UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOHYDROLOGIC RECONNAISSANCE OF LAKE MEAD NATIONAL RECREATION AREA—HOOVER DAM TO TEMPLE BAR, ARIZONA

Open-File Report 79-689

Prepared in cooperation with the National Park Service

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Released to the open file _____, 1979

Tucson, Arizona
June 1973


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GEOHYDROLOGIC RECONNAISSANCE OF LAKE MEAD NATIONAL RECREATION AREA—HOOVER DAM TO TEMPLE BAR, ARIZONA

By

R. L. Laney

INTRODUCTION

A series of geohydrologic reconnaissance studies is being made by the U.S. Geological Survey in cooperation with the National Park Service in the Lake Mead National Recreation Area. This report is one in the series of reports for specific areas and sites in the recreation area and covers about 160 square miles from Hoover Dam to Temple Bar (fig. 1). The investigation was undertaken to appraise the water resources in the area and to locate additional water supplies. The investigation included: (1) collection and analysis of well and spring data, (2) determination of the chemical quality of water, (3) reconnaissance geologic mapping at a scale of 1:62,500, and (4) determination of the geologic controls on the occurrence and movement of ground water.

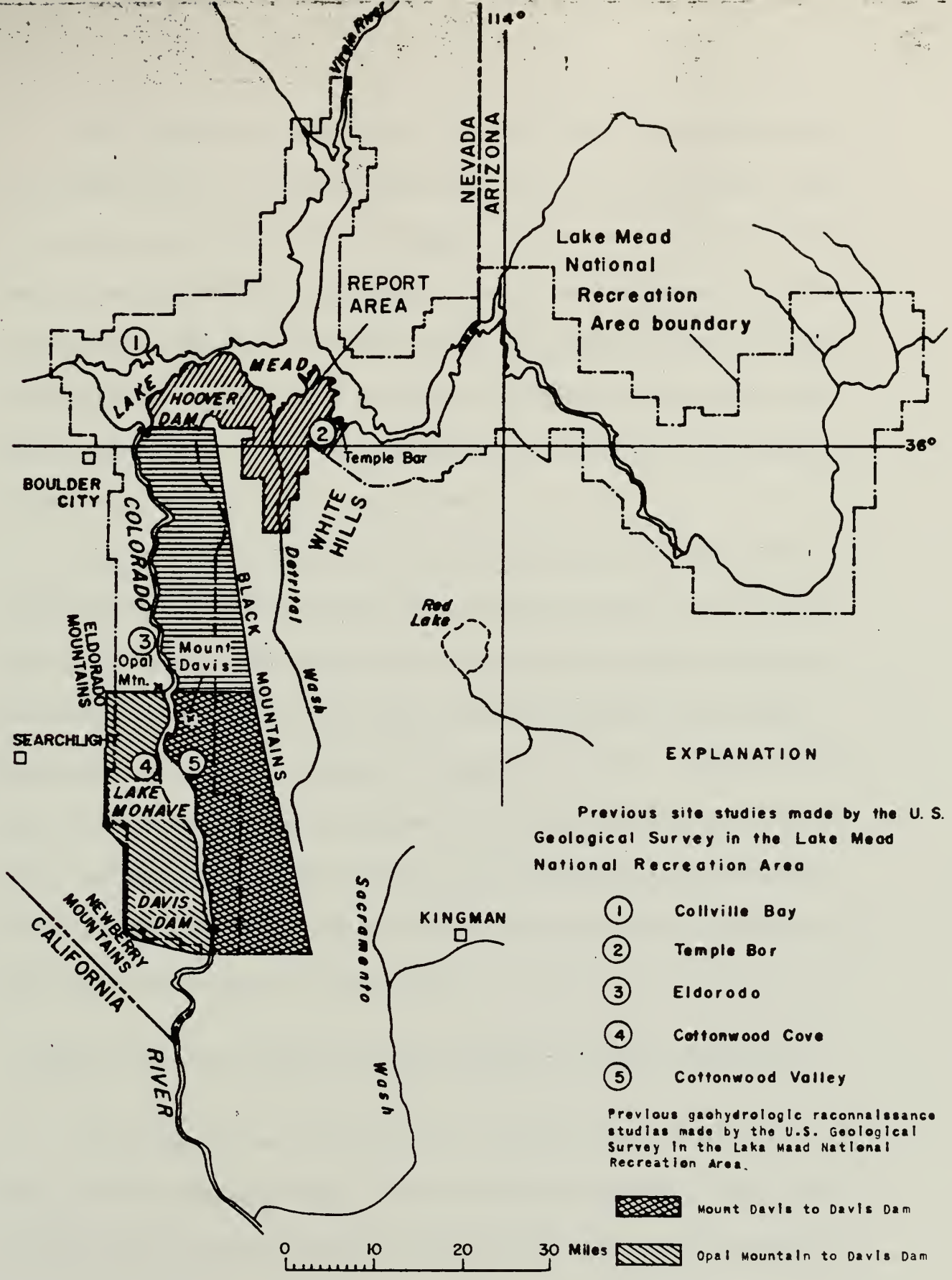


Figure 1.--Index map of Lake Mead National Recreation Area showing area of this report and areas of previous studies made by the U.S. Geological Survey.

The report area is bounded on the west, north, and northeast by Lake Mead (fig. 1). The Black Mountains occupy the western one-third of the area, and the White Hills roughly bound the area on the east. The north-trending Detrital Valley is in the central part of the area between the Black Mountains and the White Hills. The altitude ranges from about 635 feet above mean sea level at the base of Hoover Dam to about 5,200 feet at Wilson Ridge in the Black Mountains; most of the area is between 1,200 and 2,500 feet above mean sea level.

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 ranges from about 3 inches in the lower altitudes to about 10 inches in the mountains. The average annual precipitation is 5.2 inches at Boulder City, Nev., which is 5 miles west of the report area at an altitude of 2,525 feet above mean sea level (U.S. National Climatic Center, data issued annually). In most of the area the vegetation is cactus, creosote-bush, and mesquite; saltcedar is present along the shores of Lake Mead.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

The report area is underlain by crystalline and sedimentary rocks. The crystalline rocks consist of intrusive granitic rocks, metamorphic rocks, volcanic rocks, and the Fortification Basalt Member of

the Muddy Creek Formation. The granitic and metamorphic rocks and the Fortification Basalt Member are present in the Black Mountains along the west side of the area; the volcanic rocks occur mainly in the White Hills along the east side of the area.

In this report the sedimentary rocks are divided into the Muddy Creek Formation, which consists of a conglomerate facies, mudstone facies, limestone facies, and the Fortification Basalt Member; older alluvium, which consists of a poorly sorted gravel unit and the Colorado River deposits; Chemehuevi Formation; terrace gravel; and younger alluvium. The strata assigned to the conglomerate facies are divided into a lower part and an upper part. The sedimentary rocks are thickest and have their greatest areal extents east of the Black Mountains in Detrital Valley and in the White Hills.

The Muddy Creek Formation is the most widespread unit in the map area, and it unconformably overlies all older units. Interbedded flows of the Fortification Basalt Member are present throughout the Muddy Creek Formation. The older alluvium unconformably overlies the Muddy Creek Formation and older units; the most continuous exposure of the older alluvium is east of the Black Mountains in Detrital Valley. The Chemehuevi Formation is exposed on both sides of Detrital Wash near Lake Mead, and the unit unconformably overlies the Muddy Creek Formation and probably the older alluvium; however, the contact

between the Chemehuevi Formation and the older alluvium is not well exposed. Thin deposits of terrace gravel cap the older units in much of the area. The terrace gravel is mapped with the underlying unit except east of Detrital Wash, where the gravel is sufficiently thick and extensive to conceal the underlying formations. The younger alluvium is exposed in the flood plains and stream channels and is the most recent deposit in the area.

Granitic and Metamorphic Rocks

Intrusive granitic rocks of Tertiary age make up a large part of the Black Mountains and intrude metamorphic rocks of Precambrian age as plutons and dikes (fig. 2). The metamorphic rocks are well exposed on the east side of the Black Mountains and consist of banded granitic gneiss and micaceous and chloritic schist. A small exposure of sedimentary rocks of Cambrian age (Longwell, 1963, pl. 1) is mapped with the granitic and metamorphic rocks at the north end of the Black Mountains near Boulder Canyon. An outcrop directly southwest of Wilson Ridge that was mapped by Bentley (1971) as granitic and metamorphic rocks of Precambrian age has been classified as intrusive granitic rocks of Tertiary age using the potassium-argon method (Anderson, written commun., 1971), and the outcrops in the area 1 to 4 miles southwest of Wilson Ridge that were mapped by Bentley (1971) as volcanic rocks are

now known to be intrusive granitic rocks of Tertiary age (Anderson and others, 1972). The granitic and metamorphic rocks are mapped as a single unit on the basis of their similar hydrologic properties.

The granitic and metamorphic rocks do not yield water except where fractured. No wells are known to obtain water from these rocks in the report area, but two springs issue from these rocks in the Black Mountains southeast of Wilson Ridge. One of the springs, which is about three-fourths of a mile south of the map area in the $NE\frac{1}{4}SE\frac{1}{4}NE\frac{1}{4}$ sec. 13, T. 30 N., R. 22 W. (unsurveyed), was flowing at a rate of 0.3 gpm (gallon per minute) when visited by the author on February 18, 1972.

Volcanic Rocks

The volcanic rocks are exposed in the White Hills and near Hoover Dam and extend from the dam south and southwest along the Colorado River (fig. 2). The volcanic rocks are about 17,000 feet thick, are late Tertiary in age, and are composed of andesite, rhyolite, and basalt flows, flow breccia, and associated tuff, agglomerate, and clastic rocks (Anderson, 1971; Anderson and others, 1972). Pre-volcanic arkosic detritus of unknown age locally underlies the volcanic rocks and is included in this unit (Longwell, 1963, p. 20; Anderson, 1971, p. 46).

In the White Hills the volcanic rocks consist of basalt to rhyolite flows, flow breccia, tuff, agglomerate, and conglomerate. A 60- to 80-foot-thick sequence of dark-grayish-brown moderate- to well-cemented conglomerate is exposed at the mouth of Trail Rapids Wash west of Temple Bar. The conglomerate is interbedded with the volcanic rocks and contains angular fragments of basalt and andesite. West of the mouth of Temple Bar Wash, the conglomerate has an arkosic sand matrix derived from intrusive rocks; the larger clasts, some as much as 6 feet in diameter, were derived from volcanic rocks. Less than 1 mile east of Temple Bar Wash, a dark-greenish-gray arkosic conglomerate, which is mainly angular granitic clasts and some well-rounded andesite clasts, is exposed beneath the limestone facies of the Muddy Creek Formation. The arkosic conglomerate may be equivalent to the conglomerate to the west, or it possibly may be equivalent to the pre-volcanic arkosic detritus of Longwell (1963) and Anderson (1971); in this report, however, the arkosic conglomerate is mapped with the volcanic rocks. Although the volcanic rocks in the White Hills have not been dated isotopically, Blacet (U.S. Geological Survey, written commun., 1972), who is mapping the geology in the nearby Garnet Mountain quadrangle, considers them to be equivalent to the uppermost part of the volcanic rocks exposed along the Colorado River south of Lake Mead.

The volcanic rocks may transmit some water where fractured near Lake Mead; the interbedded tuff, agglomerate, and clastic rocks also may transmit water through interconnected pore spaces. The unit yields moderate quantities of water to at least six hot springs about 1 mile south of Hoover Dam (Bentley, 1971, p. 9).

Muddy Creek Formation

In the study area the Muddy Creek Formation of late Tertiary age is divided into the conglomerate facies, which consists of a lower part and an upper part; the mudstone facies; the limestone facies; and the Fortification Basalt Member. Near Hoover Dam, the coarse alluvial-fan detritus of the conglomerate facies, which was derived from local steep upfaulted mountain blocks, grades laterally within short distances into the mudstone facies, which was deposited either in closed basins or in basins that had sluggish through drainage. South of Hoover Dam, the conglomerate facies grades laterally into marine estuarine deposits (Bentley, 1971, p. 10). In Detrital Valley the mudstone facies grades laterally and vertically into the limestone facies. Potassium-argon age determinations of the volcanic rocks that underlie the Muddy Creek Formation, of flows in the Fortification Basalt Member, and of a mafic dike that has intruded the conglomerate facies along the Colorado River

south of Lake Mead indicate that the beds of the Muddy Creek are from about 4 to 12 million years old (Anderson and others, 1972, p. 280-281).

Conglomerate Facies

The conglomerate facies of the Muddy Creek Formation is best exposed west of the Black Mountains and underlies the mudstone facies in the subsurface in Detrital Valley. The conglomerate facies was derived from the mountains and in places may be nearly monolithologic, depending on whether the source area was underlain by granitic or volcanic rocks. The conglomerate facies is divided into a lower part and an upper part. The lower part unconformably overlies and in places is in fault contact with older units; east of Hoover Dam the upper part disconformably overlies or is in angular contact with the lower part.

Lower part. --The lower part of the conglomerate facies of the Muddy Creek Formation is composed of moderate- to well-cemented subangular sand- and gravel-size fragments of andesite, basalt, welded tuff, granite, granitic gneiss, and schist set in a light-reddish-brown to red silty matrix. The detritus is cemented with calcium carbonate, and, in general, the grain size ranges from silt to fine gravel; however, boulders as much as 2 feet in diameter are present in places. The lower part of the conglomerate facies is dominantly a poorly sorted thick

parallel-bedded sequence, although lenticular and crossbedded sand and gravel as much as 1 foot thick are present locally. The lower part of the facies is well exposed about 2 miles east of Hoover Dam and west and north of Fortification Hill (fig. 2), where the deposits are as much as 1,000 feet thick. High-angle faults that have displacements of less than 50 feet are present in the deposits. The lower part of the facies is moderately deformed structurally, and beds commonly dip as much as 20°. At Fortification Hill, the conglomerate facies is capped by more than 400 feet of the Fortification Basalt Member dated at 10.6 ± 1.1 million years (Anderson and others, 1972, p. 278). Northwest of Fortification Hill coarse conglomerate grades laterally into the mudstone facies within a distance of about 300 yards (fig. 2); the mudstone facies is gypsiferous at this locality.

Exposures of the lower part of the conglomerate facies generally are above the zone of saturation, and the unit is not known to yield water to wells or springs in the study area. Northwest of Fortification Hill, however, the lower part extends below maximum lake level, which is 1,221 feet above mean sea level, and may yield small to moderate amounts of water to wells.

Upper part. --The upper part of the conglomerate facies of the Muddy Creek Formation is lithologically similar to the lower part except

that the silty matrix is grayish brown to very pale brown. The upper part of the conglomerate facies is less than 300 feet thick east of Hoover Dam but thickens southward, where it is more extensively exposed (Bentley, 1971, p. 12). The structural deformation in the upper part of the facies is not as great as that in the lower part, and beds generally dip less than 15°. Generally, the upper facies is above the saturated zone and is not known to yield water to wells or springs in the study area.

Mudstone Facies

The mudstone facies comprises most of the exposures of the Muddy Creek Formation east of the Black Mountains. The mudstone facies consists of light-reddish-brown weakly to moderately cemented siltstone and claystone and some 1- to 2-inch-thick beds of very fine sandstone. In places the facies contains disseminated gypsum crystals or thin white gypsum layers; near Detrital Wash, the mudstone grades into white bedded gypsum. The facies contains halite along Detrital Wash near the southern boundary of the recreation area and grades laterally and vertically into tuffaceous marl and limestone east of the wash.

Although the age of the mudstone facies has not been determined by isotopic dating of the associated basalt flows in the area east of the

Black Mountains, the mudstone facies is overlain by basalt flows that probably are part of the Fortification Basalt Member in the Petroglyph Wash area on the east side of the Black Mountains (fig. 2). Similar basalt flows are interbedded with the upper part of the mudstone facies about $1\frac{1}{2}$ miles west of Bonelli Landing.

The mudstone facies underlies most of Detrital Valley and is overlain by the younger deposits. In the northeastern part of T. 29 N., R. 21 W. (unsurveyed), core data from exploration wells indicate that the facies is more than 1,000 feet thick (table 1). In areas of outcrop, however, the facies generally is less than 200 feet thick. Northwest of the mouth of Detrital Wash, the mudstone facies grades into bedded gypsum, which is exposed northeastward to East Point (fig. 2). Where the limestone facies is present, the mudstone exhibits vertical and lateral gradations through gray to white tuffaceous mudstone, marl, and limestone. Along Detrital Wash in the northeastern part of T. 29 N., R. 21 W. (unsurveyed), the top of a halite body in the Muddy Creek Formation is about 400 to 650 feet below the land surface. The beds that overlie the halite are upwarped into a south-plunging anticline (fig. 2), which may indicate upward movement of the low-density salt mass.

The mudstone facies is not known to yield water to wells or springs in the report area. The facies is a confining bed and probably will yield less than 1 gpm of highly mineralized water to wells.

Table 1. --Lithologic logs of wells (B-29-21)14add and (B-30-21)12adc in the Lake Mead National Recreation Area—Hoover Dam to Temple Bar

[Locations unsurveyed]

Stratigraphic unit	Rock description	Thickness (feet)	Depth (feet)
	(B-29-21)14add [From Stauffer Chemical Co. driller's log. Modified and condensed by R. L. Laney in 402- to 1,392-foot interval]		
Younger alluvium and older alluvium (undivided)	Unconsolidated valley fill	120	120
Colorado River deposits(?) of the older alluvium	Clay and sandstone	97	217
Local gravel unit of the older alluvium	Boulder conglomerate	185	402
Mudstone facies of the Muddy Creek Formation	Mudstone and siltstone with interbedded gypsum and glauberite	221	623
	Halite; some glauberite, clay, and silt as impurities and interbeds	402	1,025
Conglomerate(?) facies of the Muddy Creek Formation	Coarse red-brown sandstone and siltstone, some halite in upper part, some glauberite(?) beds as much as 1 foot thick	367	1,392

Table 1. --Lithologic logs of wells (B-29-21)14add and (B-30-21)12adc in the Lake Mead National Recreation Area—Hoover Dam to Temple Bar—Continued

Stratigraphic unit	Rock description	Thickness (feet)	Depth (feet)
	(B-30-21)12adc		
	[From Phelps Dodge Corp. geologic log. Modified and condensed by R. L. Laney in 160- to 622-foot interval]		
Terrace gravel; lower part may be Chemehuevi Formation	Recent alluvium, granitic, mainly pebble size, unconsolidated	33	33
Chemehuevi Formation	Clay, red-brown, unconsolidated	12	45
	Sandstone, brown, very fine grained, moderately indurated	15	60
	Gravel and very coarse sand beds, interbedded with red-brown unconsolidated clay. . .	100	160
Mudstone facies of the Muddy Creek Formation	Gypsum, anhydrite, claystone, and siltstone	462	622
	Siltstone, brownish-gray, progressively more clastic with depth	20	642
Conglomerate facies of the Muddy Creek Formation	Sandstone, pebbly, 10-20 percent granitic pebbles	14	656
	Conglomerate, granitic, pebble to cobble size, sandy matrix	48	704
	Boulder conglomerate, igneous boulders and breccia, strongly weathered	38	742
Granitic and metamorphic rocks	Monzonite, coarse-grained . . .	24	766

Limestone Facies

The limestone facies of the Muddy Creek Formation is exposed east of Detrital Wash, where it caps benches and mesas. The unit is mainly gray to white porous contorted thin to very thin limestone beds, but it contains some porous dense sugar-textured limestone beds that range in thickness from 3 inches to 1 foot. Lenses and irregular-shaped masses of pink to white chert are common in the facies, and plant stems are abundant in some exposures. In places the facies contains interbeds of light-reddish-brown mudstone that are a few inches to several feet thick. The weathered limestone develops a characteristic dark-gray-brown pitted surface, and the resistant chert develops a dark-brown to nearly black coating of desert varnish. The limestone is equivalent, at least in part, to the Hualpai Limestone of Longwell (1936, p. 1429).

The limestone ranges in thickness from 15 feet east of the mouth of Detrital Wash to about 250 feet in the White Hills (fig. 2). About $1\frac{1}{2}$ miles southwest of the mouth of Trail Rapids Wash (fig. 2), the limestone grades laterally into interbedded tuffaceous fine sand and silt in a distance of less than 200 yards.

Generally, the limestone facies is above lake level and above the zone of saturation. Near Temple Bar, however, the facies is below maximum lake level, which is 1,221 feet above mean sea level, and may yield small to moderate quantities of water to wells.

Fortification Basalt Member

The Fortification Basalt Member of the Muddy Creek Formation crops out on the east and west flanks of the Black Mountains (fig. 2). The member is a series of dark-gray to black olivine basalt flows that overlies and is interbedded with the conglomerate and mudstone facies of the Muddy Creek Formation. The member also overlies the volcanic rocks and the granitic and metamorphic rocks. The flows that cap Fortification Hill on the west flank of the Black Mountains are about 400 feet thick, and the flows on the east flank of the mountains are less than 300 feet thick. The flows on the west flank of the Black Mountains generally dip less than 5°; those on the east flank, however, are flat lying or may dip as much as 90°, and some flows are overturned (fig. 2). Basalt flows that probably are part of the Fortification Basalt Member are in fault contact with the lower part of the conglomerate facies northwest of Fortification Hill. In the area $1\frac{1}{2}$ to $2\frac{1}{2}$ miles northwest of Bonelli Landing in Detrital Valley, similar flows, which are less than 20 feet thick, are interbedded with the mudstone facies.

No wells have been drilled in the Fortification Basalt Member in the report area. Most of the basalt flows occupy topographically high positions and are not known to yield water to springs. The flows are saturated near Lake Mead, however, and it is anticipated that wells that penetrate this unit may yield as much as 100 gpm of potable water.

Older Alluvium

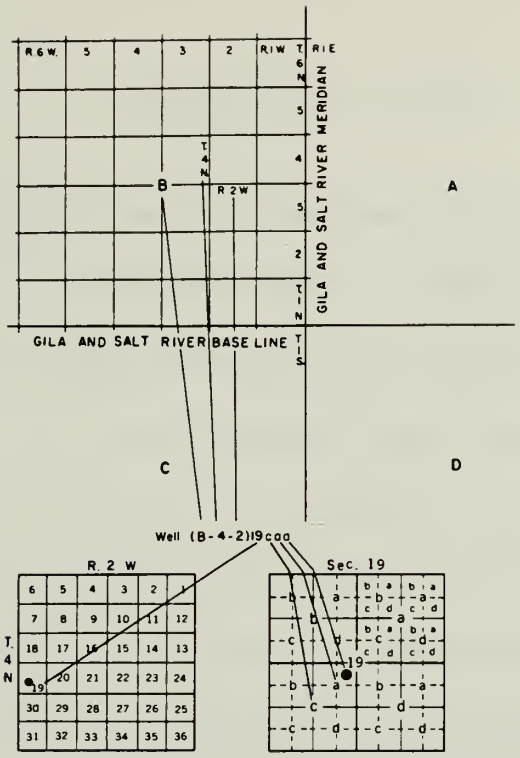
The older alluvium of probable late Tertiary and early Quaternary age consists of moderately cemented moderately deformed faulted gravel and obviously younger flat-lying weakly indurated gravel that was not involved in structural movement. In this report the older alluvium is divided into two units—the local gravel unit and the Colorado River deposits. Although the Colorado River deposits make up only a small part of the older alluvium, the deposits are mapped separately because of their hydrologic significance (fig. 2).

The older alluvium unconformably overlies the older units in most of the area. The older alluvium is involved in faulting with beds of the Muddy Creek Formation northwest of Fortification Hill and with the Chemehuevi Formation along the east side of Detrital Wash north of Temple Bar road. In much of the area younger terrace gravel, which is less than 10 feet thick, caps the older alluvium and is mapped with that unit. Bedding may be indistinct or may be well marked by sand and gravel layers; scouring, filling, and crossbedding are present in places.

Local Gravel Unit

The local gravel unit of the older alluvium is a light-gray to grayish-brown weakly cemented poorly sorted angular to subangular silty gravel of local origin. The angular clasts in the local gravel are mainly granitic, metamorphic, and volcanic detritus from the nearby mountains. The local gravel is present northwest and south of Fortification Hill, between the Black Mountains and Detrital Wash, and about 2 miles south of Temple Bar road east of Detrital Wash. In outcrop, the local gravel unit is less than 75 feet thick, but lithologic data from exploratory wells in the northeastern part of T. 29 N., R. 21 W. (unsurveyed) indicate that the local gravel may be as much as 185 feet thick in the central part of Detrital Valley (table 1, see well (B-29-21)14add; fig. 3).

The local gravel is above the saturated zone in most of the area; near Lake Mead, however, the gravel is below maximum lake level, which is 1,221 feet above mean sea level, and will yield moderate to large quantities of water to wells. The possibility of developing ground-water supplies from the local gravel unit is discussed in the section "Proposals for Exploration."



The well and spring 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 or spring number indicates the township, the second the range, and the third the section in which the well or spring is situated. The lowercase letters a, b, c, and d after the section number indicate the well or spring location within the section. The first letter denotes a particular 160-acre (0.65-km^2) tract, the second the 40-acre (0.16-km^2) tract, and the third the 10-acre (0.04-km^2) tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre (0.04-km^2) tract, three lowercase letters are shown in the well or spring 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 more than one well or spring is within a 10-acre (0.04-km^2) tract, consecutive numbers beginning with 1 are added as suffixes.

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

Colorado River Deposits

The Colorado River deposits consist of light-gray to grayish-brown moderate- to well-sorted sand- to cobble-size rounded exotic material that was transported into the area by the southwestward-flowing Colorado River. The exotic rounded clasts of the Colorado River deposits consist mainly of quartzite, chert, limestone, jasper, and granite; in places eolian dune sand is present. The Colorado River deposits are as much as 150 feet thick east of Detrital Wash and as much as 60 feet thick about 1 mile southwest of the mouth of Trail Rapids Wash. Thinner exposures are scattered in the Temple Bar area. Near Temple Bar, the deposits are folded with beds of the limestone facies of the Muddy Creek Formation into a southwest-plunging syncline.

The Colorado River deposits are above the saturated zone in most of the area. Near Lake Mead, however, the deposits are below maximum lake level, which is 1,221 feet above mean sea level, and will yield moderate to large quantities of water to wells. The possibility of developing ground-water supplies in the Colorado River deposits is discussed in the section "Proposals for Exploration."

Chemehuevi Formation

The Chemehuevi Formation of Pleistocene age is exposed along Detrital Wash, between Temple Bar and the White Hills, and in a small area about 2 miles west of Bonelli Landing. The Chemehuevi Formation is a light-reddish-brown weakly cemented silt that contains sand and gravel beds. The gravel beds consist of subangular fragments of gneiss, schist, andesite, and basalt and as much as 5 percent of rounded pebbles and cobbles of chert, quartzite, and granite. Lithologic and drillers' logs of wells indicate that the Chemehuevi is as much as 125 feet thick in Detrital Valley and as much as 250 feet thick near Temple Bar (tables 1 and 2).

Along the east side of Detrital Wash north of Temple Bar road, a 40- to 50-foot-thick sequence of the unit is exposed. The lower 10 feet of the section is white porous limestone interbedded with thin greenish-gray tuffaceous clay. The limestone is unconformably overlain by 20 to 30 feet of light-reddish-brown silt that includes resistant sand ribs 1 to 3 inches thick and gravel beds as much as 1 foot thick. The silt is overlain by 10 to 15 feet of light-grayish-brown weakly consolidated gravel. The limestone may be part of the Muddy Creek Formation, which is capped by the Chemehuevi Formation in exposures near the mouth of Detrital Wash. An unusual gypsiferous conglomerate in the Chemehuevi Formation is exposed near its contact with bedded gypsum of the mudstone

Table 2. --Modified drillers' logs of wells (B-31-19)33acc1 and (B-31-19)33acc2 in the Lake Mead National Recreation Area—Hoover Dam to Temple Bar

[Locations unsurveyed]

Stratigraphic unit	Rock description	Thickness (feet)	Depth (feet)
	(B-31-19)33acc1		
Chemehuevi Formation	Gravel, $1\frac{1}{4}$ inches in diameter, dry	40	40
	Gravel, coarse, dry	45	85
	Sand rock, decomposed	20	105
	Clay, brown, sandy	7	112
	Sand and gravel, water	14	126
	Clay, brown, sandy	16	142
	Water sand	6	148
	Clay, brown, sticky	22	170
	Sand, dry	10	180
	Clay, brown, sticky	3	183
	(B-31-19)33acc2		
Chemehuevi Formation	Sand, gravel, and boulders	35	35
	Cement gravel	35	70
	Sandstone and cement gravel	50	120
	Gravel, water	5	125
	Clay, sandy, water	45	170
	Gravel, water	4	174
	Sandstone, brown	11	185
	Clay, gravelly, water	15	200
	Clay, gravelly	37	237
	Gravel, water	5	242
	Clay, gravelly	8	250

facies of the Muddy Creek Formation about 1 mile east of the mouth of Detrital Wash. The gypsiferous conglomerate is composed of fragments of crystalline rocks as large as pebble size set in a fibrous interwoven mesh of gypsum crystals. The gypsum probably was derived from erosion of the bedded gypsum to the east and probably was recrystallized after its deposition. The solution of reworked gypsiferous detritus may cause the water to be of poor chemical quality in the Chemehuevi Formation in other areas. (See table 4, well (B-30-20)6bdd.)

Between Temple Bar and the White Hills, the Chemehuevi Formation is a light-reddish-brown silty gravel to silt and may be as much as 100 feet thick. At Temple Bar the lower part is mainly silt and siltstone and rests on the limestone facies of the Muddy Creek Formation; the Chemehuevi grades upward into a light-grayish-brown weakly consolidated gravel bed that is 20 to 25 feet thick. The grayish-brown gravel that caps the formation includes as much as 10 feet of terrace gravel. Southwest of Temple Bar, the Chemehuevi is coarser and contains basalt boulders as much as 1 foot in diameter, and the light-grayish-brown gravel is not as evident as it is at Temple Bar. In the area of this report the Chemehuevi Formation generally is finer grained than the Chemehuevi south of Hoover Dam (Bentley, 1969; 1970; 1971).

The Chemehuevi Formation unconformably overlies the older alluvium and the Muddy Creek Formation and is capped by as much as

10 feet of terrace gravel. West of Detrital Wash, the thin cap of terrace gravel obscures the contact between the Chemehuevi Formation and the older alluvium.

In most places the Chemehuevi Formation is flat lying and undeformed; along the east side of Detrital Wash north of Temple Bar road, however, the formation has been faulted and folded and is in fault contact with the older alluvium in several places. Near Temple Bar, the Chemehuevi Formation and older units form a south-plunging syncline.

Although the Chemehuevi Formation is fine grained in the area of this report, it is capable of yielding moderate amounts of water to wells. During a pumping test run on June 21, 1967, well (B-31-19)32ada (unsurveyed), the principal well at Temple Bar, was reported to yield 300 gpm (0.67 cubic foot per second) from the Chemehuevi Formation; a transmissivity value of 20,000 gallons per day per foot (2,670 feet squared per day) was reported at the time of the test (table 3).

Terrace Gravel

Thin deposits of terrace gravel of Quaternary age are common throughout the study area. Generally, the gravel is less than 10 feet thick and is a practical mapping unit only in the area east of Detrital Wash. Elsewhere, the terrace gravel is mapped as part of the underlying unit. In a large undissected area along the Temple Bar road east

of Detrital Wash as much as 15 feet of terrace gravel was deposited on a surface cut on the Muddy Creek Formation. The gravel is of local origin, light grayish brown, very weakly cemented, and coarse grained and is made up of subangular granitic, metamorphic, and volcanic-rock detritus. The largest fragments in the detritus are vesicular basalt boulders as much as 2 feet in diameter. In many places dense caliche as much as 5 feet thick is present near the surface; the surface generally is covered by cobbles and basalt boulders, which are coated with black to dark-brown desert varnish, and smaller jagged and pitted fragments of tan caliche. The unit is above the zone of saturation in most of the area and, thus, is of little hydrologic significance.

Younger Alluvium

The younger alluvium of Quaternary age is exposed in stream channels and on flood plains and alluvial slopes. The unit consists of pale-brown unconsolidated and undeformed sand and gravel of local origin. The younger alluvium is less than 50 feet thick in most places but may be as much as 75 feet thick along parts of Detrital Wash.

The younger alluvium is above the zone of saturation in most of the area; near the mouth of Detrital Wash, however, the unit may store a small amount of water. The younger alluvium may yield small quantities of water to wells in the major washes where it is a few tens of

feet thick and underlain by impermeable rocks. The younger alluvium also is important hydrologically in that it transmits streamflow to underlying deposits.

HYDROLOGY

All the streams in the Lake Mead National Recreation Area are ephemeral, except the Colorado River. Because the amount of precipitation that falls on the area is small and the evaporation rate is large—more than 20 times the amount of annual precipitation—most of the precipitation evaporates soon after it reaches the ground, or it is transpired by vegetation. The streamflow in the small drainage basins in the Lake Mead area is meager and extremely variable. Flow occurs only about once a year in any one drainage (Bentley, 1971, p. 18), and only a small amount of water is available for recharge to the groundwater system.

Movement and Occurrence of Ground Water

Lake Mead is the principal control on the movement and occurrence of ground water in the report area. The volume of ground water contributed by the lake is much greater than that contributed by the basins that surround the lake, although in terms of potential groundwater development the deposits saturated by the lake water probably

extend less than 1 mile from the lake. In the permeable rock units near the lake, however, the infiltrating lake water raises the level of saturation and lowers the ground-water gradient, thus extending the effect of the lake a greater distance. The water level in the saturated deposits near the lake varies in response to changes in lake level. When the lake level rises, lake water recharges the adjacent permeable deposits; when the lake level declines, ground water discharges to the lake. The general ground-water movement is toward the lake and westward and southward parallel to the Colorado River.

Springs

In the report area the only known permanent springs above the level of Lake Mead are those described by Bentley (1971, p. 23) in the area half a mile to 5 miles south of Hoover Dam. Southeast of Wilson Ridge outside the boundary of the Lake Mead National Recreation Area, two small springs issue from the granitic and metamorphic rocks (fig. 2). When visited by the author on February 18, 1972, spring (B-30-22)13ad (unsurveyed) was discharging 0.3 gpm of good-quality water (tables 3 and 4).

Monkey Cove Spring (fig. 2) is a large spring in Trail Rapids Bay west of Temple Bar; the spring was covered by Lake Mead during this investigation, and the exact location could not be determined;

however, it is near the mouth of Temple Bar Wash between the altitude of the January 1972 lake level—which was 1,160 feet above mean sea level—and the altitude of the November 1964 lake level—which was 1,089 feet above mean sea level when the spring was sampled for chemical analysis (tables 3 and 4). The spring is reported to flow at a rate of 1,200 gpm (table 3). Lake Mead was at low level in the middle 1960's when construction work on the Temple Bar Boat Anchorage was hampered by bank seepage, and other seeps were noted about 0.3 mile west of the boat anchorage (C. L. Keele, National Park Service, oral commun., 1972). These seeps indicate that Temple Bar is an area of natural ground-water discharge. Ground water that moves northward parallel to Temple Bar Wash is forced to the surface by the synclinal structure near Temple Bar (fig. 2). The southward-dipping silt and siltstone beds in the lower part of the Chemehuevi Formation (table 2) are low in permeability and may act as a barrier to the horizontal movement of ground water.

Wells

Four wells have been drilled at Temple Bar, one of which has been abandoned. The three wells used for public supply obtain their water from the Chemehuevi Formation (tables 2 and 3). Well (B-31-19)32ada (unsurveyed), which furnishes the main water supply

at Temple Bar, is 200 feet deep; the two auxillary wells at Temple Bar—wells (B-31-19)33acc1 and (B-31-19)33acc2 (unsurveyed)—are 183 and 250 feet deep, respectively. An aquifer test made on June 21, 1967, at the principal well indicated a yield of 300 gpm with 45 feet of drawdown; the test indicated that the transmissivity was 20,000 gallons per day per foot or 2,670 feet squared per day (E. S. Davidson, U.S. Geological Survey, written commun., 1967). At the present time (1972), the principal well furnishes about 185 gpm of water to Temple Bar except during peak usage, when the yield may decrease to 50 gpm; the auxillary wells yield smaller amounts of water than the principal well and are used as backup supplies during peak usage.

C. L. Keele (National Park Service, oral commun., 1972) reports that well (B-30-20)6bdd (unsurveyed) in Detrital Wash at the Temple Bar road yields 70 gpm of water, probably from the Chemehuevi Formation; however, the water contains 1,150 mg/l (milligrams per liter) dissolved solids (tables 3 and 4). In Detrital Valley 1 to 9 miles south of well (B-30-20)6bdd (unsurveyed) 15 test wells were drilled at depths ranging from 185 to 1,392 feet below land surface. The wells were drilled into a 30- to 437-foot-thick sequence of permeable silt, sand, and gravel that overlies the fine-grained beds of the Muddy Creek Formation; no water was reported in the test wells, which may indicate that ground water is present along Detrital Wash only near Lake Mead.

Quality of Water

Water samples were collected for chemical analysis from one spring and three wells as a part of this investigation; in addition, four chemical analyses that were made prior to this investigation are included in table 4. Well (B-31-19)32ada (unsurveyed) furnishes most of the water being used for public supply at Temple Bar. The water from this well contains about 500 mg/l dissolved solids, which is the maximum concentration recommended by the U. S. Public Health Service (1962) for drinking water. The dissolved-solids content in the water from this well increased from 436 mg/l in 1967 to 506 mg/l in 1972. Water from Monkey Cove Spring, which is in Trail Rapids Bay north of the principal well and is below the 1972 level of Lake Mead, had a dissolved-solids concentration of 480 mg/l in 1964. At Temple Bar, water from auxillary wells (B-31-19)33acc1 and (B-31-19)33acc2 (unsurveyed) contains 1,000 and 1,710 mg/l dissolved solids, respectively. Two analyses of water from well (B-31-19)33acc1 (unsurveyed) indicate that the dissolved-solids content increased $2\frac{1}{2}$ times from 1957 to 1964. Sodium and sulfate are the main ions in the water from the auxillary wells. The auxillary wells are used only during periods when the demand for water is large. These wells tap the silt and clay of the Chemehuevi Formation and bottom as much as 100 feet below the maximum level of Lake Mead

(table 2). The chemical composition of the water from the auxillary wells is similar to that of the water from Lake Mead, which indicates that the Chemehuevi Formation is recharged by water from the lake in the area of these wells (table 4). The dissolved-solids content of the water in Lake Mead ranges from 600 to 750 mg/l (Irelan, 1971, p. 9). The principal well at Temple Bar yields water of better quality than that of the water in Lake Mead or that of the water from the auxillary wells because the principal well is in a major wash where the Chemehuevi Formation receives more infiltration from streamflow than from Lake Mead.

Water from well (B-30-20)6bdd (unsurveyed) at the Detrital Wash picnic area contains 1,150 mg/l dissolved solids and 470 mg/l sulfate. This water probably is derived from the Chemehuevi Formation and is not recommended for drinking purposes (table 4).

Spring (B-30-22)13ada (unsurveyed) is southeast of Wilson Ridge in the Black Mountains. The spring discharges a small amount of water of good chemical quality from the granitic and metamorphic rocks. Water from this spring contains less than 500 mg/l dissolved solids.

PROPOSALS FOR EXPLORATION

The principal source of ground water in the report area is the permeable rocks adjacent to Lake Mead. Smaller amounts of water

can be developed in the permeable rocks farther from the lake and in less permeable rocks near the lake. In much of the western part of the area and locally in the eastern part the granitic, metamorphic, and volcanic rocks that border the lake generally are fractured sufficiently to allow movement of small amounts of water to wells. Wells drilled in fault zones near the lake may yield small to moderate amounts of water. The younger alluvium may yield small amounts of water to wells drilled in the larger washes where the unit is a few tens of feet thick and is underlain by less permeable rocks; however, these wells may not be dependable sources of water during dry periods. Near Lake Mead, large-diameter wells drilled to shallow depths in the younger alluvium may yield small to moderate quantities of water.

The least favorable areas for developing ground-water supplies are those that are underlain by the mudstone facies of the Muddy Creek Formation. Even in the area near Lake Mead this unit will yield only small amounts of water to wells, and the water probably will contain large amounts of dissolved solids.

Four sites are recommended for future ground-water development in the Lake Mead National Recreation Area between Hoover Dam and Temple Bar. The sites, which are listed in order of decreasing favorability, are south of the lake near Temple Bar (site 1), near the

mouth of Detrital Wash (site 2), northwest of Bonelli Landing (site 3), and northwest of Fortification Hill (site 4). (See figure 2.)

Site 1

In the Temple Bar area additional ground-water supplies may be developed by (1) drilling shallow wells into the Chemehuevi Formation near or along Temple Bar Wash and Trail Rapids Wash, or (2) drilling deeper wells into the Colorado River deposits of the older alluvium. The principal well at Temple Bar—well (B-31-19)32ada (unsurveyed)—is near the mouth of Temple Bar Wash and bottoms 200 feet below the land surface in silt beds of the Chemehuevi Formation. The water from this well is of better chemical quality than the water from the auxillary wells or than the water from Lake Mead (table 4) because the Chemehuevi Formation penetrated by the principal well receives much of its recharge from the infiltration of streamflow in Temple Bar Wash. Shallow wells drilled along or near the wash south of the principal well probably will yield about the same amount of water as the principal well—185 gpm—and small quantities of good-quality water probably can be obtained from shallow wells drilled in the lower reaches of Trail Rapids Wash. The lower reaches of Trail Rapids Wash are underlain by volcanic rocks at shallow depths, and these rocks probably will not yield more than about 5 gpm of water to wells. Wells that are drilled in Trail Rapids Wash

should be located south of the exposures of volcanic rocks, where the Chemehuevi Formation underlies the younger alluvium. The auxillary wells at Temple Bar—wells (B-31-19)33acc1 and (B-31-19)33acc2 (unsurveyed)—are 0.6 mile east of the principal well (fig. 2). Although the auxillary wells bottom in the Chemehuevi Formation, the water is of poorer quality than that from the Chemehuevi at the principal well. In the area of the auxillary wells the Chemehuevi Formation probably receives most of its recharge from infiltration from Lake Mead, and the dissolved-solids content of the water from the wells is greater than that of the water in Lake Mead because of the solution of salts in the Chemehuevi. In the Temple Bar area wells that penetrate the fine-grained deposits of the Chemehuevi Formation probably will yield poor-quality water except along the major washes.

In the Temple Bar area moderate to large quantities of ground water probably can be obtained by drilling wells to depths greater than those of the existing wells or by deepening the existing wells. The volcanic rocks, limestone facies of the Muddy Creek Formation, Colorado River deposits of the older alluvium, and the Chemehuevi Formation are folded into a southwest-plunging syncline, and the trace of its axial plane trends southwest through Temple Bar (fig. 2). The Colorado River deposits of the older alluvium are exposed along the east flank of the syncline and in places along the west flank. The porous weakly cemented

gravel of the Colorado River deposits involved in the folding may be present below the Chemehuevi Formation at depths of as much as 500 feet below the land surface. The Colorado River deposits will yield moderate to large quantities of water to wells. Although no chemical-quality data are available for water in these deposits, the unit probably receives its recharge by infiltration from Lake Mead, and the ground water probably contains about the same amount of dissolved solids as the lake water. The most favorable location for wells in the Colorado River deposits is near Lake Mead in the area about half a mile east and west of Temple Bar. Wells should be drilled to the limestone facies of the Muddy Creek Formation, which underlies the Colorado River deposits and is exposed on the arm that projects into the lake north of the Temple Bar Boat Anchorage (fig. 2).

Site 2

Shallow wells drilled in Detrital Wash between Lake Mead and the Temple Bar road may yield moderate quantities of water. The aquifers in this area are the Chemehuevi Formation and the younger alluvium. The Chemehuevi Formation is as much as 125 feet thick 1.2 miles southwest of the Detrital Wash picnic area (table 1, well (B-30-21)12adc). Although water in the well at the Detrital Wash picnic area contains more than 1,100 mg/l dissolved solids (table 4), the

water from wells drilled adjacent to the lake may be of better chemical quality; prior to drilling a production well, one or more test holes should be drilled to verify this evaluation. Lake water that infiltrates into the Chemehuevi Formation or younger alluvium will have a dissolved-solids content of between 600 and 750 mg/l. The most favorable location for drilling is along the west side of Detrital Wash. Wells drilled along the west side of Detrital Wash should not extend below the top of the bedded gypsum in the mudstone facies of the Muddy Creek Formation, which underlies the Chemehuevi Formation at a depth of about 160 feet. Limestone that may be part of the Muddy Creek Formation is exposed in places in a structurally disturbed zone along the east side of the wash between Temple Bar road and Lake Mead, and, if the limestone is part of the Muddy Creek Formation, gypsiferous mudstone probably is present at shallow depths.

Site 3

The Chemehuevi Formation is recharged by infiltration from Lake Mead about 2 miles northwest of Bonelli Landing. About 60 feet of interbedded fine-grained sand and gravel of the formation is exposed, and the deposits extended below the level of Lake Mead (1, 160 feet above mean sea level) when the area was visited by the author in January 1972. Wells should be as close to maximum lake level—1, 221 feet above mean

sea level—as possible and should be drilled to the top of the mudstone facies of the Muddy Creek Formation, which probably will be penetrated at a depth of about 75 feet.

Site 4

Shallow wells drilled in the local gravel unit of the older alluvium near Lake Mead northwest of Fortification Hill may yield as much as 50 gpm of water; the chemical quality of the water will be similar to that of the lake water. In this area the older alluvium is as much as 100 feet thick and consists of weakly cemented sandy gravel that includes boulders as much as 4 feet in diameter. The unit is capped by as much as 5 feet of hard siliceous caliche, which may impede the infiltration of water from Lake Mead. The conglomerate facies of the Muddy Creek Formation underlies the older alluvium to the southwest; if this unit underlies the entire outcrop of older alluvium, additional ground-water storage is available. Test drilling will be required to fully evaluate the potential for ground-water development in this area.

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