WATER WELL SITING INVESTIGATION
WEST OF CALLVILLE BAY
LAKE MEAD NATIONAL RECREATION AREA
NEVADA

Terracon

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NEVADA

for: National Park Service

Project No. 64947206

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1.0 INTRODUCTION

The National Park Service (NPS) is assessing the feasibility of using groundwater as a public water supply source at Callville Bay Marina, in the Lake Mead National Recreation Area (LMNRA) of Nevada and Arizona. LMNRA receives over 8 million visitors a year and the potable water demands are increasing rapidly. The purpose of this project is to provide the NPS with information regarding the anticipated quantity and quality of potable groundwater available in this area. As part of the study, Terracon's is evaluating aquifer yield potential and water quality relative to standards set forth in the Safe Drinking Water Act.

Although the lake water has acceptable mineral quality, it contains microorganisms regulated by the USEPA Surface Water Treatment Rule. It is possible that filtration of lake water by aquifer materials could result in water not subject to this treatment requirement. However, groundwater recharge by lake water can result in excessive mineral concentrations due to the presence of sulfate and other soluble salts in the sediments. Accordingly, the overall exploration target is a well site with sufficient yield to meet water demand, acceptable mineral quality, and sufficient filtration to remove microorganisms. Laney and Bales (in progress) described the peninsula located west of Callville Bay as a likely location for a groundwater exploration well. The purpose of the investigation reported on herein is to map the principal geologic units present in the peninsula for the purpose of selecting a preferred test drilling location. Geophysical surveying was originally proposed but the geologic mapping indicates insufficient velocity or resistivity contrasts between the target aquifer unit and the underlying (unacceptable) strata. Therefore, geophysical surveys were deleted from the scope of the investigation.

Presently, water is pumped from the lake for public use. In the future, this water must undergo treatment to remove microorganisms prior to use. It is expected that a successful well would provide potable water not requiring filtration. Previous attempts to develop potable water supply wells in the LMNRA have been largely unsuccessful due to siting in mineralized strata or poor well construction. Should the present effort prove successful at Callville Bay, it may have application to other marinas within the LMNRA.

1.1 Location of Study Area

The study area is located within Sections 16, 17, 20 and 21, Township 21 South, Range 65 East, M.D.B.M. in Clark County, Nevada. The study site was located on a peninsula situated

between Water Barge Cove and Swallow Bay, in an area generally southwest of Callville Bay. The peninsula extends north to south approximately one mile and east to west a maximum of one-half mile. A graded gravel roadway constructed by the NPS provides access from the Callville Bay campground to the eastern portion of the peninsula. The roadway leads to the present NPS surface water supply source which is a barge-mounted pump located approximately 150 feet out from the shoreline. The location of the study area is depicted in Figure 1 (Appendix A) which is a portion of the U.S. Geological Survey 7.5 minute series topographical maps, "Callville Bay, Nev.-Ariz.", Provisional Edition 1983 and "Hoover Dam, Nev.-Ariz.", Provisional Edition 1983.

1.2 Previous Work

A series of hydrogeologic reconnaissance reports have been prepared by the U.S. Geological Survey, in cooperation with the NPS, for the LMNRA including both Lake Mead and Lake Mohave. Laney and Bales (in progress) prepared a geohydrologic reconnaissance report of Las Vegas Wash to Virgin River, Nevada, which is a portion of the LMNRA. This report is the last in the series of U.S. Geological Survey hydrogeologic reports for the LMNRA. Previous hydrogeologic reports for the LMNRA have been prepared by Bales and Laney (1992), Laney (1982, 1979a, 1979b, and 1979c), and Bentley (1979a, 1979b, and 1979c). The report by Laney and Bales (in progress) identified the (lake) water-saturated gravels on the peninsula west of Callville Bay as an area with potential for groundwater development. According to Laney and Bales (1992) the largest potential source of water in the LMNRA is from (lake) water-saturated sediments. Other potential sources of groundwater include groundwater in local basins, groundwater related to perennial streams, and springs in the Muddy Mountains. These sources may have deteriorated water quality relative to the (lake) water-saturated sediments. Additionally, there could be substantial costs with transmission and power supply. In the case of spring development, there could be additional, adverse effects on wildlife.

2.0 OBJECTIVES

Exploration for a potable water supply well will include the following:

- Geologic Reconnaissance;
- Exploration Well Drilling; and
- Lithologic Logging, Aquifer Testing, and Laboratory Testing.

Favored well site locations are near the lake shore and above the high water level at the southern portion of the peninsula. Preferred aquifer materials include older alluvial gravels and coarse-grained, ancestral Colorado River deposits. Permeable sediments with low concentrations of gypsum and other soluble minerals are of interest. The sediments may filter out microorganisms present in the lake water. This report describes the geologic reconnaissance and provides recommendations for further work.

The original Scope of Work called for use of both surficial geologic mapping and seismic geophysical techniques to select a test well location. The scope was modified to delete the geophysical surveys because of unsuitable subsurface conditions and, instead, add construction of a second exploration well.

3.0 GEOLOGIC RECONNAISSANCE

For both geologic and logistical reasons, the exploration area was limited to the peninsula west of Callville Bay. Considerations included drill-site accessibility, presence of coarse grained deposits, and proximity to recharge by lake water. Because of reduced circulation and attendant potentially higher microorganism populations at the north ends of Swallow Bay and Water Barge Cove, the well location search was further restricted to the central and southern portions of the peninsula near the open waters of the lake. An existing roadway constructed by the NPS provided access to part of the peninsula. Coarse grained older alluvial deposits were mapped by Laney and Bales (in progress) on the eastern portion of the peninsula. Although the extensive shoreline suggests a wide selection of potential drilling sites, access by drilling equipment and support vehicles is limited to selected areas unless there is substantial development of access roads and drilling pads. Such development has obvious cost and aesthetic drawbacks.

3.1 Site Geology

In ascending order, the principal geologic units in the peninsula area include the Horse Spring Formation, the Older Alluvium, and the Younger Alluvium. Of these, only the Older Alluvium units are of interest because they have the potential for favorable permeability, acceptable water quality, and sufficient saturation. The general occurrence of theses units in the peninsula area is shown in Figure 2, Appendix A. Basically, the Horse Spring Formation is near lake level at the western side of the peninsula, whereas the Older Alluvium occurs beneath most of the remainder of the peninsula. The Younger Alluvium is not mapped

because it is a very thin unit in the present-day washes and of no hydrologic significance relative to the purpose of the present investigation. Regionally, the lithologic units dip slightly to the east.

The Older Alluvium is divided into two mappable units for the purpose of this report. These are the upper, generally fine-grained, poor to moderately cemented sediments of the Upper Unit of the Older Alluvium (Upper Unit) and cemented gravels of the Older Alluvium (Cemented Gravels). Both the Upper Unit and the Cemented Gravel Units dip gently to the east. Additionally, the cemented Gravels have been gently folded. Regionally the lithologic units dip slightly to the east. The Horse Spring strata are generally folded. A discussion of the geologic units observed in the field area is presented in the following sections.

3.1.1 Younger Alluvium and Cemented Alluvium

The younger alluvium consisted of silty sandy gravels, present in the base of the drainage washes. The thickness appeared to range from a thin veneer to an estimated 10 feet in the base of the main drainage wash. Because of limited areal extent and thickness and primarily because the unit is unsaturated, it was not separately mapped in this investigation.

Cemented alluvium capped the ridges in the field area (Photograph P-1, Appendix B). This carbonate-cemented alluvium generally consisted of silty sand and carbonate gravels and cobbles, with a trace amount of metamorphic gravels, chert, and basaltic lag boulders. The lag boulders were apparently of local origin, based on proximity to Callville Mesa. The cemented cap appeared to conformably overlie the Upper Unit and the cemented gravel unit in the north half of the study area.

3.1.2 Older Alluvium

Laney and Bales (in progress) in their hydrogeologic reconnaissance report, observed that Older Alluvium is divided into two units, the Upper and the Lower Unit. The two units were not continuous throughout the field area; therefore, the Upper and Lower Unit were mapped together as Older Alluvium. The Lower Unit was described as generally well cemented and coarser grained whereas the Upper Unit was characterized as having a higher percentage of fine grained material such as silts and sands.

During the field reconnaissance, the upper fine grained unit was identified and an overlying, well cemented gravel was also identified. Based on observed field relationships, the Cemented Gravels may: a) overlie the Upper Unit, b) be a facies of the Upper Unit, or c) be a fault contact. The relationship of the Cemented Gravels to the underlying Upper Unit is not well understood in terms of structural or stratigraphic relationships, but probably represents an erosional disconformity. Because of the significance of the Cemented Gravels as an exploration well target area, they were mapped separately.

The clasts observed in both of the mappable units were generally of the same composition, except that clasts in the Upper Unit appeared to be larger (boulders and cobbles) than those in the Cemented Gravel Unit (gravels). The Upper Unit and the Cemented Gravel Unit are described separately in the following sections.

3.1.2.1 Upper Unit

The Upper Unit generally trends north 50 degrees east and dips to the east approximately 5 degrees. This unit typically formed tan-colored vertical cliffs due to undercutting wave action in the beach zone (Photographs P-1 and P-2, Appendix B). At the cliff face on the southwestern end of the peninsula, steeper dips were observed in connection with an apparent high angle fault. This fault appeared to have only a minor amount of displacement which apparently occurred prior to and during the deposition of the upper portion of the Upper Unit. The Upper Unit consists of interbedded silt, silty sands with gravels, cobbles, boulders, and thin gravel layers. The clasts consisted of angular to subangular boulders and subangular to subrounded cobbles of carbonates, intermediate intrusives, schists, rounded river cobbles, a minor amount of red sandstone, and trace amounts of red and black chert. This unit was generally poorly cemented with occasional moderately cemented layers. Rounded river cobbles were concentrated in a layer located in the upper portion of this unit where it crops out along the western cliff face. These river cobbles were also identified in the northeastern portion of the study area along the access road. In the beach zone, large slump blocks consisting of poorly cemented sands with gravels had developed due to undercutting wave action.

According to Laney and Bales (in progress), the Upper Unit has a high gypsum content, and is generally fine grained.

3.1.2.2 Cemented Gravel Unit

The Cemented Gravel Unit was observed in the eastern portion of the peninsula where it consisted of moderate to well cemented gravels (Photograph P-1, Appendix B). Clasts consisted of subrounded to subangular carbonates, intermediate intrusives, red sandstone, river cobbles, minor quantities of red and black chert, and schist. The unit was fractured. In Large slump blocks of cemented gravels characteristically developed due to undercutting wave action (Photograph P-1, Appendix B).

Strikes measured on the beds at the southern portion ranged between North 30 degrees West and North 22 degrees East with shallow (less than 20 degrees) dips to the east or west, respectively (see Figure 2, Appendix A).

According to Laney and Bales (in progress), this unit has low intergranular permeability. Groundwater is likely present within the fractures of this unit; however, the fractures may not provide sufficient filtration of the lake water. A well not intercepting fractures may have low production due to the low, primary permeability of the Cemented Gravels.

3.1.3 Horse Spring Formation

The exposed Horse Spring Formation in the study area consisted of fine grained sands and silts. Principal exposures are at to slightly above lake water level along the west and southwest sides of the peninsula (Photograph P-2, Appendix B). Other exposures are present to the north and in the wash bottoms northeast of the peninsula. The Horse Spring Formation consisted of moderately cemented reddish-orange to tan sand and silt with altered volcanic clasts. This lithology is evident in the exposures on the west-central and southern portions of the peninsula near the present lake level. Beds dip as much as 30 degrees and strikes with various orientations were measured (Figure 2, Appendix A, Photograph P-2, Appendix B). Anticlinal and synclinal structures were inferred from the strike and dip measurements of the silty-sand outcrops along both the western shoreline and the southwestern end of the peninsula (see Figure 3, Appendix A).

The Horse Spring Formation, according to Laney and Bales (in progress) is highly mineralized, and would likely yield less than one gallon per minute of water to a well.

3.2 Structural Interpretation

Two cross sections A-A' and B-B' (Figure 3, Appendix A) illustrate the structural relationships of the described geologic units. Cross Section A-A' was located west to east across the southern portion of the field area. The Upper Unit appears flat-lying in this cross-section. Based on strike and dip measurements, a synclinal structure was identified in the Cemented Gravels. These dips may be due deposition on an inclined surface, (primary) not structural. The depth of the Cemented Gravels below the present level of Lake Mead is unknown. The limbs of the syncline dip about 30 degrees. The contact between the Upper Unit and the Cemented Gravels may represent erosion of the Upper Unit with later deposition of the Cemented Gravels. Based on the regional eastward dip, the maximum thickness of the Cemented Gravels should be at the southeastern end of the peninsula.

The Horse Spring Formation is inferred to underlie both units of the Older Alluvium. The eastward extension of the folded Horse Spring strata under the Cemented Gravels is unknown. Strike and dip measurements indicate that a shallow anticline is located in the Horse Spring Formation. The axis of the anticline trends northwest to southeast.

Cross Section B-B′ is oriented north to south along the western portion of the peninsula. The Upper Unit unconformably overlies the Horse Spring Formation. A syncline with an axis trending northeast-southwest is inferred from strike and dip measurements.

4.0 GEOPHYSICAL SURVEY

Seismic and surface electrical resistivity surveys were originally considered to assist in delineating favorable strata for exploratory drilling. However, results of the Terracon geologic mapping indicated that the seismic survey would probably not provide useful information. Similar seismic velocities were expected in the fine grained, poorly to moderately cemented sediments of the Horse Spring strata and both units of the Older Alluvium. Further, the shallow depth of the Horse Spring-alluvial contact indicated that the Horse Spring Formation would not be a good reflector of seismic energy with the result that the interface of the shallow, permeable strata and the deeper, less permeable and mineralized Horse Spring strata would not be defined.

A surface resistivity survey, although originally considered, was not included in the proposed Scope of Work. Surface resistivity provides an average resistivity of earth materials with

depth. Coarse-grained, presumably more porous and permeable strata would likely have higher resistivity. Saturation of these materials would likely result in a resistivity decrease due to the conductivity of the fluids. Depth to water could be inferred. It was reasoned that there likely was insufficient resistivity contrast between the units identified to be cost effective. The depth to saturated material was, in all likelihood determined by the lake level. For all of these reasons, resistivity was not pursued as a sufficiently diagnostic technique.

5.0 INTERVIEW WITH ROBERT LANEY

Mr. Robert Laney, formerly with the U.S. Geological Survey and a principal investigator on prior geologic and hydrogeologic investigations in the Lake Mead area, was interviewed for information regarding the potential well sites and for his opinion regarding the geologic interpretation of the study area as presented herein. Mr. Laney provided the following:

1) Concurrence with placement of the exploration well sites (Figure 2, Appendix A). The sites appeared to be sufficiently inland to provide microorganism filtration of the lake water, without adding undue TDS concentrations to the water. However, the sites are exploratory only and may not produce usable water quality or flow rates.

2) Agreement that geophysical surveys would likely not provide any usable information based on the nature of the sediments in the field area.

3) Opinion that juxtaposition of the Lower Unit of the Older Alluvium against the Upper Unit may be the result of either depositional history or faulting.

4) Opinion that the fine grained material underlying the Older Alluvium is the Horse Spring Formation.

6.0 PRIOR EXPLORATION WELL

Laney and Bales (in progress) reported on an exploratory water supply well (D-21-65)9dbb, drilled at Callville Bay Marina in 1967. The well was reportedly installed in 178 feet of Older Alluvium and 22 feet of fine-grained deposits of the Horse Spring Formation. A water sample from the well contained 3,700 milligrams per liter (mg/L) of dissolved solids, 1200 mg/L of sulfate and 1,190 mg/L of chloride. The well yield was low and the water quality was well below the drinking water standards in terms of TDS, sulfate, and chloride.

7.0 FINDINGS AND CONCLUSIONS

- Groundwater in the area of investigation is primarily a result of lateral inflow of lake water.

- Lake water reportedly saturates rocks up to one-half mile inland. However, the longer residence time of the water in the gypsiferous rocks and their lower permeability increases the concentrations of total dissolved solids and individual parameters (e.g. sulfate, chloride). Preferred locations for exploratory wells are close to the shore where lake water would be stored in the aquifer materials for a short period of time yet still provide the necessary filtration to remove microorganisms.

- The western portion and the southwestern end of the peninsula are most likely underlain by the fine-grained Tertiary Horse Spring Formation which cropped out at the lake water level (Winter 1994-1995). This formation is expected to yield approximately one gallon per minute of water to wells. The overlying sediments of the Upper Unit, in the western half of the peninsula are unsaturated. Therefore, exploration should focus on other areas of the peninsula where saturated strata overlie the Horse Spring Formation.

- The northeast and northwest ends of the peninsula are surrounded by lake water with minimal circulation as compared to the water adjacent to the southern end of the peninsula. Stagnant water would be expected to have a generally higher microorganism population. Further, the saturated sediments adjacent to the northerly portion of the peninsula appear to be the low permeability Horse Spring Formation. Therefore, the northern portions of the peninsula are not suitable drilling locations because of aquifer material and water quality reasons.

- Based on the geologic reconnaissance conditions, the southeastern portion of the peninsula provides the best opportunity to site an exploration well. Two exploration well locations were selected (Figure 2, Appendix A).

- The southeastern end of the peninsula has the thickest section of saturated gravel deposits. Based on the mapped locations and overall eastward dip of the

peninsula strata, the greatest thickness of saturated gravels is expected in this part of the peninsula. Although the gravels have an inferred low permeability, interconnected fractures within the unit should provide a connection between the lake water and the proposed exploration well. Water sampling results for the test well(s) should indicate whether filtration will be sufficient to remove the microorganisms. Aquifer testing will indicate well yield.

- Seismic surveys would probably not provide useful information based on the lithologic units present and the inferred depth to groundwater. The effort and expense would be better suited to construction of an additional exploration well to increase the probability of favorable well yield and water quality.

- Native American artifacts along the western ridge of the peninsula require archaeologic clearance prior to commencement of drilling or testing. Subsurface conditions indicate a low permeability aquifer. Further, road construction in this area would be costly and cause aesthetic impairment. For these reasons, this portion of the peninsula is generally unsuitable for a test well site.

8.0 RECOMMENDATIONS

- Drill an exploratory well at the southeastern end of the peninsula in the Cemented Gravels of the Older Alluvium (Figure 2, Appendix A). If fine grained sediments of the Horse Spring Formation are encountered, drilling should be terminated.

- In lieu of seismic surveys, install a second test well on the southeastern portion of the peninsula.

9.0 CLOSURE

This non-intrusive assessment relied upon readily accessible information and was not designed to provide extensive data accumulation or detailed inferences as to the condition of subsurface soils or groundwater. No chemical testing of the soil or water was performed on this property. The scope of work performed will not provide sufficient information to eliminate the possibility of low yield aquifer conditions or water of unacceptable quality. In general,

significantly greater levels of effort, including intrusive sampling, test well construction, and analytical testing, would be required to approach this type of result.

This report, prepared for the exclusive use of the National Park Service for specific application to the project as discussed herein, has been prepared in accordance with generally accepted hydrogeology practices within the constraints of the client's directives. No warranties, either expressed or implied, are made or intended.

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Contour interval 20 meters, underwater contour interval 10 meters.

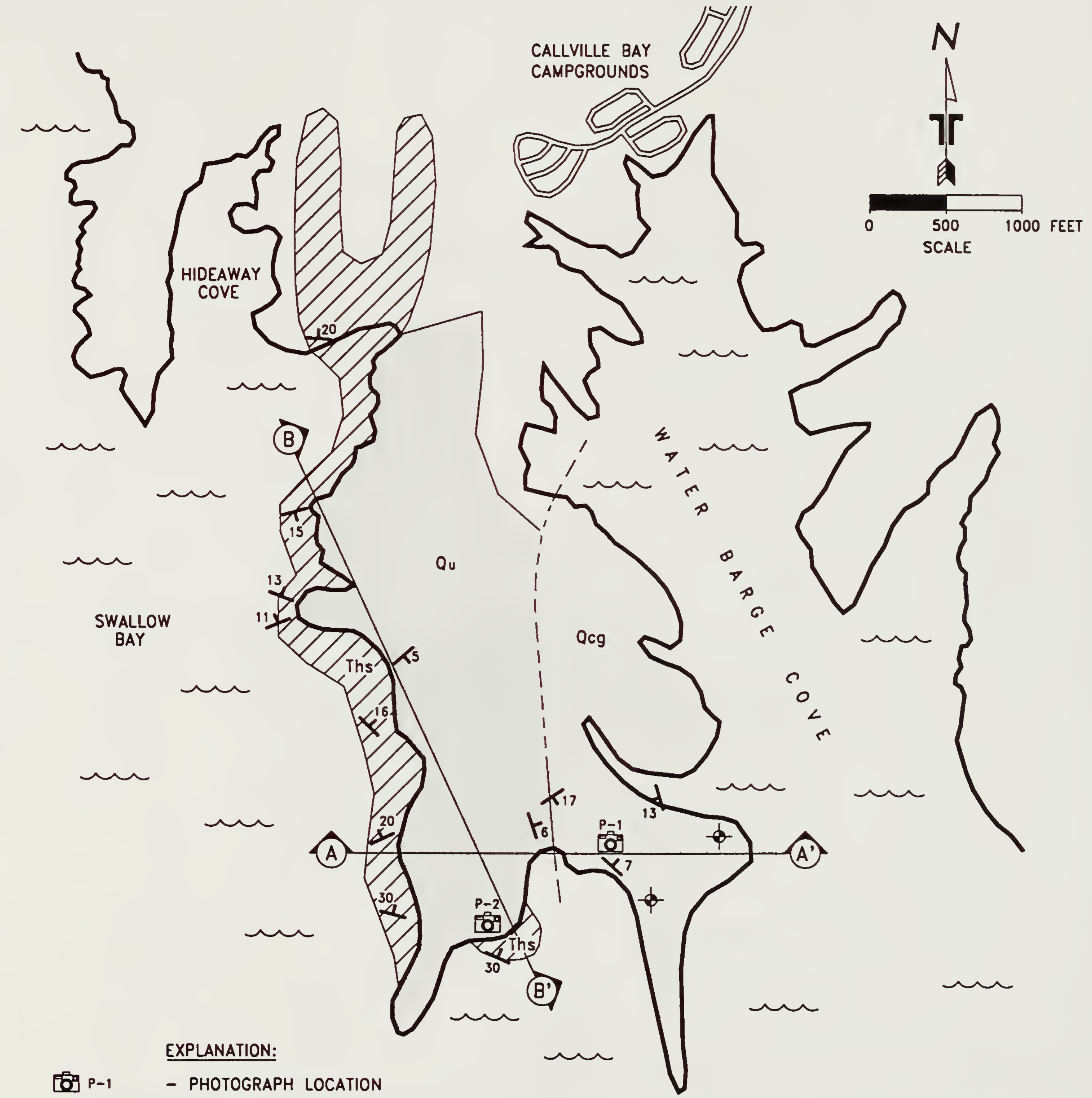
N

1 1/2 0 1 MILE

1 .5 0 1 KILOMETER

U.S.G.S. 7 1/2 Quodrangle Maps "Hoover Dam, Nev.–Ariz." and "Callville Bay, Nev.–Ariz."

CLIENT: NATIONAL PARK SERVICE	Terracon	LOCATION MAP
PROJECT: GEOLOGIC RECONNAISSANCE		PROJECT NO.: 64947206 / FIGURE: 1



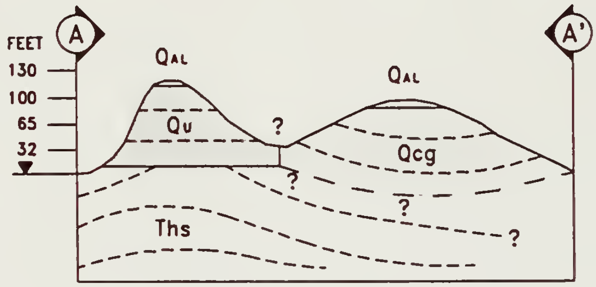
EXPLANATION:

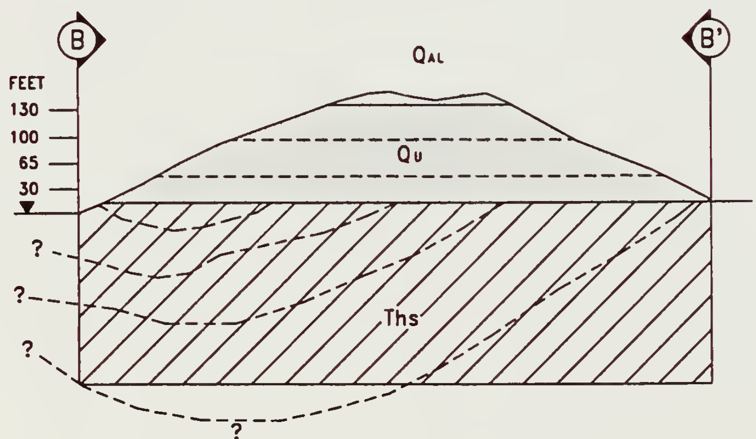
- P-1 – PHOTOGRAPH LOCATION
- – PROPOSED EXPLORATION WELL LOCATION
- 30 – STRIKE AND DIP OF BEDS
- – APPROXIMATE LOCATION OF CONTACT DASHED WHERE INFERRED
- A — A – LOCATION OF CROSS SECTION
- – WATER

LITHOLOGIC UNITS:

- Qu – QUATERNARY-TERTIARY UPPER OLDER ALLUVIUM
- Qcg – CEMENTED GRAVEL OLDER ALLUVIUM
- Ths – TERTIARY HORSE SPRING FORMATION

CLIENT: NATIONAL PARK SERVICE	Terracon	SITE DIAGRAM
PROJECT: GEOLOGIC RECONNAISSANCE		PROJECT NO.: 64947206 — FIGURE: 2





LITHOLOGIC UNITS:

- QAL – QUATERNARY ALLUVIUM
- Qu – QUATERNARY–TERTIARY UPPER UNIT OLDER ALLUVIUM
- Qcg – CEMENTED GRAVELS OLDER ALLUVIUM
- Ths – TERTIARY HORSE SPRING FORMATION
- — — — ——— – APPROXIMATE LOCATION OF CONTACT DASHED WHERE INFERRED
- - - - - - - - - - – BEDDING PLANES

VERTICAL SCALE: 5 X EXAGGERATION

HORIZONTAL SCALE: 1 INCH = 1000 FEET

CLIENT: NATIONAL PARK SERVICE	Terracon	CROSS SECTIONS
PROJECT: GEOLOGIC RECONNAISSANCE		PROJECT NO.: 64947206 · FIGURE: 3

Photograph P-1

Photo view to the west. Cemented Gravels (Qcg) are shown in the foreground. The tan Upper Unit of the Older Alluvium (Qu) is shown in the background. A cemented alluvial cap (Qal) overlies the upper unit. Photograph location shown on Figure 2.

CLIENT: NATIONAL PARK SERVICE	Terracon	PHOTOGRAPHIC RECORD	
PROJECT: GEOLOGIC RECONNAISSANCE		PROJECT NO.: 64947206	APPENDIX: B-1

Photograph P-2

Photo view to the north.
East dipping Horse Spring Formation in the foreground overlain by light colored colluvial materials from the Upper Unit of the Older Alluvium.
Photograph location shown on Figure 2.

CLIENT: NATIONAL PARK SERVICE	Terracon	PHOTOGRAPHIC RECORD	
PROJECT: GEOLOGIC RECONNAISSANCE		PROJECT NO.: 64947206	APPENDIX: B-2