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GEOLOGICAL SURVEY

GEOHYDROLOGIC RECONNAISSANCE OF LAKE MEAD NATIONAL
RECREATION AREA—MOUNT DAVIS TO DAVIS DAM, ARIZONA

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NATIONAL RECREATION AREA—MOUNT DAVIS TO
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INTRODUCTION

In June 1968, the National Park Service requested the U. S. Geological Survey to make a water-resources investigation of the part of the Lake Mead National Recreation Area along Lake Mohave between Mount Davis and Davis Dam. Because the area along the east side of the lake seems to have the greatest water-producing potential and because of time limitations, the fieldwork was confined to that area. The area along the west side of the lake is underlain by extensive outcrops of granitic and metamorphic rocks.

The area of investigation extends from Mount Davis to the southern boundary below Davis Dam (fig. 1) and eastward to the drainage divide in the Black Mountains. This report is one of a series of areal reports that will be prepared for the Lake Mead National Recreation Area; previous site studies have been made at Callville Bay, Temple Bar, Eldorado, Cottonwood Cove, and Cottonwood Valley.

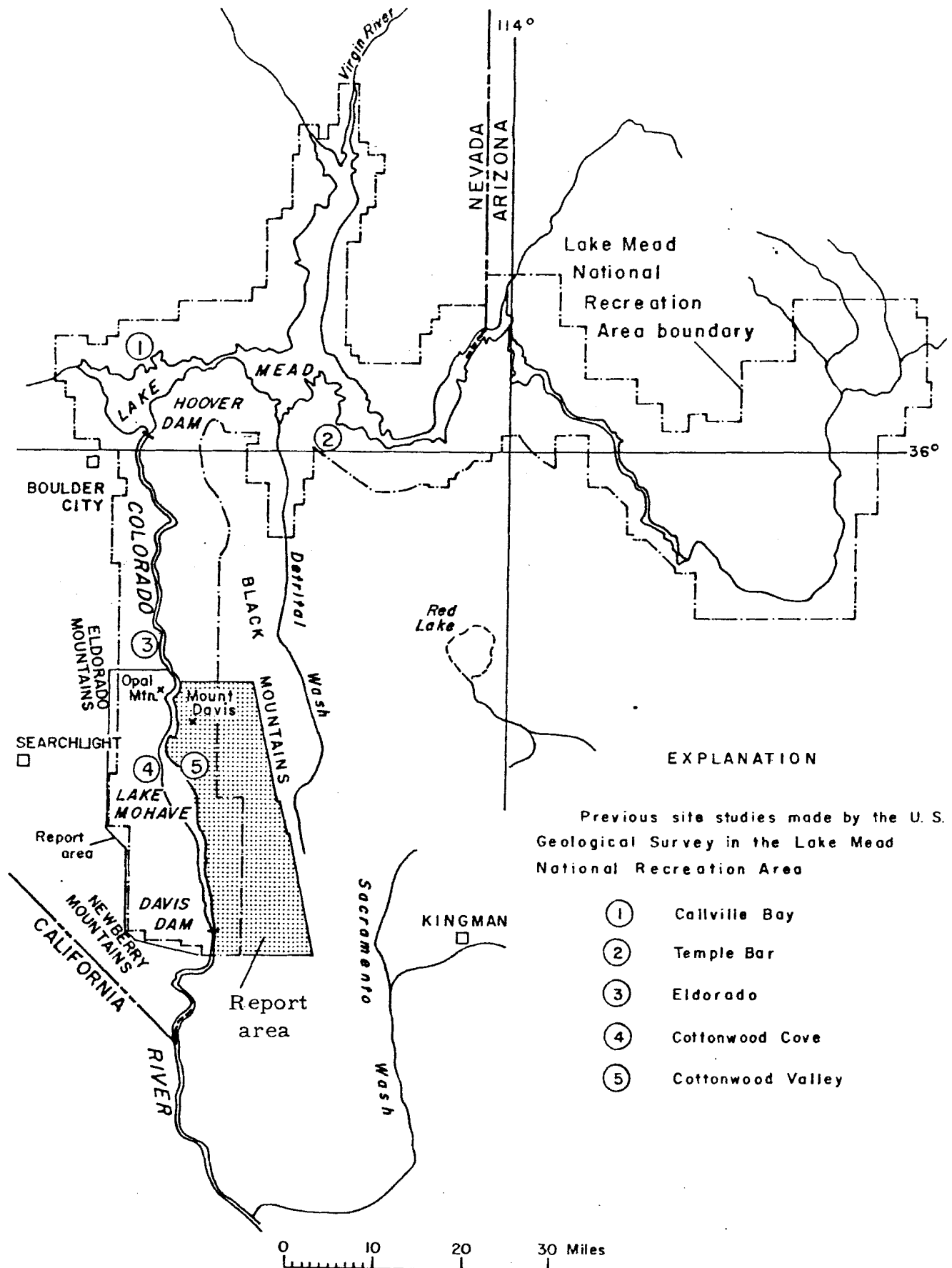


Figure 1.--Area of report.

The investigation was conducted under the immediate supervision of H. M. Babcock, district chief of the Water Resources Division in Arizona.

The investigation, started in July 1968 and completed in January 1969, was undertaken to appraise the existing water resources and to locate additional water supplies. The report describes the geology, hydrology, and availability of water. The investigation included the collection and analysis of well-production data obtained from pump tests and well owners; determination of streamflow and ground-water interrelations; collection and analysis of spring information, most of which was furnished by the Bureau of Land Management; determination of the chemical quality of water; reconnaissance geologic mapping on a scale of 1:62,500; determination of the rocks' ability to store and yield water; collection and analysis of subsurface information from drillers' logs; and determination of the geologic controls on the hydrologic boundaries.

The altitude of the area ranges from about 520 feet at the Colorado River below Davis Dam to about 5,000 feet above mean sea level along the crest of the Black Mountains. The land slopes about 200 feet per mile from the base of the mountains to Lake Mohave and has been dissected to depths of 100 feet by ephemeral streams. The

climate is arid and is characterized by hot summers and mild winters. The average annual precipitation is about 5 inches in the Lake Mead National Recreation Area and about 10 inches along the summit of the Black Mountains (U.S. Weather Bureau [no date]). The vegetation generally consists of cactus and other desert growth, except along the shoreline of Lake Mohave where phreatophytes, mainly saltcedar, have gained a strong foothold.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Granitic and volcanic rocks form the main mass of the Black Mountains, and the alluvial units and the Bouse and Chemehuevi Formations are exposed on the dissected alluvial slope that extends from the edge of the mountains to Lake Mohave (fig. 2). The Black Mountains block is a compound horst, west of which repetitive faulting has tilted some blocks to the east and others to the west (Longwell, 1963, p. 34-43). The eastward tilting is confined generally to the southern third of the mapped area and continues southward (Lausen, 1931, p. 50).

The sedimentary rocks were grouped into four broad classifications for purposes of mapping—pre-Bouse alluvium and Bouse Formation undifferentiated, older alluvium, Chemehuevi Formation, and younger alluvium. The older and younger alluvium and the

Chemehuevi Formation contain both Colorado River deposits and locally derived alluvium. The thin terrace and piedmont gravels that crop out in the area were not mapped separately but are included with the underlying unit, which in most instances is the older alluvium.

Granitic Rocks

The oldest rocks exposed in the area are granite and granitic gneiss of Precambrian age, which form the basement complex and are the lowermost barrier to the movement of ground water. The rocks generally do not yield water except along fractures and weathered zones. At least three wells, one spring, and one mine are believed to obtain small quantities of water from these rocks (table 3).

Volcanic Rocks

The volcanic rocks overlie the granitic rocks in the Black Mountains, form the bulk of Mount Davis, and crop out in isolated exposures near Lake Mohave. The rocks have been studied in reconnaissance investigations by several geologists (Schrader, 1909; Wilson, 1962; Longwell, 1963) and in detail by Ransome (1923) in the Oatman mining district south of the report area and by Lausen (1931) in the Oatman and Katherine mining districts. The volcanic

rocks are several thousands of feet thick, are Mesozoic(?) and Tertiary in age, and are composed of andesitic, rhyolitic, and basaltic flows and associated tuff and agglomerate. The uppermost sequence of basaltic volcanic rocks in the Black Mountains is interbedded with and underlain by fanglomerate deposits, which may be correlative with the pre-Bouse alluvium. Most of the rocks in the northern two-thirds of the report area dip 20°-70° W; in the southern third the rocks dip 30°-40° E. The volcanic rocks transmit some water through fractures and interbedded tuff and agglomerate beds; in general, however, the unit is too impermeable to yield water readily to wells. The unit yields small quantities of water to three wells, at least nine springs, and two mines in the area (table 3).

Pre-Bouse Alluvium and Bouse Formation Undifferentiated

The pre-Bouse alluvium crops out mainly near the shores of Lake Mohave, where it consists of fanglomerate and some interbedded lenses of clay and silt. The pre-Bouse alluvium is Tertiary in age. The Bouse Formation, which is not differentiated from the pre-Bouse alluvium (fig. 2), unconformably overlies the pre-Bouse alluvium and crops out only in scattered exposures along the banks of Lost Cabin Wash and nearby washes in the west-central part of T. 23 N.,

R. 21 W. The Bouse Formation consists dominantly of clay and marl and is Pliocene in age (Metzger, 1968). The pre-Bouse alluvium and possibly the Bouse Formation are equivalent in part to the Muddy Creek Formation defined by Longwell (1963) in the Willow Beach-Lake Mead area, which is about 15 miles north of the map area. Both the pre-Bouse and the Bouse predate the establishment of the Colorado River in the area.

The pre-Bouse alluvium may be several thousands of feet thick (Metzger, oral commun., 1968), but only a few hundred feet is exposed in the map area. In general the unit is poorly bedded. Imbrication of the pebbles and cobbles indicates that drainage was from the east and west to a central trough, whose axis is 1 to 2 miles east of the present Colorado River. The beds are tilted as much as 20° and are offset by high-angle faults of undetermined displacement. The fanglomerate of the pre-Bouse alluvium is reddish brown to light and medium gray, depending on the dominant rock type. The fanglomerate consists of angular to subangular fragments of granitic and volcanic rocks that are moderately to firmly cemented with calcium carbonate. The grain size is generally from coarse sand to fine gravel, but pebble and cobble beds are common. The clay and silt that are interbedded with the pre-Bouse fanglomerate

normally are lenticular, but in places alternating beds of clay and silt are fairly continuous. The beds are from less than a fraction of an inch to 3 inches thick. The clay and silt are light greenish or yellowish gray and are tuffaceous.

Although the pre-Bouse alluvium is not known to yield water to wells or springs in the area, small to moderate yields may be expected from wells drilled in the unit near Lake Mohave. Well yields generally will decrease with increased distance from the lake. Less cemented zones in the pre-Bouse alluvium near Parker, which is about 75 miles south of the report area, yield small to moderate quantities of water to wells 1 to 6 miles from the Colorado River (Metzger, 1965).

The Bouse Formation separates the pre-Bouse alluvium from the Colorado River deposits in the Parker-Blythe-Cibola area (Metzger, 1968). The formation is composed of greenish-gray clay or very light-gray to white marl and a basal limestone 1 to 3 inches thick. The unit is lenticular and the exposures discontinuous because of post-Bouse erosion, and the maximum observed thickness of the unit is about 30 feet. The unit is too fine grained to yield water readily to wells. Because of its limited occurrence in the area, the formation was mapped with the pre-Bouse alluvium.

Older Alluvium

The older alluvium of probable late Tertiary and early Quaternary age crops out in broad high terraces between the Black Mountains and Lake Mohave and generally is capped by piedmont gravel. The older alluvium probably underlies most of the alluvial slope, where younger units are exposed at the surface, and unconformably overlies the pre-Bouse alluvium and Bouse Formation undifferentiated. Some well-cemented steeply dipping gravel beds that crop out north of the report area and possibly within the report area were incorrectly mapped as older alluvium by Longwell (1963, p. 11-12). These beds exhibit no evidence of Colorado River deposition, are lithologically similar to the pre-Bouse alluvium, and probably should be included with that unit.

The older alluvium is composed of Colorado River deposits and locally derived fan gravel, which intertongues with and grades into the river deposits. The Colorado River deposits and fan gravel show abundant scouring and channel filling where exposed. The river deposits are composed of gray and brown clay, gray and yellowish-gray sand, and rounded pebbles chiefly of granite, schist, quartzite, limestone, and chert. The fan gravel consists of angular to sub-angular pebble-size fragments of granitic and volcanic rocks in a

silty matrix. The fan gravel is olive, brownish, yellowish, or pinkish gray. The river and fan-gravel deposits are weakly to moderately cemented by calcium carbonate. In general, the older alluvium is poorly bedded and in places has been deformed by tilting of as much as 5° and by high-angle normal faulting generally having displacement of less than a few feet. Several hundred feet of the unit is exposed in the area, and Lausen (1931, p. 49) reported that holes drilled by the Reclamation Service (now Bureau of Reclamation) in or near sec. 6, T. 21 N., R. 21 W., penetrated more than 300 feet of gravel deposits in an old river channel.

Weakly cemented zones in the older alluvium appear to be moderately to highly permeable, and, where the unit is saturated, it is probably a good aquifer. The largest yields can be obtained near Lake Mohave, where the saturated thickness of the unit is greatest, and yields will decrease with increased distance from the lake. Four wells are believed to obtain small to moderate quantities of water from these rocks in the area (table 3).

Chemehuevi Formation

The Chemehuevi Formation of Pleistocene age, where present, generally overlies the older alluvium and is separated from it by an unconformity. The formation is exposed only in the terraces that border

Lake Mohave and the flood plain of the Colorado River. Longwell (1963, p. 12-13) described a thick section of laminated clay in the Chemehuevi Formation near Davis Dam and mentioned that the clay from that area was used in the construction of the dam. During the present study, no thick clay section was found in the Chemehuevi Formation. About 20 feet of laminated clay, exposed in a pit 2 miles northeast of Davis Dam, unconformably underlies the Chemehuevi Formation and probably is a facies of the older alluvium.

The Chemehuevi Formation is composed of weakly cemented alternating beds of silt, clay, sand, and pebble gravel overlain by unconsolidated gravel capped by sand. The composition of the gravel is similar to that of the river deposits of the older alluvium. Bedding is well developed in the clay and poorly developed in the coarser materials. No evidence of structural deformation was observed.

The formation, although not widespread, probably is the best aquifer in the area and will transmit water readily to wells. Two wells, which have maximum yields of more than 1,000 gpm (gallons per minute), obtain water from the Chemehuevi Formation (table 3).

Younger Alluvium

The younger alluvium of Holocene age is exposed in stream channels and small flood plains in the mountains, in channels and flood plains on the alluvial slope, and in the flood plain of the Colorado River below Davis Dam. The unconsolidated terrace gravel on the alluvial slope was not mapped in this study. The younger alluvium is composed of unconsolidated sand and gravel. The unit generally is drained; however, in places in the mountains where it is underlain by impermeable rock, the younger alluvium may be saturated and may yield small to moderate quantities of water to wells.

STREAMFLOW

All the streams in the area are ephemeral, except the Colorado River. No streamflow data are available for the ephemeral streams in the area; however, the U.S. Geological Survey has maintained five peak-flow gaging stations in surrounding areas for several years (table 1). The data from these stations indicate that streamflow from the small drainage basins near Lake Mohave is meager and extremely variable; flow occurs only about once a year from any one drainage basin. The annual flow of the streams ranges from no flow to several times the volume of the mean annual flow. The average mean annual

Table 1. -- Mean annual flow at selected gaging stations on ephemeral streams in northwestern Arizona,
southern Nevada, and southeastern California

Stream	Location	Period of record	Altitude (feet)	Drainage area (sq mi)	Mean annual flow (ac-ft) ^{1/}	Range of annual flows (ac-ft)	Mean annual flow per unit area (ac-ft per sq mi)	Average number of runoff events per year
Sacramento Wash tributary near Topock, Ariz.	SE-1/4NE-1/4 sec. 14, T. 16 N., R. 20 W., Gila and Salt River meridian and base line	1964-68	969	11.3	4.6	0-20	0.41	1.0
Little Meadow Creek near Oatman, Ariz.	NE-1/4SW-1/4 sec. 16, T. 19 N., R. 19 W., Gila and Salt River meridian and base line	1965-68	2,900	8.5	.6	0- 1.8	.07	1.25
Ringbolt Wash near Hoover Dam, Ariz.	SW-1/4 sec. 19, T. 30 N., R. 22 W., Gila and Salt River meridian and base line	1965-68	1,800	1.2	.06	0- 0.1	.05	1.0
Eldorado Valley tributary near Nelson, Nev.	SE-1/4SE-1/4 sec. 36, T. 24 S., R. 63 E., Mount Diablo meridian and base line	1964-68	2,470	1.4	8.2	0-39	5.9	.80
Chemehuevi Wash tributary near Needles, Calif.	SE 1/4SE-1/4 sec. 19, T. 5 N., R. 23 E. (unsurveyed), Santa Barbara meridian and base line	1960-68	1,580	2.0	5.5	0-18	2.7	.56

^{1/} Mean annual flow estimated from peak flow record (B. N. Aldridge, written commun., 1968) except that of Chemehuevi Wash tributary near Needles, Calif., for 1963-68 period, when the station was equipped with a flood-hydrograph recorder.

discharge per unit area for the five stations is about 2 acre-feet per square mile. Because all the stations are in alluvial channels, which are subject to loss of streamflow by infiltration, the stations are not necessarily located at the point of maximum unit discharge. However, the conditions at the gaging stations are similar to those in the Lake Mead National Recreation Area south of Mount Davis.

In the Lake Mead National Recreation Area south of Mount Davis most of the streams have drainage basins of only a few square miles. Only three streams drain areas large enough to merit discussion—Lost Cabin Wash and Granite Wash in T. 23 N., Rs. 20, 21, and 22 W., each having a drainage basin of about 16 square miles, and an unnamed wash in Tps. 21 and 22 N., Rs. 20, 21, and 22 W., having a drainage area of about 13 square miles. Applying the estimated unit discharge of 2 acre-feet per square mile to these streams, mean annual flows of about 30 acre-feet were computed for Lost Cabin and Granite Washes, and 25 acre-feet was computed for the unnamed wash.

Because of the small quantity of surface water available for development in the area, no additional studies of runoff or runoff utilization were made. No runoff was observed during fieldwork; therefore, no surface-water samples were collected for chemical analysis except from Lake Mohave (table 4).

GROUND WATER

Movement and Occurrence

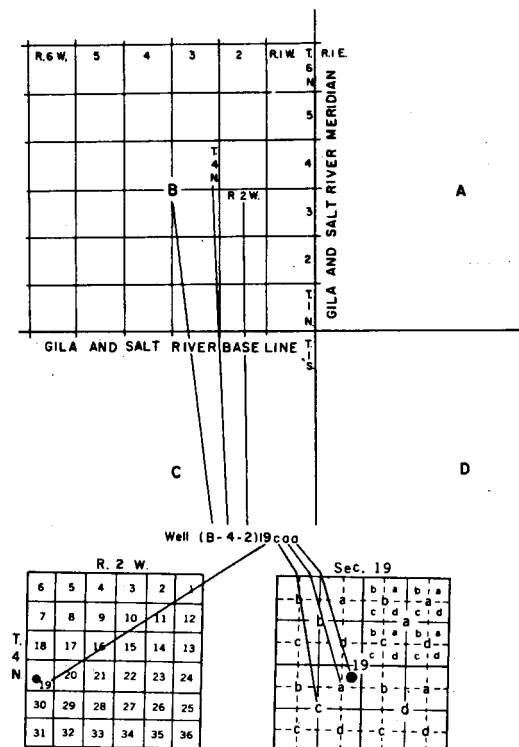
The regional movement of ground water is westward from the mountains to Lake Mohave. No significant movement of ground water occurs from the permeable rocks adjacent to Lake Mohave and similar rocks below the dam, because the dam and an impermeable granite ridge that extends from the dam to the mountains on both sides effectively block the underflow.

Since the filling of Lake Mohave in 1950, water from the lake has moved outward into the unconsolidated rock units adjacent to the lake, and they now are saturated below the approximate mean lake-surface altitude of 635 feet; downstream from Davis Dam the permeable rocks adjacent to the Colorado River are saturated below the approximate mean river surface, which is about 520 feet above sea level. Above these altitudes, the unconsolidated rocks are drained, except where consolidated bedrock underlies the ground surface at shallow depths. In these areas ground water may accumulate in a thin saturated layer or perched-water zone in the overlying unconsolidated rocks. The alluvial units near the lake and river probably are hydraulically connected, although

sufficient water-level data to substantiate this assumption are lacking. In general, the ground water is believed to be unconfined (i. e., nonartesian).

The distance that the water-bearing sedimentary rocks extend from Lake Mohave depends on the altitude of the contact between these rocks and the underlying consolidated rocks in relation to the altitude of the lake surface. The thickness of the sedimentary rocks is known in a few places near Lake Mohave but can only be estimated in the area between the lake and the mountains. Although well (B-22-21)35bbb (fig. 3) is reported to have penetrated hard rock at a depth of 210 feet below the land surface (table 2), a 730-foot dry hole, (B-21-21)27acc, was reported to be entirely in sedimentary rocks. The lack of subsurface data precludes an accurate estimate of the distance that the water-bearing sedimentary rocks extend from the lake; however, the chances of completing a productive well in the sedimentary rocks within 1 mile of the lake are favorable, and the chances become less favorable with increasing distance from the lake.

The aquifer in the area receives a small amount of recharge from precipitation. Most of the precipitation returns to the atmosphere through evaporation and through transpiration by plants; some



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (B-4-2)19caa designates the well as being in the $NE\frac{1}{4}NE\frac{1}{4}SW\frac{1}{4}$ sec. 19, T. 4 N., R. 2 W. Where there is more than one well within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 3. --Well-numbering system in Arizona.

Table 2. --Drillers' logs of wells in the Lake Mead National Recreation Area—Mount Davis to Davis Dam

	Thick- ness (feet)	Depth (feet)		Thick- ness (feet)	Depth (feet)
(B-21-21)7bdb			(B-25-22)29ddd		
Sandy clay	19	19	Broken rock, gravel and sand	20	20
Large stones and gravel	3	22	Volcanic clay and broken rock	30	50
Sandy red clay	5	27	Broken volcanic rock—burned shale, red	50	100
Sharp coarse sand	4	31	Broken volcanic rock—some small strata of gravel	50	150
Sandy red clay	3	34	Solid rock, fractured	15	165
Sharp coarse sand	6	40	(end of log)		
Fine black sand, red clay	20	60			
Sharp coarse sand	8	68	TOTAL DEPTH		200
Sandy red clay	31	99	(B-25-22)31ded		
Red sandstone (very hard)	9	108	Clean sand	99	99
Hard conglomerate (quartz)	17	125	Conglomerate	7	106
Conglomerate with small fractures yielding black sand	22	147	Gravel	3	109
TOTAL DEPTH		147	Conglomerate	19	128
(B-21-21)7bdc			Clean sand	3	131
Decomposed granite and gravel	41	41	Conglomerate	7	138
Solid granite	49	90	Sand	4	142
TOTAL DEPTH		90	Conglomerate	14	156
(B-24-22)8ccb			Gravel	29	185
Surface sand and gravel	45	45	Hilltop (author's note: volcanic rocks)	5	190
Fine sand	95	140	TOTAL DEPTH		190
Conglomerate	60	200			
TOTAL DEPTH		200			

water flows out of the area via the Colorado River. Only a small part of the precipitation collects in stream channels where some of it infiltrates to the ground-water reservoir.

Discharge

Water that infiltrates to ground water along the mountain fronts or from streamflow in the arroyos west of the mountains moves westward toward Lake Mohave and is discharged into the lake, is discharged by wells, or is lost by evapotranspiration.

Springs. --During this investigation, an attempt was made to locate all the springs in the area and to obtain the pertinent hydrologic data regarding them (table 3). A small quantity of the ground water that flows toward the lake and river is discharged by springs in the volcanic and granitic rocks in the Black Mountains. No springs are known to issue from the saturated rocks adjacent to the lake or river.

Wells. --Thirteen wells have been completed in the area—six have been abandoned, four have not been put into service, and one is a dry hole (table 3). A domestic well, (B-21-21)21bcc, and a stock well,

Table 3. - Occurrence of water in wells, springs, and mines in the Lake Mead Recreation Area—Mount Davis to Davis Dam and adjacent area

Location: See fig. 3 for description of well-numbering system.

Depth of well or mine: E, estimated.

Land-surface altitude: Determined from Geological Survey topographic maps.

Water level: E, estimated; R, reported.

Yield: < , less than amount shown; E, estimated; R, reported.

Use: (A), formerly for use shown, now abandoned; D, domestic; I, irrigation; M, mining; N, not used; (P), proposed use, not yet in service; PS, public supply; S, stock.

Remarks: C, chemical analysis of water shown in table 4; D, drillers' log shown in table 2.

Location	Name or type of occurrence	Aquifer	Depth of well or mine (feet)	Diameter of casing (inches)	Depth of casing (feet)	Land-surface altitude (feet above mean sea level)	Water level		Yield (gpm)	Use	Remarks
							Depth below land surface (feet)	Date measured (month, year)			
(B-21-20)7aab	Tyro well	Granitic rocks	---	---	---	2,640	---	---	---	M (A)	
7ccd	Weed spring	Granitic rocks	---	---	---	2,260	---	---	< 5	S	
20acb	Arabian mine	Volcanic rocks	---	None	---	2,490	---	---	---	N	Water reportedly used for highway construction.
27ada	Spring	Volcanic rocks	---	---	---	3,200	---	---	< 1	S	
29dbd	Cabin spring	Volcanic rocks	---	---	---	2,310	---	---	< 5	S	
(B-21-21)5cab	Katherine mine	Granitic rocks	970	None	---	935	294.6	7/68	200	PS	C; specific capacity = 0.9 gpm per foot of drawdown; water has objectionable taste.
7bdb	Lake Mohave Resort well No. 2	Older(?) alluvium	147	14	103	970	18.5 R	12/64	70 R	PS (A)	D; specific capacity = 0.6 gpm per foot of drawdown.
7bdc	Lake Mohave Resort well No. 1	Older(?) alluvium	90	8	70	960	8 R	/56	75 R	PS (A)	D.
12bcc	Roadside mine	Volcanic rocks	55 E	None	---	1,910	50 E	11/68	< 5 E	N	C.
21bcc	Warm spring well	Granitic(?) rocks	500	8	200	980	210 R	/48	4-5 R	D	C; pumps dry in 1 hour; pump intake at 450 feet.
27acc	Dry well	---	730	---	---	1,400	Dry	11/68	None	---	
(B-22-20)9aab	Burns spring	Volcanic rocks	---	---	---	3,640	---	---	5-10	S	
16abd	Rhyolite spring	Volcanic rocks	---	---	---	3,750	---	---	< 5	S	
33ceb	Spring	Volcanic rocks	---	---	---	3,080	---	---	< 1	S	
33cdb	Spring	Volcanic rocks	---	---	---	3,190	---	---	< 1	S	
(B-22-21)23adc	Box spring	Volcanic rocks	---	---	---	1,940	---	---	< 1	S	
26abb	Dug well	Volcanic rocks	10	36	---	1,940	9.3	11/68	---	D (A)	C; well at spring site.
35bbb	Mohave Lake View well	Older alluvium	214	---	---	1,690	192 R	6/63	2-5	PS (A)	C; "hard rock" at 210 feet.
(B-23-21)27aba	Calles spring	Volcanic rocks	---	---	---	1,630	---	---	< 1	S	C.
36adc	Chalk spring	Volcanic rocks	---	---	---	2,270	---	---	< 5	S	
(B-24-21)23eda	Lost cabin well	Granitic rocks	---	8	---	3,760	---	---	5-10	S	C; well at spring site.
(B-24-22)8ccb	Cottonwood Valley well	Chemehuevi Formation	200	16	200	671	37.0	9/67	1,000	PS (P)	D; C; specific capacity = 72 gpm per foot of drawdown; transmissivity = 17,650 ft ³ /day/ft (transmissibility = 132,000 gpd per foot).
(B-25-21)28cbb	Klondyke dug well	Volcanic rocks	---	None	---	2,841	32.5	1/69	---	M (A)	C.
(B-25-22)29ddd	Desert Rose well No. 1	Volcanic rocks	200	12	150	781	87 R	/61	15-20 R	PS (P)	D.
31ded	Desert Rose well No. 2	Chemehuevi Formation	190	12	182	720	103 R	12/62	1,300 R	I (P)	D.
33cec	Desert Rose well No. 3	Older(?) alluvium	225	8	212	800	175 R	1/63	75 R	PS (P)	

(B-24-21)23cda, are the only known producing wells in the area. Three mines are known to contain water (table 3), and two of these mines have been used as a water supply; water from the Arabian mine, (B-21-20)20acb, was used in the construction of State Highway 68 in 1965-66, and the Katherine mine, (B-21-21)5cab, supplies water to about 12 vacation homes for sanitary purposes. Water for domestic use in these homes is hauled from another source.

Aquifer and Well-Production Characteristics

A step-drawdown test was made by personnel of the Geological Survey in September 1967 on the National Park Service well, (B-24-22)8ccb, at the proposed campground in Cottonwood Valley (H. M. Babcock, written commun., 1967). The well was drilled to a depth of 200 feet in the Chemehuevi Formation near the shoreline of Lake Mohave, and the water-level altitude is about the same as the mean lake-surface altitude of 635 feet. The well was pumped at rates of 400, 700, and 1,000 gpm and had drawdowns of 4.3, 8.1, and 13.9 feet, respectively, and respective specific capacities of 93, 86, and 72 gpm per foot of drawdown. The transmissivity of $17,650 \text{ ft}^3/\text{day}/\text{ft}$ (cubic feet per day per foot of aquifer) (or a transmissibility of 132,000 gpd per foot [gallons per day]) may not be accurate because it was determined in

the early minutes of the test before recharge from the lake influenced the rate of drawdown. Nevertheless, the transmissivity indicates the probable high productivity of wells drilled in the Chemehuevi Formation near the lake.

A pump test was made by personnel of the Geological Survey at the abandoned Katherine mine, (B-21-21)5cab, to evaluate the potential of the mine as a water supply and to determine the hydraulic characteristics of the fractured granite (H. M. Babcock, written commun., 1969). The mine consists of a main shaft about 970 feet deep and several thousand feet of horizontal levels, stopes, and interconnecting excavations (Dimmick and Ireland, 1927, p. 717). The static water level is at about the same altitude as the near lake surface and is about 295 feet below the land surface.

About 5,600,000 gallons of water was pumped in 4 days, of which 5,200,000 gallons came from storage in the mine excavations, and 400,000 gallons flowed into the mine from the fractured granite. The test data were analyzed on the basis of the rate of water-level change at three pumping rates and during the recovery period. The sustained yield of the mine was determined to be 130-140 gpm at the 450-foot pumping level. The yield will increase as the pumping level is lowered, and a yield of about 200 gpm will be obtained at the 550-foot pumping level. When the mine was in operation, it was necessary to pump at a

rate of about 275 gpm to keep the mine dewatered to the 600-foot level (Robie, 1928, p. 550). The sustained yield and computed specific capacity of about 0.9 gpm per foot of drawdown are much higher than would be expected for a well completed in the same aquifer because of the small water-collecting area of a well compared to that of a mine.

Although the altitude of the pumping level was about 150 feet below the altitude of the Lake Mohave surface at the end of the test, inflow from the lake did not influence the rate of drawdown during the test. No significant hydraulic connection was found to exist between the lake and the mine, but the 4 days of pumping may not have been of sufficient duration to determine the complete absence of any connection.

QUALITY OF WATER

Water samples were collected for chemical analysis from four wells, two mines, and one spring during this investigation (table 4). In addition, a water sample from Lake Mohave was analyzed for comparison of the chemical quality of surface water and ground water. Water samples were collected from two wells prior to this investigation, and the analyses are included in this discussion.

Table 4. --Chemical analyses of water from selected sources and drinking-water standards, Lake Mead National Recreation Area—Mount Davis to Davis Dam and adjacent area

[Analyses by U. S. Geological Survey, except as indicated. Results in milligrams per liter, except as indicated. Calculated dissolved solids:
The sum of the determined constituents, using the carbonate equivalent of the bicarbonate]

Location	Source	Date of collection	Temperature (°C)	Silica (SiO ₂)	Iron (Fe)	Arsenic (As)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Boron (B)	Dissolved solids		Hardness as CaCO ₃		Sodium adsorption ratio (SAR)	Specific conductance (micro-mhos at 25°C)	pH	Color (scale units)	Percent sodium	Aquifer
																		Calculated	Residue on evaporation at 180°C	Calcium magnesium	Non-carbonate						
(B-21-21) 5cab (Filtered water) 1/	Katherine mine	11/27/68	--	26	0.06	0.00	215	26	290	7.8	270	0	6.4	755	2.2	0.8	0.39	1,460	1,540	645	424	5.0	2,800	7.9	0	49	Granitic rocks
(Unfiltered water)	do.	11/27/68	25.5	25	.15	.00	210	31	296	8.2	256	0	3.2	760	2.2	.8	.39	1,460	1,570	650	440	5.1	2,800	7.9	10	49	do.
(B-21-21) 12bcc	Roadside mine	11/14/68	10	36	.01	.00	200	23	171	6.1	240	0	314	315	3.8	1.8	.29	1,190	1,230	597	398	3.1	1,910	8.2	0	38	Volcanic rocks
(B-21-21) 21bcc	Warm Springs well	11/21/68	30.5	17	.13	.00	11	1	136	4.8	96	12	66	64	2.1	101	.53	462	466	28	0	11	761	8.7	0	90	Granitic(?) rocks
(B-22-21) 26abb	Dug well	11/21/68	17	93	.32	.00	21	14	130	1.0	804	49	197	240	2.2	1	.72	1,540	1,580	112	0	22	2,430	9.0	20	91	Volcanic rocks
(B-22-21) 35bbb 2/	Mohave Lake View well	6/ /63	--	--	--	--	63	14	78	--	210	0	152	38	.8	--	--	555	--	218	--	--	--	7.6	--	--	Older alluvium
(B-23-21) 27aba	Calles Spring	1/ 8/69	15	50	.02	--	35	14	54	--	177	3	37	48	2.2	--	--	330	--	144	10	--	553	8.3	--	--	Volcanic rocks
(B-24-21) 23cda	Lost Cypria well	1/ 8/69	--	37	.00	--	82	17	42	--	326	0	45	34	1.0	--	--	418	--	274	7	--	671	8.2	--	--	Granitic rocks
(B-24-22) 3ccn	Cottonwood Valley well	9/28/67	21	25	.00	.04	115	37	135	--	182	0	410	110	.7	--	--	923	--	440	291	--	1,410	7.9	--	--	Chemchuevi Formation
(B-25-21) 28cbb 2/	Klondyke dug well	1/ 8/69	16.5	38	.15	--	478	123	219	--	494	0	1,360	248	2.2	--	--	2,710	--	1,700	1,300	--	3,380	7.7	--	--	Volcanic rocks
	Lake Mohave at Lake Mohave resort	1/ 9/69	--	9.5	.00	--	88	31	109	--	163	0	300	97	.6	--	--	715	--	348	215	--	1,150	8.2	--	--	--
Drinking-water standards:																											
(Recommended maximum content) 4/		--	--	--	.3	.01	--	--	--	--	--	--	250	250	.8	45	--	--	500	--	--	--	--	--	15	--	--
(Mandatory maximum content) 2/		--	--	--	--	.05	--	--	--	--	--	--	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--

1/ Water filtered through a 0.45 micron field filter; see table 5 for special analyses.

2/ Analysis by Valley Laboratories, Inc., Phoenix, Ariz.

3/ Water turbid.

4/ Data from U. S. Public Health Service (1962).

Because of the interest of the National Park Service in the Katherine mine as a water supply, analyses for spectrographic trace-elements and radioactivity were made of the water (table 5) in addition to the standard analysis (table 4).

Well (B-24-22)8ccb obtains its water from the unconsolidated rocks adjacent to Lake Mohave. The water is similar in chemical characteristics to the water from the lake, which indicates that the rocks obtain most of their recharge from Lake Mohave. The quality of the water from this well meets the standards set by the U.S. Public Health Service (1962) for drinking water on interstate carriers, although the concentrations of arsenic, sulfate, and dissolved solids exceed the recommended maximum concentrations where more suitable supplies are available.

Water from the other sources sampled is from volcanic rocks, granite, or older alluvium. These sources are high on the alluvial slope and are not believed to derive water from the Colorado River or Lake Mohave. The water from these sources, including those that obtain water from the same aquifer, is characterized by extreme differences in the type and concentrations of dissolved minerals. Dissolved-solids concentrations range from 330 mg/l (milligrams per liter) at spring (B-23-21)27aba, which issues from volcanic rocks, to 2,710

Table 5. --Spectrographic and radiochemical analyses of water from Katherine mine and drinking-water standards

analyses in milligrams per liter, except as indicated. See table 4 for standard chemical analysis. Concentration: ND, specifically sought, not detected; <, less than figure shown. Drinking-water standards: M, concentration greater than stated amount is grounds for rejection of supply. Samples collected November 27, 1968]

Spectrographic trace-elements analysis		
Element	Concentration	Drinking-water standards (U. S. Public Health Service, 1962)
Aluminum (Al)	0.025	--
Manganese (Mn)	2.9	0.05
Molybdenum (Mo)	.008	--
Chromium (Cr)	<.02	M .05
Rubidium (Rb)	<.005	--
Nickel (Ni)	<.015	--
Copper (Cu)	<.0003	1.0
Silver (Ag)	<.002	M .05
Tin (Sn)	<.02	--
Lead (Pb)	<.02	M .05
Zinc (Zn)	ND	5
Bismuth (Bi)	<.02	--
Cobalt (Co)	<.015	--
Titanium (Ti)	<.007	--
Cadmium (Cd)	ND	M .01
Vanadium (V)	<.002	--
Strontium (Sr)	2.4	--
Barium (Ba)	.12	M 1.0
Beryllium (Be)	<.005	--
Lithium (Li)	.14	--
Radioactivity analysis		
Radioactivity		
Total alpha activity, micromicrocuries per liter	27.	--
Total beta + gamma activity, micro- microcuries per liter	18	1,000
Radium (Ra), micro- microcuries per liter	.56	3
Uranium (U), micro- grams per liter	1.0	--

mg/l in well (B-25-21)28cbb, also in volcanic rocks. Fluoride concentrations in water from the sources away from the lake were large, and only two samples, those from wells (B-22-21)35bbb and (B-24-21)23cda, had concentrations that did not exceed the mandatory limit established by the Public Health Service (1962; table 4).

The cause of the large nitrate concentration (101 mg/l) in well (B-21-21)21bcc is not known. Most large concentrations of nitrate in ground water are of organic origin (Hem, 1959, p. 117). In well (B-21-21)21bcc the absence of an accompanying large chloride concentration and the absence of a suspected organic source indicate that the large nitrate concentration is due to an inorganic cause.

Water from the Katherine mine is highly mineralized and has an objectionable taste (tables 4 and 5). Concentrations of dissolved solids and chloride exceed the maximum concentrations recommended by the U. S. Public Health Service (1962), and the concentration of fluoride (2.2 mg/l) exceeds the mandatory limit. The spectrographic trace-elements and the radioactivity analyses did not show the presence of mineral concentrations or radioactivity in excessive amounts in water from the mine (table 5).

CONCLUSIONS AND RECOMMENDATIONS

The surface-water development potential is almost nonexistent in the area, except for the Colorado River. Flow in the ephemeral streams is meager—about 30 acre-feet per year from the largest drainage basins—and is extremely variable from year to year.

The principal source of ground water in the area is the unconsolidated sedimentary rocks adjacent to Lake Mohave; the lake is the main source of recharge to the aquifer. The most favorable rock unit for the development of ground-water supplies is the Chemehuevi Formation, which will yield more than 1,000 gpm of water to wells. The Chemehuevi Formation is not widespread and is present only near the lake. The older alluvium probably will yield from 100 to 1,000 gpm of water to wells, and the pre-Bouse alluvium may yield moderate quantities. The water level in the sedimentary rocks adjacent to the lake is about 635 feet above mean sea level—approximately the same altitude as the mean lake surface. In general the chemical quality of the water from the unconsolidated rocks adjacent to the lake is satisfactory for a public supply.

Well yields will decrease with increasing distance from the lake. The chances of consolidated rock underlying the land surface at shallow depths become greater with increasing distances from the

lake, and the alluvial units will not yield water to wells as readily as the Chemehuevi Formation. More subsurface data are needed to determine the ground-water potential in most of the alluvial slope. The granitic and volcanic rocks yield small quantities of water to several springs and wells in the Black Mountains. However, development of ground-water supplies in the Black Mountains probably is not practical, because of the small quantity of water available and because much of the water is highly mineralized. Although the Katherine mine will yield water at a sustained rate of more than 200 gpm, the water is highly mineralized, has an objectionable taste, and is not suitable for public supply without treatment.

The most productive wells will be in the sedimentary rocks along a narrow strip of land adjacent to Lake Mohave. Wells can be developed in the sedimentary rocks of the alluvial slope, although well yields can be expected to decrease with increased distance from the lake. Test wells should be drilled to consolidated rock or to a point where a sufficient water supply is obtained—probably 20 to 30 feet below the static water level in the Chemehuevi Formation, 100 to 150 feet in the older alluvium, and 200 to 300 feet in pre-Bouse alluvium and Bouse Formation undifferentiated. In order to determine the water-bearing characteristics of the sedimentary rocks in the alluvial

slope, about five test wells should be drilled from 2 to 3 miles from Lake Mohave. The wells should be drilled about 5 miles apart along a line from sec. 33, T. 25 N., R. 22 W., on the north to sec. 5, T. 21 N., R. 21 W., on the south. Drill cuttings should be collected at 10-foot intervals and sieve analyses made of the cuttings from the saturated zone to determine the size of well screen and gravel packing necessary to prevent post-development sanding.

Two areas are of special interest for the potential development of a water supply—the Desert Rose subdivision, which is in the southwest part of T. 25 N., R. 22 W., and the 2-square-mile Ohaco Sheep Ranch property in contiguous sections 2 (T. 23 N., R. 22 W.) and 35 (T. 24 N., R. 22 W.). (See fig. 2.)

Three private wells are in the Desert Rose subdivision; well (B-25-22)31dcd has a reported maximum yield of 1,300 gpm. The most favorable location in the subdivision for a large-producing well is in the Chemehuevi Formation in section 31 (T. 25 N., R. 22 W.). Wells drilled in the other sedimentary rock units near the lake probably will yield moderate quantities of water.

No wells are on the Ohaco Sheep Ranch property. The property is underlain by the older alluvium and the pre-Bouse alluvium and Bouse Formation undifferentiated; both units will yield moderate

quantities of water where saturated. The west boundary of the property is 1/4 to 1/2 mile from the lake; the southwest corner, because of its proximity to the lake, is the most favorable location for water exploration.

The water level in the Desert Rose subdivision and the Ohaco Ranch property is at about the same altitude as the mean lake surface. The wells should be drilled to depths of 20 to 30 feet below the static water level in the Chemehuevi Formation, 100 to 150 feet in the older alluvium, and 200 to 300 feet in the pre-Bouse alluvium and Bouse Formation undifferentiated. The wells should be at least 18 inches in diameter in order to accommodate gravel packing.

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