,739 ft for the most likely depth.

The altitudes of bedrock interpreted from the seismic-refraction data were lower than the altitudes determined from the lithologic logs of the test holes drilled by Crandall, Leroy and Associates (1960)—the differences ranging from 4 to 86 ft (using the two-layer model) and 5 to 75 ft (using the three-layer model). Differences in these data may be due to the way the seismic data were interpreted or the difference in location of the test holes and the seismic lines. Another explanation is that what Crandall, Leroy and Associates (1960) called granite bedrock (weathered) might actually be cobbles or decomposed granite above the bedrock surface. The location of the test holes ranged from 50 to 150 ft from the seismic lines, and thus the bedrock surface may have been deeper under the seismic line than in the nearby test hole. Natural or manmade changes to surface altitudes may be additional reasons why the interpreted depths to bedrock that were based on seismic-refraction data were greater than the depths indicated by data from the test holes in the area.

The water levels interpreted from lines *E, F,* and *G* closely match the measured water levels in well 5S/1E-20M1. The well is about 100 ft north of the southeast end of line *E*, 400 ft east of the north end of line *F*, and 200 ft south of the northwest end of line *G*. The depth to water in the well was about 45 ft below land surface when line *E* was done, and depth to water at the southeast end of the line was interpreted to be about 46 ft below land surface. The depth to water in the well was about 29 ft below land surface when lines *F* and *G* were done, and the interpreted depths were about 26 ft below land surface on the north end of line *F* and about 31 ft below land surface on the northwest end of line *G*. This is the only well located in Little Valley, and Crandall, Leroy and Associates made no mention of this well in their report. No drill-log data were found for the additional wells located elsewhere in the study area.

SUMMARY

Seismic refraction is a geophysical technique that can be used to economically map the thickness and extent of geologic materials. For this study, seismic-refraction methods were used to obtain refractions of bedrock at depths as great as about 300 feet.

Two interpretations were made for this study. The two-layer model assumed that there is no saturated unconsolidated layer present in the study area, and this interpretation provided a minimum depth to bedrock. The three-layer model assumed that an undetected unconsolidated saturated layer was present in the study area when the surveys were conducted, and this interpretation provided a most likely depth to bedrock. Interpreting the data in these ways also allowed for estimating the thickness of the unsaturated and saturated layers.

The unsaturated unconsolidated surface layer, as estimated using the most-likely-depth model, ranged in thickness from 12 to 83 feet in the valley and from 24 to 131 feet northeast of the valley. The mean compressional velocity for this layer was found to be about 1,660 feet per second using this method. A saturated middle layer was not detected, probably because of insufficient thickness; however, for the most-likely-depth model, this layer was assigned a velocity of 5,000 feet per second. Depth to this layer was verified using the water level from the only well that could be measured in the study area.

Depths to bedrock were verified using lithologic logs from test holes drilled in a previous study in and adjacent to the valley. The test holes indicate that bedrock in the west part of the valley ranges from land surface to at least 40 feet below land surface. The test holes provide no indication of depth to bedrock in the rest of the study area. Bedrock within the valley, using the three-layer depth model of interpretation, was found to range from land surface (exposed) to a depth of 176 feet below land surface; northeast of the valley, bedrock ranged from 118 to 331 feet below land surface. The mean compressional velocity for bedrock was measured at about 12,000 feet per second, and the bedrock was interpreted to be weathered granite.

The bedrock slope from Little Valley is downward toward the northeast. The altitude of bedrock generally was found to decrease from the floor of the valley northward and from west to east. The profiles of the minimum and most likely depths to bedrock in Little Valley show little evidence of ancestral channels eroded in bedrock prior to deposition of the valley-fill material. The bedrock under the valley's ephemeral stream may have been previously eroded; however, the channel does not seem to be wide or deep enough to allow for much ground-water flow out of the valley toward the west. In general, the bedrock surface throughout the study area seems to be uneven.

References Cited

Biehler, S., and Lee, T.C., 1993, Subsurface structure of the Hemet Basin, Riverside County, California—a geophysical study: Department of Earth Sciences, University of California, Riverside, California, 41 p.

Clark, S.P., ed., 1966, Handbook of physical constants: Geological Society of America (New York), Memoir 97, 587 p.

Crandall, Leroy and Associates, 1960, Report of preliminary soils investigation: proposed Little Valley dam project Hemet, California, for the Eastern Municipal Water District (pre-final submittal): Hemet, California, 6 p., 4 plates, and 1 appendix [available for inspection at U.S. Geological Survey, 5735 Kearny Villa Road, Suite O, San Diego, CA 92123].

Crother, C.M. and Tewksbury, Joanna, 1992, Multipurpose wetlands in a legislated environment, presented before the California Water Pollution Control Association Conference, April 1992, Sacramento, California, 10 p., 11 figures [available for inspection at U.S. Geological Survey, 5735 Kearny Villa Road, Suite O, San Diego, CA 92123].

Fett and Associates, 1967, Geophysical investigation of the San Jacinto Valley, Riverside County, California, for Eastern Municipal Water District (pre-final submittal): Hemet, California, 81 p. and 3 appendixes [available for inspection at U.S. Geological Survey, 5735 Kearny Villa Road, Suite O, San Diego, CA 92123].

Haeni, F.P., 1988, Application of seismic-refraction techniques to hydrologic studies: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chapter D2, 86 p.

Rimrock Geophysics, Inc., 1988-1993, User's guide to SIPT2 V-4.0, a personal computer program for interpreting seismic refraction data using modeling and iterative ray tracing techniques: Lakewood, Colorado, 12 p.

Sander, J.E., 1978, The blind zone in seismic ground-water exploration: Ground Water, v. 16, no. 6, p. 394-397.

Soske, J.L.,1959, The blind-zone problem in engineering geophysics: Geophysics, v. 24, no. 2, p. 359-365.