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The Hydrogeology of Rose Valley and Little Lake Ranch, Inyo County, California

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Submitted for fulfillment of the thesis requirements for the degree of:

Master of Science in Geology
Hydrogeology Concentration

California State University, Bakersfield

April, 2002

ABSTRACT

Little Lake, located in the southern end of the Rose Valley in the southeastern California desert, has no surface inflow, yet it contains water year round. Since the floor of the Rose Valley receives only 6 inches per year of precipitation and has an annual evapotranspiration of 80 inches, it is unlikely that Little Lake recharge is derived solely from precipitation falling on the valley floor. Also water from the Sierra Nevada and the Coso Range does not genetically resemble water found at Little Lake. However, geochemical evidence does suggest that the water at Little Lake may be derived from aquifers in the adjacent southern Owens Valley to the north. The probable avenues of groundwater transport southward through the Rose Valley may be one or more of the following: the Coso Sand, Coso Lake Beds, or Rhyolite Tuff Members of the Coso Formation; the deposits of the Pleistocene Owens River channel; and the alluvial basin fill derived from the Sierra Nevada Mountains and Coso Range.

Rose Valley narrows to the south near Little Lake. In this area groundwater is conducted to the surface through a network of springs in and around the lake. The valley's southern terminus is Little Lake Gap. Little Lake Gap is an erosional feature carved through igneous and metamorphic basement rocks of the Coso Range by the Pleistocene Owens River. The decrease in thickness and areal extent of the alluvial aquifer(s) in the Little Lake Gap area force south-flowing groundwater to the surface in the Little Lake area. The resulting springs supply water to the lake and adjacent marshes.

ACKNOWLEDGMENTS

Firstly, I would like to offer a special thanks to my Lord and Savior and best friend Jesus Christ who guided me to Cal State, Bakersfield to learn more about people, geology, and hydrogeology. I would like to acknowledge the following persons for their assistance in making this project a worthwhile endeavor. My sincere thanks goes to Dr. Jan Gillespie for her extreme sacrifice, patience, constructive comments, and many trips out to Little Lake and the Rose Valley. Thanks goes to Dr. Rob Negrini who always encouraged me to stay focused and complete this work. My heartfelt thanks are extended to Dr. Geoff Thyne who taught me a valuable lesson in proofreading my work several times before submitting it to him. Special thanks goes to Jim Ostdick, who helped me in the well head elevation survey and made many constructive comments on the organization of the thesis. Thanks goes to the geology staff at CSUB who taught me how to be a geologist, a critical writer, and a better thinker. I would also like to thank Carie Myer for helping me locate equipment. Special thanks is deserving to my three children, Luke, Tim, and Andrea, who had to sacrifice a great deal while dad was gone to the Rose Valley for many weeks and many hours at the computer typing the thesis. A heartfelt thanks is extended to my wonderful wife Rose, who put up with me and was always gracious in reading my drafts. Her support helped me to make it over the mountain. Special love goes to my five-year-old daughter, Andrea, who allowed me to work on my "pieces." Thanks goes to the people of the Rose Valley and southern Owens Valley who put up with my requests and pestering to gain access to their wells. My gratitude goes to Zona Holt who fed me, encouraged me, and allowed me to lodge in a spare room while I worked on my project in the southern Owens Valley. I would like to thank Mr. Kennedy, REHS and Director Bob Heard, REHS of the Inyo County Environmental Health Department for allowing me to gain access to well logs used in this research. Thanks are in order to Karl Kirschenmann well drilling contractors for giving me data on Dunmovin and Little Lake Hotel wells. Special thanks goes to Larry Jackson of the LADWP for his tireless efforts on trying to remember depths and types of sediments in the Haiwee Reservoir area. I would like to thank Mr. Glenn Singley of the LADWP, Bishop office for working closely with me on this project. My gratitude is extended to Mr. Tim Thompson of Western Water Company who supplied water level data for the southern Owens Valley. Thanks goes to the pastors and friends at my church who prayed with me many times when I felt overwhelmed on the size of the project. I would like to thank the members and officers of Little Lake Ranch for allowing me access on their "Little piece of paradise." Thanks to the members for letting me leave my equipment and flags all over the ranch. Finally, I would like to thank the caretakers of Little Lake Ranch, George and Sheila Salteros, who without the many home-cooked meals and the friendship, this project may have been less colorful. This project has taught me more than geology and hydrogeology, it taught me that desert people are fascinated by geology and groundwater issues and without their help this project would not be completed.

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1.0 Introduction

This investigation describes the geological and hydrogeological characteristics of southern Owens Valley, Rose Valley, Little Lake, and Little Lake Ranch located in the arid high desert of southeastern California (Figure 1). The investigation includes: a description of the study area; a synopsis of the findings of previous workers in the region; a summary of the materials and methods employed in this study; data and discussions about the area's hydrology, lithology, stratigraphy, and aqueous geochemistry; and a soil survey/hydraulic conductivity analysis of the surface sediments of Little Lake Ranch located in the southern Rose Valley. Two final sections summarize the author's conclusions and offer recommendations for further investigations. Appendices of important related information and a pocket containing five map plates are attached to the end of the report.

1.1 Statement of the Problem

Many previous workers have studied groundwater in both the Owens and the Indian Wells Valleys (Danskin, 1988; Dutcher and Moyle Jr., 1973; Thyne et al., 1999), but there has been comparatively little study of the hydrogeology of Rose Valley which separates the Owens and Indian Wells groundwater basins. Critical environmental issues arising from lowered groundwater tables to the north of the study area in the adjacent Owens Valley may soon stir interest in Rose Valley's groundwater. Although Rose Valley is small and unpopulated, it contains permeable formations that may connect the larger alluvial aquifer in Owens Valley with the equally large Indian Wells Valley alluvial aquifer to the south. A key piece to this puzzle is Little Lake that lies in the southern end of the Rose Valley. Little Lake has formed in the past 5,000 years (Mehringer and Sheppard, 1978). Duffield and Smith (1978) attribute the formation of Little Lake as a result of the damming of groundwater by

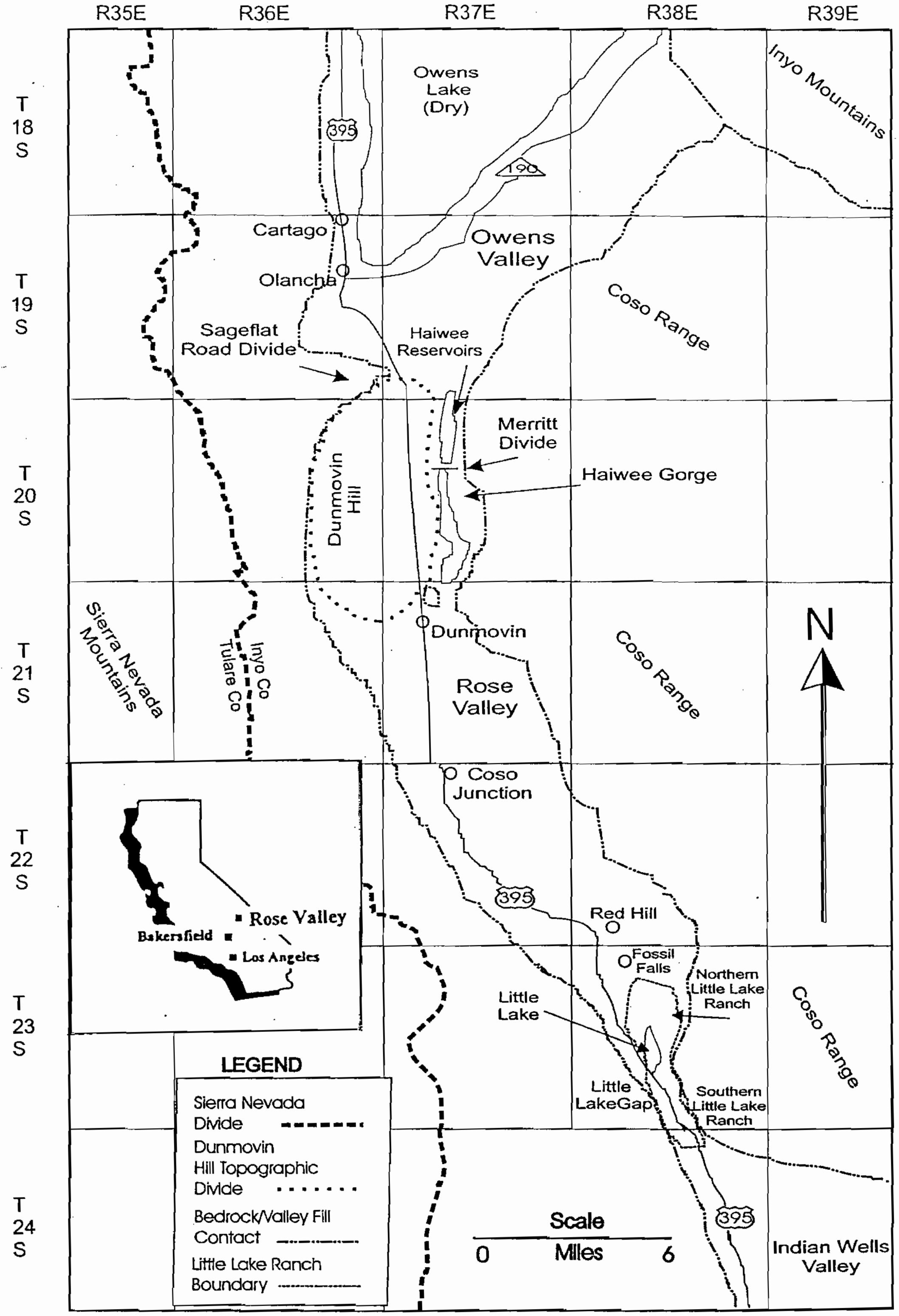


Figure 1. Location of Rose Valley and Little Lake Ranch, Inyo County, California.

coalescing alluvial fan deposits of the Sierra Nevada and Coso Range from the west and the east respectively, to form a dam south of the lake. However, these authors did not address either the source or destination of groundwater that is found at Little Lake. Recent geophysical data suggests that Little Lake may be dammed by either a buried basalt flow or granitic bedrock structure that is acting as a subsurface dam, slowing groundwater flow to the south into the Indian Wells Valley (Thompsett, et al., 1997). There have been virtually no studies concerning the origin of groundwater supplying Rose Valley and Little Lake.

1.2 Purpose and Scope of this Study

The main objectives of this study are to assess the hydrogeologic mechanisms responsible for the presence of Little Lake in the southern end of the Rose Valley, and to characterize the role of the Rose Valley aquifer in the regional hydrologic system. These problems are addressed by four primary means: 1) hydrological measurements and field observations; 2) analysis of regional, lithological, and stratigraphic data to identify potential porous and permeable aquifer materials; 3) a geochemical analysis of water samples from the southern Owens Valley, Rose Valley, Coso Range, and Little Lake to investigate possible groundwater flowpaths; and 4) a soils analysis of Little Lake Ranch to characterize both physical properties and the hydraulic conductivity of the shallow sediments in this portion of the study area.

1.3 Location of the Study Area

Rose Valley and Little Lake are located in Inyo County, California, at latitude 35° 57' N, longitude 117 ° 54' W, near the western boundary of the Basin and Range geomorphic province (Figure 1). Rose Valley, a southern extension of Owens Valley, lies approximately 125 miles northeast of Bakersfield and 140 miles north of Los Angeles. Rose Valley is bounded by the Sierra Nevada to the west, the Coso Range to the east, Owens Valley to the north, and Indian Wells Valley to the south (Figure 1). Little Lake Ranch is located in the southern Rose Valley and the northwestern Indian Wells Valley, and is divided into a northern and southern portion with Little Lake Gap being the dividing line (Figure 1). The elevation of Rose Valley ranges from 4,800 feet at Dunmovin Hill, in northern Rose Valley, to 3,000 feet at Little Lake Gap, south of Little Lake in the southern part of the valley. The total area of the Rose Valley from Merritt Divide in the north, located east of Dunmovin Hill, south to Little Lake Gap, is approximately 175 square miles (Figure 1). The southern Owens Valley portion of the study area is located from Merritt Divide north to Cartago, and extends from the base of the Sierra Nevada east to the base of the Inyo Mountains.

2.0 Previous Studies

2.1 Geologic Overview - Structural Geology

The Basin and Range physiographic province is composed of extensional fault-bounded mountain ranges with intervening, down-dropped valleys which generally trend in a north-south direction. The Sierra Nevada is the westernmost block of these mountain ranges, separating the Basin and Range from California's Great Valley geomorphic province. The Sierra Nevada forms the structural boundary on the west side of both the southern Owens and Rose Valleys, while the Inyo Mountains in the southern Owens Valley and the Coso Range in the Rose Valley provide the structural boundaries to the east (Figure 1). These two combined valleys form the major structural depression between the aforementioned mountain ranges.

The Owens Valley is a major structural depression within the Inyo-Mono block of the Walker Lane belt (Stewart, 1988). The Walker Lane belt is a 63- to 190-mile-wide by about

450 miles long structural zone, located along the western edge of the Basin and Range geomorphic province (Beanland and Clark, 1994). This belt is marked by normal and strike-slip faulting and diverse topography (Beanland and Clark, 1994). Rose Valley is the southern extension of the Owens Valley and is also within the Walker Lane belt.

The major faults in the study area include the southern part of the Owens Valley fault, the Sierra Nevada frontal fault zone, an unnamed fault in the eastern Rose Valley, here referred to as the Rose Valley fault, and the Little Lake fault located in the Little Lake Gap area of southern Rose Valley and northwestern Indian Wells Valley (Figure 2). Other faults bordering the northeastern portion of Rose Valley occur on Haiwee Ridge and in the Coso Range (Figure 3) (Stinson, 1977).

The Owens Valley fault is a 63-mile long right-lateral strike-slip fault with a subordinate normal fault component (Beanland and Clark, 1994). This fault follows the floor of the Owens Valley from beneath Owens Dry Lake north beyond Big Pine, and has an overall strike of 340° and a dip of 80° ± 15° ENE (Beanland and Clark, 1994 and Jennings, 1994). Vittori et al. (1993) places the south end of the fault at the south edge of the Owens Lake playa, based on offset of Holocene shorelines. Total vertical displacement across the Owens Valley fault zone, as assessed from gravity data, is 8,025 feet, east side down, at Owens Dry Lake (Hollett et al., 1991). The Owens Valley fault offsets Holocene deposits and was active as recently as 1872 (Hart et al., 1989). The strike-slip component of displacement along this fault in the 1872 earthquake averaged approximately 6.0 m while the normal displacement (predominately down-to-the-east) averaged approximately 1.0 m (Beanland and Clark, 1994). The late Quaternary slip-rate of the Owens Valley fault is believed to be 3 mm/yr (Hart et al., 1989).

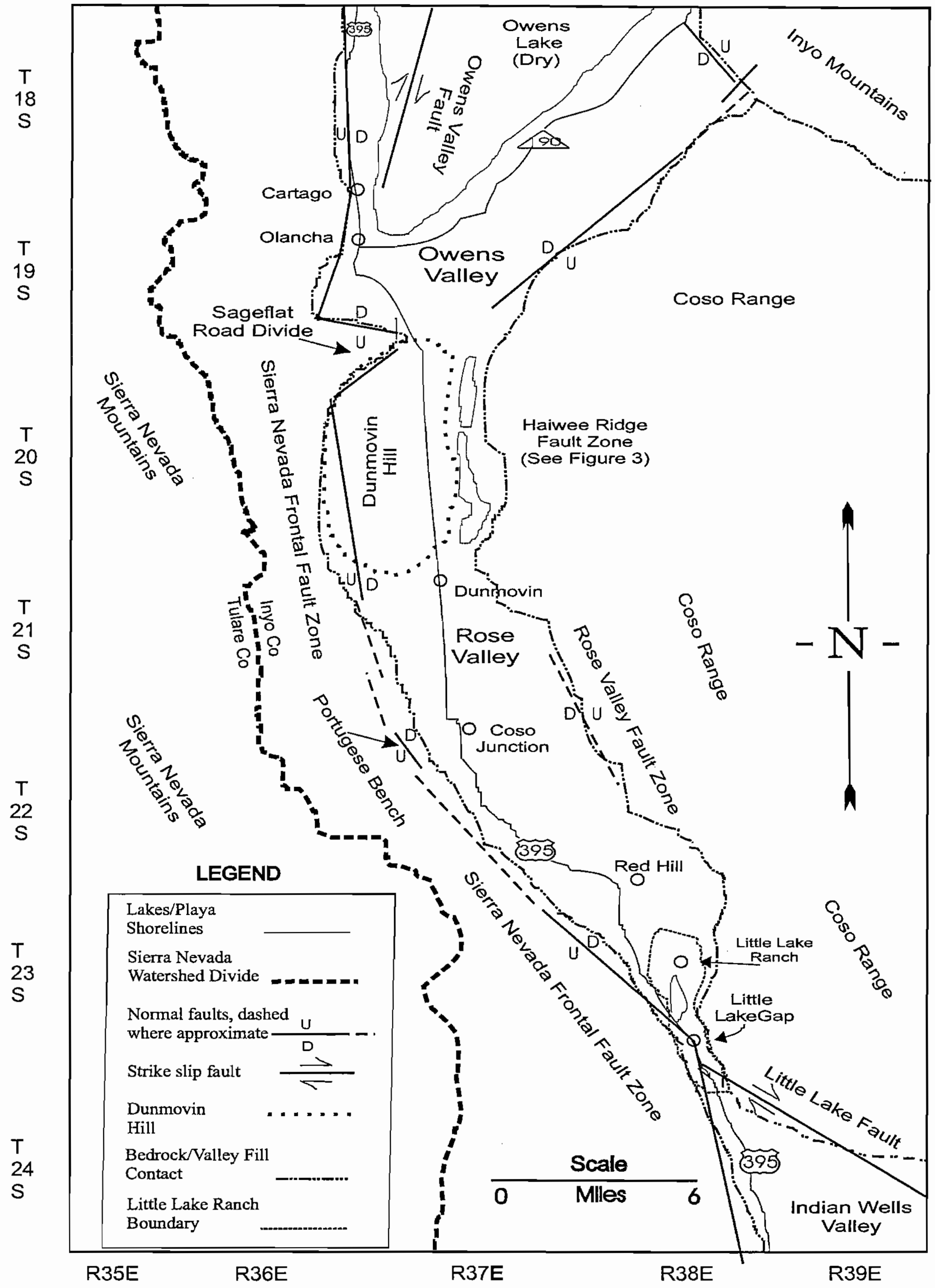


Figure 2. Faults associated with the study area, Owens and Rose Valleys, Inyo County, California. After Stinson, 1977, Jennings, 1994, and Vittori et al., 1993.

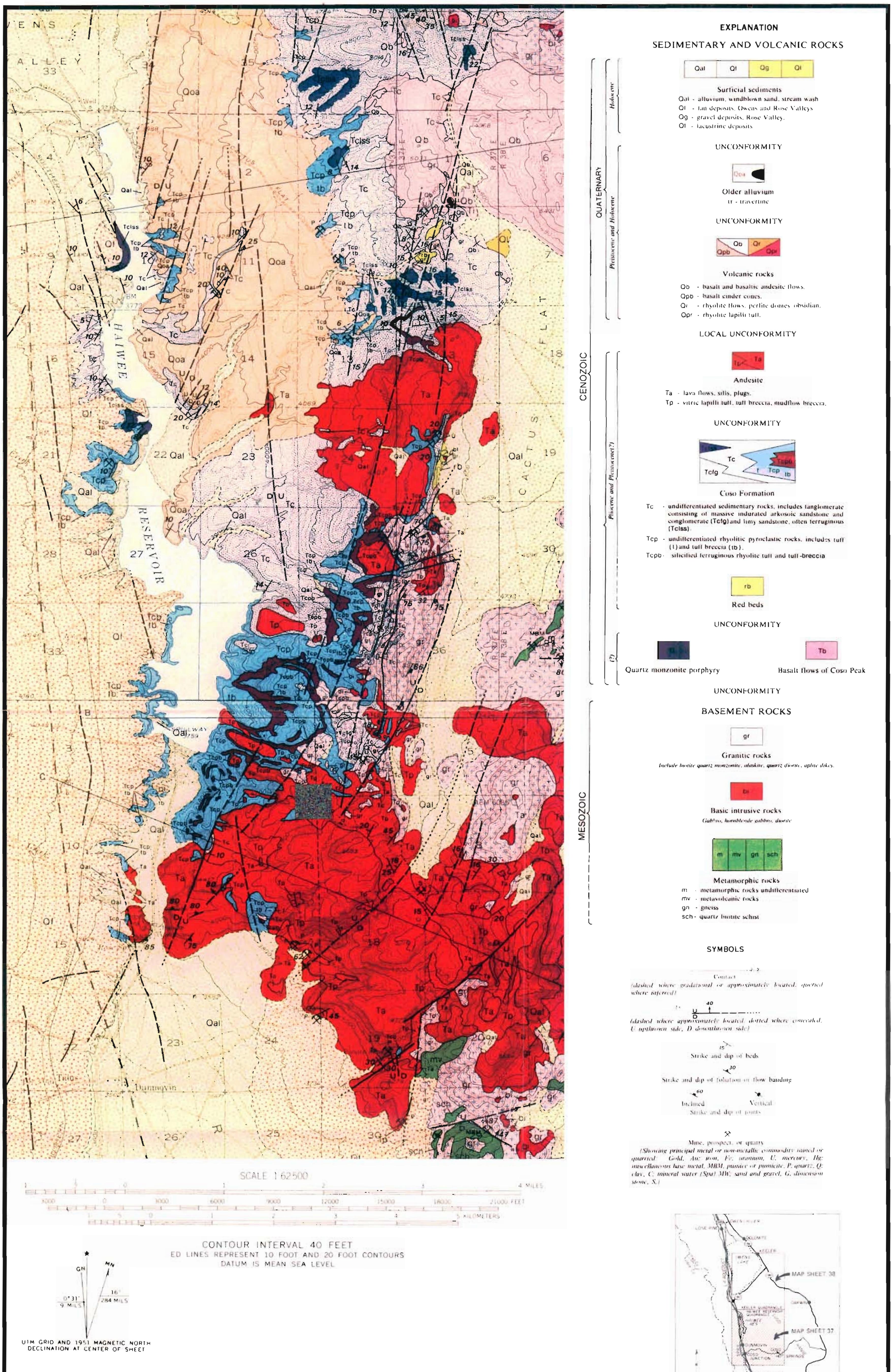


Figure 3. Faults and geology of Haiwee Ridge, Coso Range, Inyo County, California, (Stinson, 1977).

The Sierra Nevada frontal fault is a normal fault located along the eastern base of the Sierra Nevada. Miocene high-angle block faulting along the Sierra Nevada frontal fault created the more than 5,000 feet of vertical relief between the Sierran east-facing front and the southern Owens and Rose Valley's floor (Christiansen and McKee, 1978). This fault is the major bounding fault on the west side of the Owens and Rose Valleys (Jennings, 1994) (Figure 2). Portuguese Bench represents a surface expression of a smaller left-stepping offset fault that strikes parallel to the Sierra Nevada frontal fault. This prominent fault scarp, rising approximately 40 feet above the surrounding Sierra Nevada-sourced alluvial fans, is located in the Rose Valley west of Coso Junction (Figure 2). Springs flow year round on this scarp providing potable water to the two ranches that are located on this site. Portuguese Bench is preserved here because it lies between two active alluvial fans that have eroded and buried the fault scarp both north and south.

Stinson (1977) mapped a normal unnamed fault that extends approximately ten miles along the west-facing slope of the Coso Range in eastern Rose Valley (Figure 2). For the purpose of this study, this fault will be known as the Rose Valley fault. Structurally controlled displacement, as interpreted by geophysical methods, of up to 5,600 feet occurs solely along the down thrown block of this fault, and as a result has caused the alluvial fill to thicken rapidly in the eastern portion of the Rose Valley (Rockwell Report, 1980). Movement on the Rose Valley fault is responsible for the uplift of the Coso Range on the east side of Rose Valley (Rockwell Report, 1980).

The southwestern terminus of the Rose Valley is bounded by a left-stepping strike-slip fault known as the Little Lake fault (Roquemore and Zellmer 1983). The Little Lake fault, a right lateral strike-slip fault, located south of Little Lake, strikes southeast from the

Sierra Nevada frontal fault toward the Coso Range and into the Indian Wells Valley (Figure 2) (Roquemore and Zellmer, 1983). The Little Lake fault crosses Highway 395 south of Little Lake Gap near the 3,000-foot elevation contour before it enters southern Little Lake Ranch (Roquemore and Zellmer, 1983). In southern Little Lake Ranch, a small sag pond provides evidence for the existence of this fault. A cinder cone lies directly on top of the Little Lake fault at the southeastern boundary of southern Little Lake Ranch. Along the fault trace, several more sag ponds are found on southeast dipping basalt lava flows, as the fault continues southeast from the cinder cone into the Indian Wells Valley.

The structure of northern Rose Valley, in the Haiwee Reservoir area, is controlled by a series of normal faults along Haiwee Ridge which defines the western boundary of the Coso Range (Rockwell Report, 1980). The main normal faults along the west side of this ridge are north-trending with dip-slip displacement down to the west (Figure 3) (Power, 1958). Also located on the west side of this ridge are many smaller faults with displacements of 25 feet or less, strike N 15° E to N 20° E, and also dip to the west (Power, 1958). At the north end of Haiwee Ridge, the Coso Formation is warped into an asymmetric monoclinal fold (Power, 1958). The axial trend of this fold is north of and in line with the west-dipping normal faults (Power, 1958). The exposed Coso Lake Beds Member of the Coso Formation dips approximately 10° W on the western slope of Haiwee Ridge. They are warped up sharply near the summit of the ridge, and within a distance of 300 feet from the summit, the lake beds change abruptly to a dip of 40° W before flattening out further east (Power, 1958).

The Coso Range is a tectonic block bounded by normal faults of the southern Owens Valley/Rose Valley graben (Babcock, 1977). East of Rose Valley, smaller-scale, north-south trending graben structures are present within the Coso Range (Rockwell Report, 1980). The

Coso Range east of Rose Valley contains the Coso Hot Springs Geothermal Area (CGA) (Figure 4). These springs are hydrothermally active and are currently being used to generate electricity for the adjacent China Lake Naval Weapons Center.

2.2 Rose Valley and Southern Owens Valley Boundaries

The Rose Valley boundaries are: the Sierra Nevada Mountains to the west; the Coso Range to the east; Merritt Divide to the north; and Little Lake Gap to the south (Figure 1). The Sierra Nevada lie to the west of the southern Owens Valley. The Coso Range and the Inyo Mountains form the east and southeast boundaries, respectively of the southern Owens Valley. Dunmovin Hill and Sageflat Road Divide combine to form the partial southern boundary of the southern Owens Valley, west of north Haiwee Reservoir (Figure 1).

The Rose Valley, in the north, is separated from the Owens Valley by a topographic high known as Dunmovin Hill (Figure 1). Dunmovin Hill, of Pleistocene (?) age, is composed of a massive landslide or series of debris flow deposits that originated in the Sierra Nevada and extended east to the base of the Coso Range. The eastern terminus of Dunmovin Hill has been eroded as a result of the Pleistocene Owens River overflowing Pleistocene Owens Lake. Consequently, there is a canyon-like opening, known as Haiwee Gorge, between the southern Owens Valley and the Rose Valley (Figure 1). Rose Valley, in the south, is separated from the Indian Wells Valley by an approximately 1,000 foot wide water-carved canyon known as Little Lake Gap (Figure 1). The walls on both sides of this gap form a narrow opening splitting the Coso Range. Little Lake Gap was formed by the erosive action of the Pleistocene Owens River and is therefore, probably Pleistocene in age.

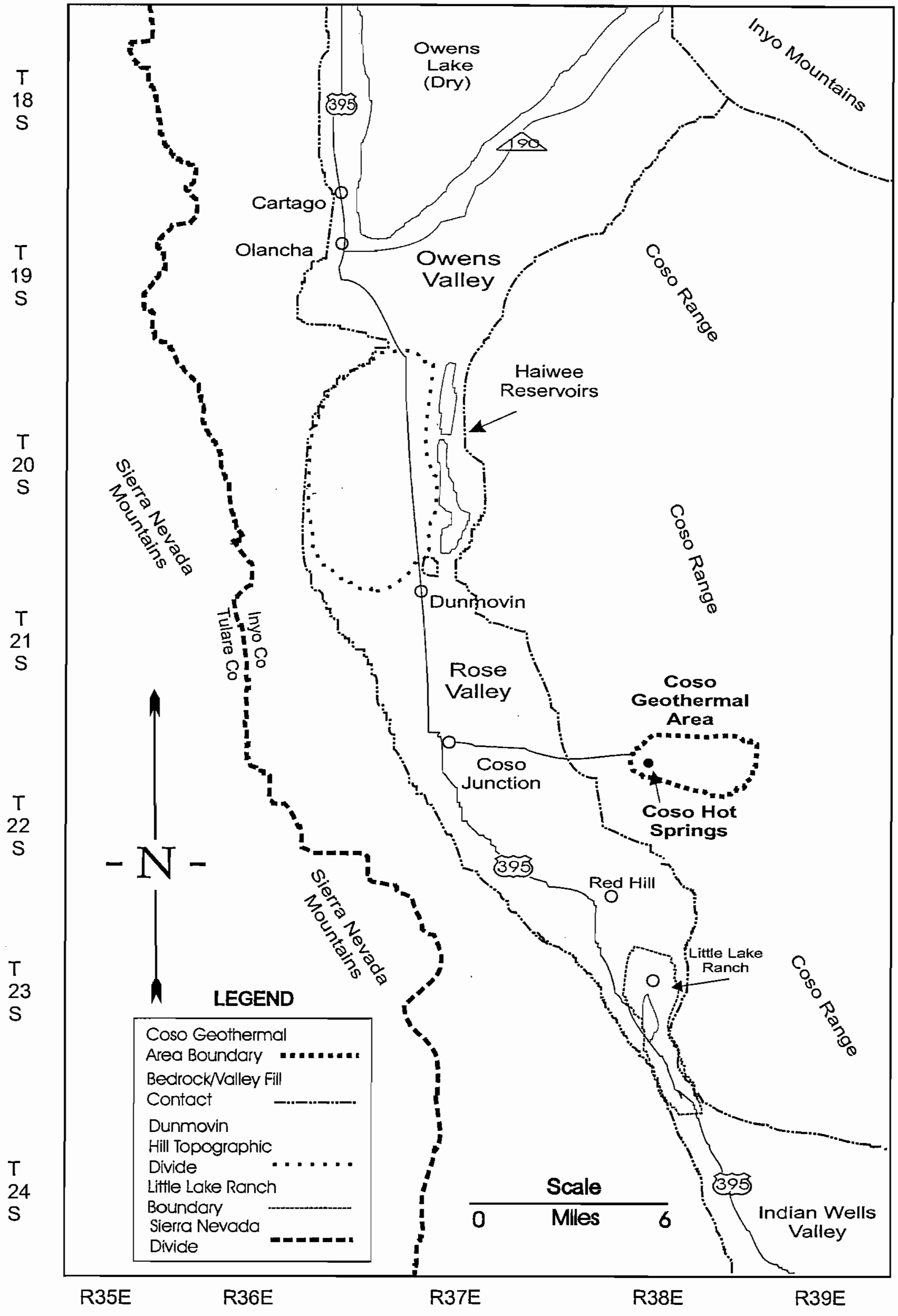


Figure 4. Location of Coso Geothermal Area, Coso Range, Inyo County, California.

2.3 Lithology and Stratigraphy

Examination of previous studies of the lithology and the stratigraphy, within the study area, will be considered here. The following geologic entities in the southern Owens Valley and Rose Valley are pertinent to this study and thus will be explored: the Sierra Nevada and Coso Range basement rocks, an overview of the Coso Formation's three members, younger volcanic rocks, older alluvial fan gravels, recent alluvial fan deposits, debris flows, and recent lake deposits. In addition, the erosional and depositional effects of the Pleistocene Owens River in the Rose Valley will also be investigated.

2.3.1 Sierra Nevada and Coso Range Basement Complex

Rose Valley is underlain by igneous and metamorphic basement rocks of the Sierra Nevada and Coso Range of Paleozoic to Mesozoic age which occur at depths from 3,000 to 5,600 feet (Pakiser et al., 1964; Rockwell Report, 1980). Basement rocks in the Sierra Nevada and the Coso Range constitute a crystalline complex dominated by plutons that range in composition from gabbroic through granitic (Duffield and Smith, 1978). The Coso Range basement complex is unconformably overlain by patches of late Cenozoic sedimentary and volcanic rocks of the Coso Formation (Power, 1958).

Basement rocks of the southern Sierra Nevada west of the southern Owens Valley and the Rose Valley are predominately Mesozoic age granite and granodiorite plutons and associated metamorphic roof pendants of Paleozoic and Mesozoic metasedimentary rocks (Duffield and Smith, 1978). The Inyo Mountains are comprised of overprinted Quaternary volcanic rocks underlain by faulted and folded metamorphic and metasedimentary rocks as old as Precambrian. The Coso Range is composed of pre-Cretaceous metamorphic rocks and Mesozoic granitic plutons, Tertiary and Quaternary volcanic rocks, and Plio-Pleistocene lakebeds of the Coso Formation (Duffield and Bacon, 1981). Basement rocks of the Coso Range are overlain by either the Basal Fanglomerate Member of the Coso Formation, late Tertiary Coso Sand Member deposits of the Coso Formation, or late Tertiary and early Quaternary basaltic cinder cones and fissure flows (Power, 1958). They may also be overlain by silica-rich volcanoes of the Coso rhyolite volcanic dome field, located east of the Rose Valley (Lamphere and Dalrymple, 1975).

2.3.2 Coso Formation - Previous Studies

Studies within the southern Owens Valley and the Rose Valley by Power (1958), Duffield and Smith (1978), and Schaer (1981) form the basis of the discussion on the lithology and stratigraphy of the Coso Formation. The Coso Formation unconformably overlies Mesozoic granitic basement rocks of the western Coso Range and the Rose Valley. The Coso Formation, of Miocene (?) and Pliocene age, is a heterogeneous assemblage of primarily lacustrine deposits with lesser amounts of volcanic tuff (Power, 1958). It records repeated lake deposit cycles, volcanism, uplift, erosion on Haiwee Ridge, and almost continuous deposition in the southern Owens and Rose Valleys (Power, 1958; Bacon et al., 1982). Haiwee Ridge contains exposures of three members of the Coso Formation: the Basal Fanglomerate Member (rb), the Coso Lake Beds Member (Tc) and the Rhyolite Tuff Member (Tcp) (Figure 3).

Schaer (1981), under contract to the U.S. Atomic Energy Commission, explored the Coso Formation/bedrock contact for potential economic sources of uranium in seven bore holes: OV-A, OV-B, OV-C, OV-D, OV-E, OV- F, and OV-H (Figure 5). He found granitic basement rocks in the area of north Haiwee Reservoir to occur below a depth of 2,002 feet (Schaer,1981) (Figure 6). The Coso Formation has a cumulative below ground thickness of

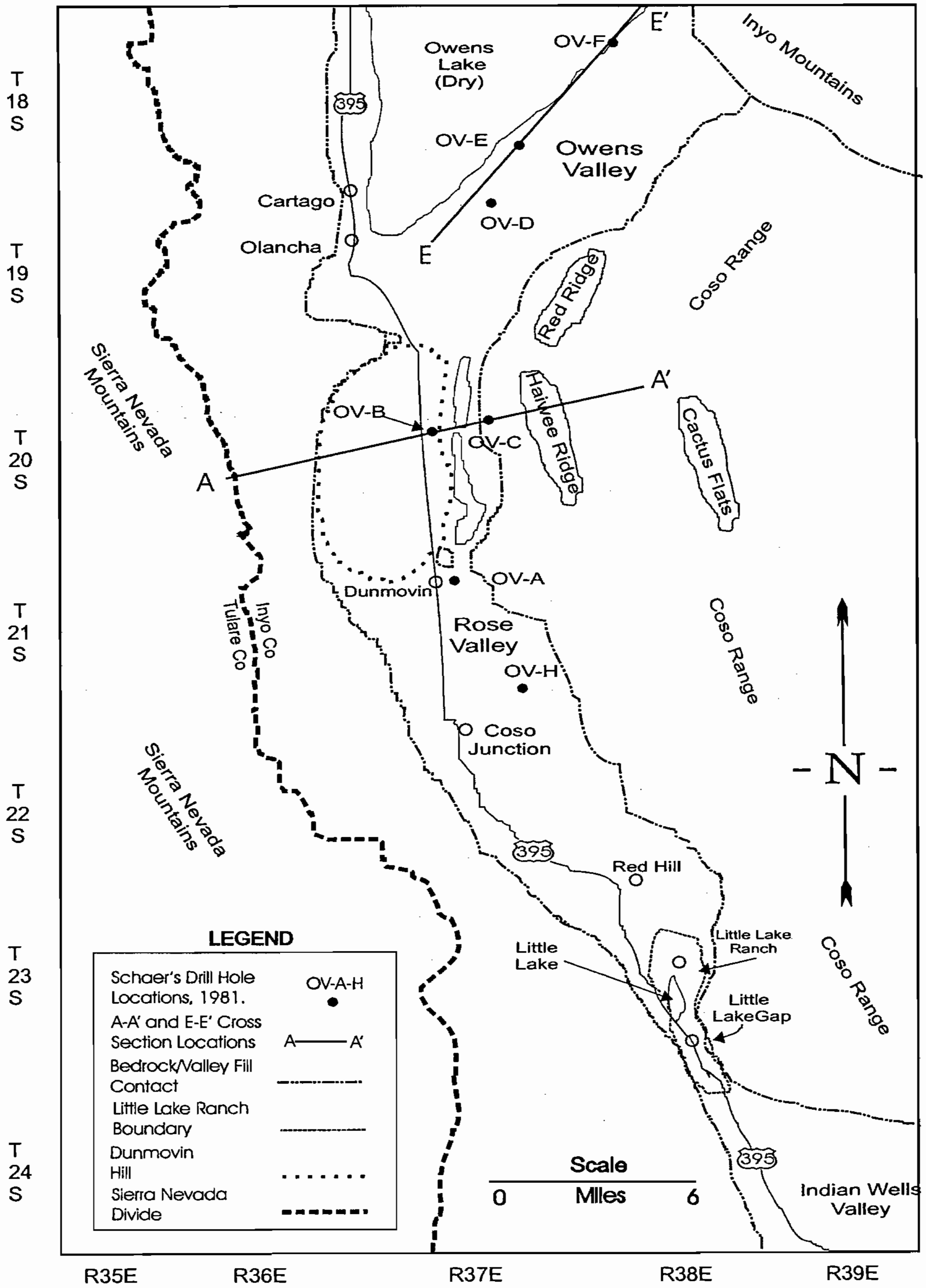
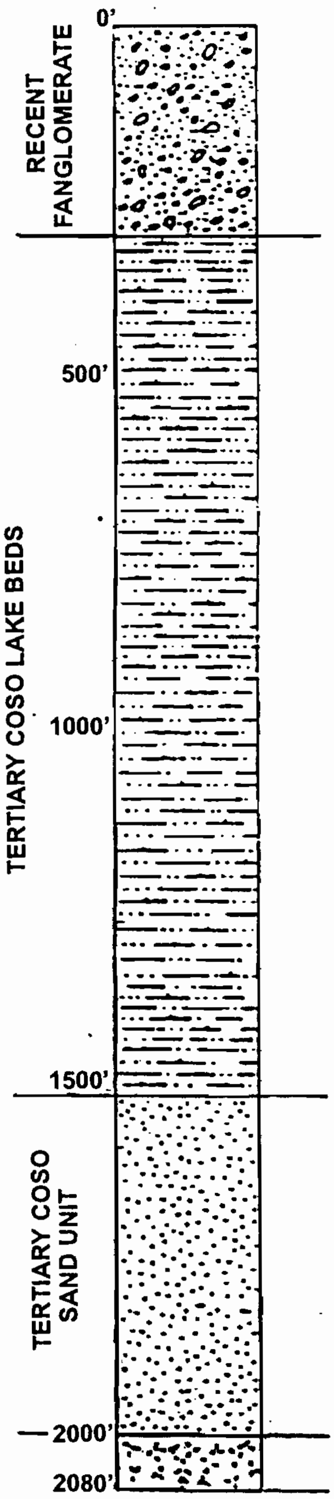


Figure 5. Schaer's Rose Valley, Haiwee Ridge, and southern Owens Valley drill hole locations, Inyo County, California. (Schaer, 1981). A-A' Cross Section found on Figure 9. E-E' Cross Section found on Figure 10.

approximately 1,700 feet in the vicinity of Haiwee Ridge located in the northern Rose Valley (Schaer, 1981) (Figure 6).

The Coso Formation was deposited in a large lake centered in Rose Valley (Schaer, 1981). The position of the lake's southern boundary extended to the northern Indian Wells Valley (Houghton, 1994). The position of the lake's northern boundary was located between Haiwee Ridge and Red Ridge (Figure 5). It was probably controlled by recurrent uplift of the tilted Coso fault block and by damming resulting from volcanic activity originating to the east in the Coso Range (Schaer, 1981). Sand beds of the Coso Formation occupy this uplifted northern portion of the Coso block (Schaer, 1981). These sand beds are probably laterally equivalent to the lacustrine strata found in the northern Rose Valley and may indicate that paleo-drainages built a coarse sand delta deposit into ancestral Pliocene Rose Lake (Schaer, 1981).

The Coso Formation is important with regard to this investigation because some workers have proposed that this formation acts as a barrier for groundwater flow from the Owens Valley to the Rose Valley (Lee, 1912; Knopf, 1918; Danskin, 1988). This determination may have been made based on the surface presence of sandstone beds that occur discontinuously along the east shore of south Haiwee Reservoir. However, most of the sedimentary layers in the Coso Formation are loosely cemented, and composed of fine to coarse grain sizes. Some of the coarser layers provide sufficient porosity and permeability to function as suitable aquifer material. In the Rose Valley, the Coso Formation consists of the following four members: Basal Fanglomerate Member, Coso Sand Member, Coso Lake Beds Member, and Rhyolite Tuff Member (Schaer, 1981, Power, 1958; Knopf, 1918). In the southern Owens Valley the Owens Lake Sand and Owens Lake Bed Members are laterally



Fanglomerate--Consisits of coarse, unsorted, crudely layered polymictitic gravels.

Carbonate Mudstone-Consists of micrite with minor clay and sparse, poorly sorted, angular to subrounded clasts ranging from silt to pebble sized.

Arkosic Sand--Poorly sorted sand with clasts varying from silt to granule sized, angular to subrounded in an iron-stained clay matrix.

Quartz Monzonite

Figure 6. Borehole OV-C showing the Coso Lake Beds and Coso Sand Members (Tertiary Coso Sand Member) of the Coso Formation east of Haiwee Reservoir, Rose Valley, Inyo County, California (Schaer, 1981). The fanglomerate is interpreted to be the debris flow deposit of Dunmovin Hill. For location of OV-C see Figure 5.

equivalent to the Coso Formation's Coso Sand Member and Coso Lake Beds Member found in the Rose Valley, respectively (Schaer, 1981).

a. Basal Fanglomerate Member of the Coso Formation

The Basal Fanglomerate Member of the Coso Formation is not well developed in the borings drilled by Schaer, 1981. Consequently, Schaer (1981) never describes it in any of his deep borings. According to Schaer (1981), this member appears to have a very erratic distribution. The Basal Fanglomerate Member crops out on and wedges out against the upper flanks of Haiwee Ridge (Schaer, 1981; Power, 1958). Its maximum exposed thickness is 400 feet. The Tertiary-age Basal Fanglomerate Member is composed of granite fragments of arkosic sand and gravel derived from the underlying Coso Range basement rocks along with small amounts of pyroclastic material (Power, 1958). This fanglomerate is lenticular and grades basinward from the summit of Haiwee Ridge into fine-grained, better-sorted, thin-bedded, ripple-marked sandstones of the overlying Coso Sand Member of the Coso Formation (Schaer, 1981). Schaer (1981) suggests that the Basal Fanglomerate Member represent reworked colluvial deposits localized by basement topography and structures.

b. Coso Sand Member

The Pliocene Coso Sand Member consists of poorly consolidated, fine-to-coarse-grained, red to buff arkosic alluvial gravels, sand, and red clay beds derived from the granitic basement rocks of the Coso Range plus reworked Sierra Nevada fan material (Figure 7). The sand is poorly sorted with clasts varying from silt to gravel size embedded in an iron-stained clay matrix (Schaer, 1981). The Coso Sand Member ranges in thickness from 200 to 880 feet, and occurs at depths from 1,500 to 3,000 feet (Figure 8) (Schaer, 1981). The greatest reported thickness (880 feet) is found approximately 1.5 miles west of Haiwee

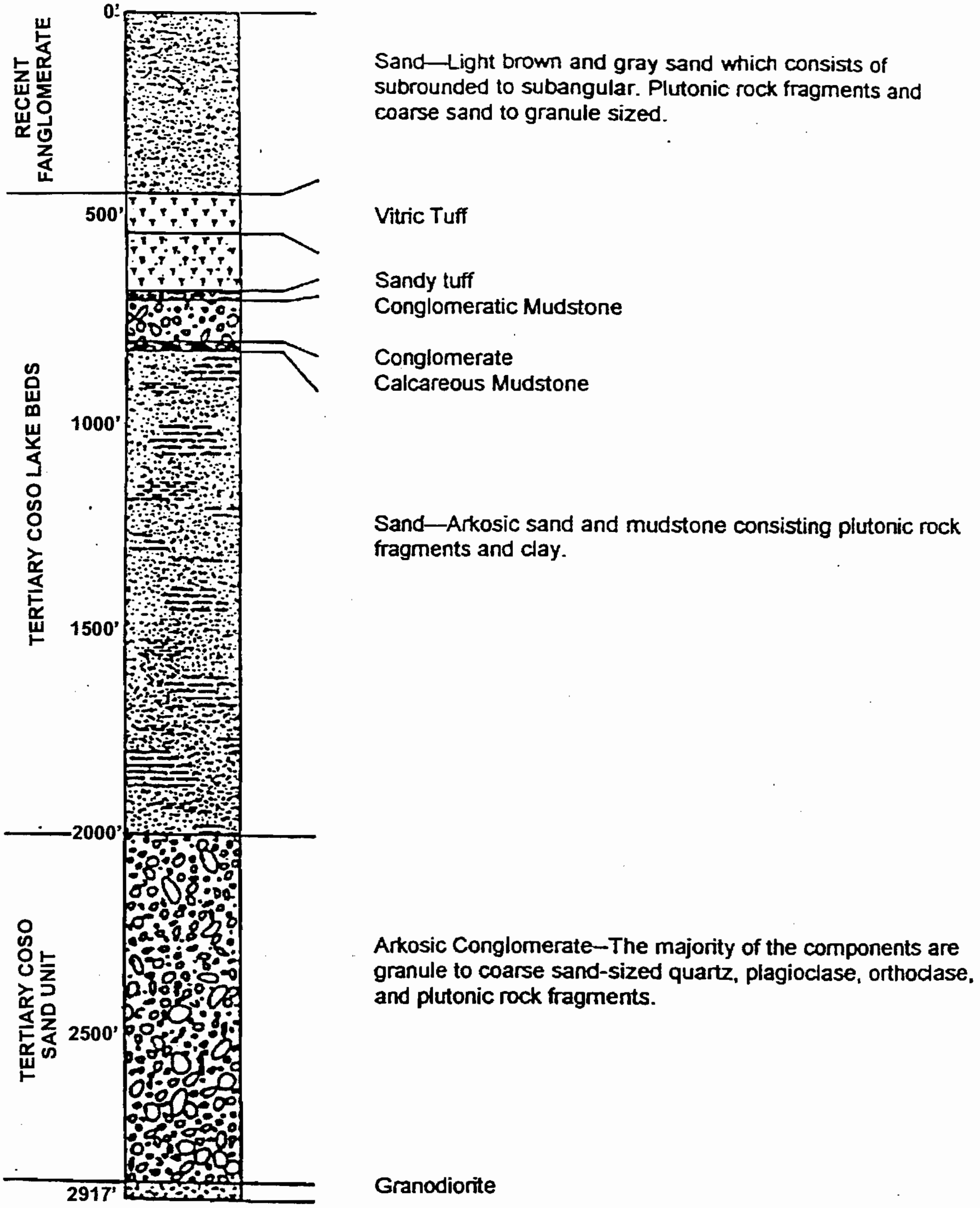


Figure 7. Stratigraphic column of the Coso Formation at Dunmovin Hill, west of Haiwee Reservoir, northern Rose Valley, Drill Hole OV-B, Inyo County, California. (Schaer 1981). For location of OV-B, see Figure 5.

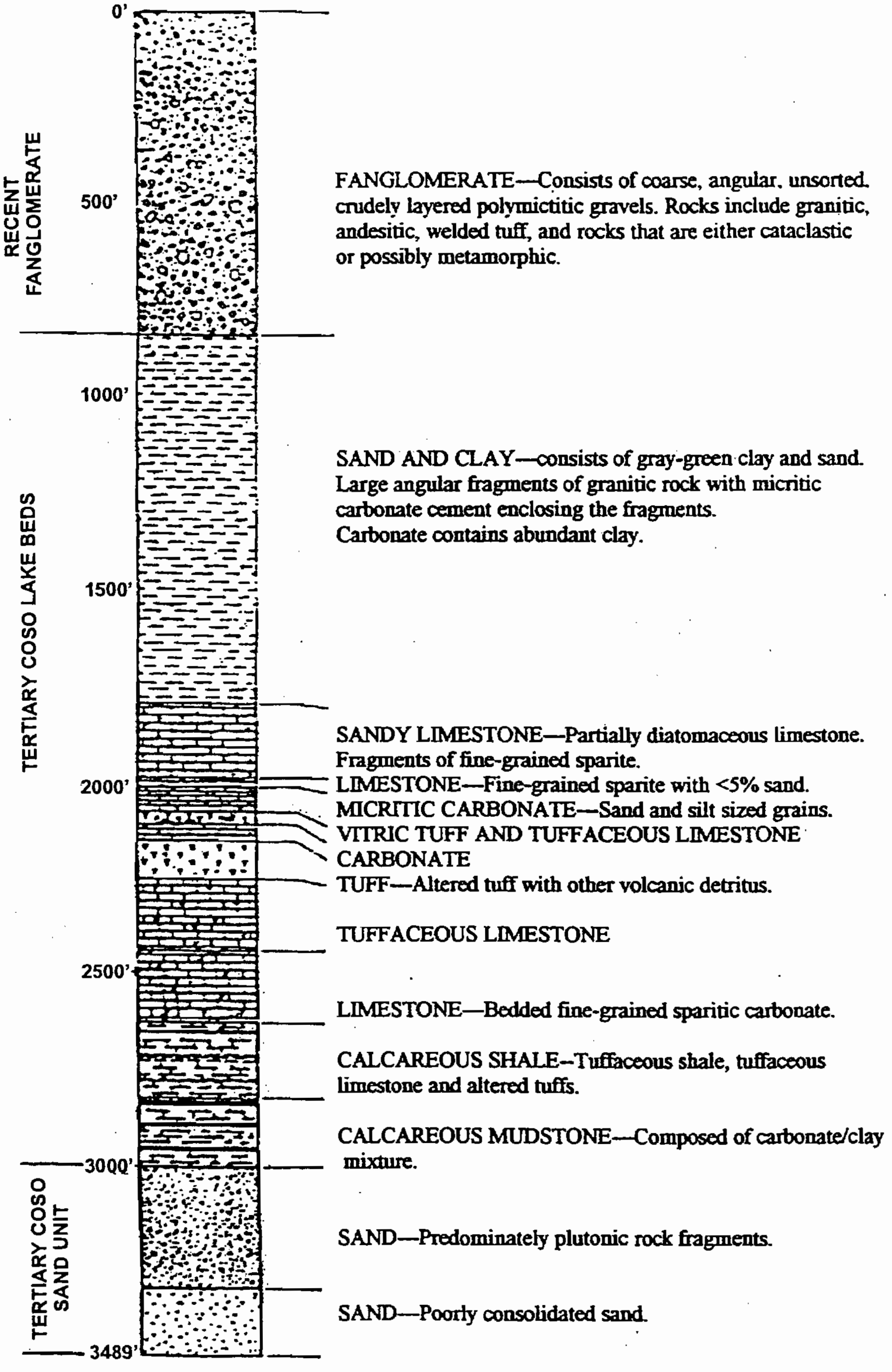


Figure 8. Coso Formation - Coso Sand (Tertiary Sand Unit) and Coso Lake Beds Members, Schaer drill hole OV-A, south of Haiwee Reservoir, northern Rose Valley, Inyo County, California. (Schaer, 1981). For location of OV-A, see Figure 5. (Power, 1958; Schaer, 1981).

Reservoir below Dunmovin Hill in borehole OV-B (Figures 5 and 7) (Schaer, 1981). Its thickness decreases rapidly to the east and increases to the west at the expense of the overlying Coso Lake Beds Member (Schaer, 1981). On the flanks of Haiwee Ridge and probably elsewhere along the flanks of the depositional basin, the Coso Sand Member grades laterally to the east into the underlying Basal Fanglomerate Member (Schaer, 1981). Schaer's boreholes OV-B and OV-A illustrate the lithology of the Coso Sand in the northern Rose Valley, west and south of south Haiwee Reservoir, respectively (Figures 7 and 8).

c. Coso Lake Beds Member

Due to uplift of the Coso block, west-dipping outcrops of the Coso Lake Beds Member are exposed east of Haiwee Reservoir along the west-facing slope of Haiwee Ridge (Figures 3 and 9). The outcrop is composed of interlayered white-to-buff siltstones and fine-grained sandstones and tuff deposits that interfinger with the Basal Fanglomerate Member near the summit of Haiwee Ridge (Power, 1958). The Coso Lake Beds dip westward from 10° to 20° into the subsurface below Haiwee Reservoir. Approximately one-quarter mile west from Haiwee Reservoir's west shore, the Coso Lake Beds Member interfingers with the debris flow deposits of Dunmovin Hill (Figure 9). In the subsurface, in this vicinity, the Coso Lake Beds Member has an approximate cumulative thickness of 1,600 feet (Figure 9).

The Coso Lake Beds were laid down in ancestral Rose Lake during the late Pliocene to early Pleistocene. They occur from the Rose Valley north to the southern Owens Valley, where they are known as the Owens Lake Bed Member, and extend around the northern portion of Haiwee Ridge southeast into Cactus Flats (Power, 1958) (Figure 5). They extend south in the subsurface through Little Lake Gap and occur along the south-facing slopes of the Coso Range in the northern Indian Wells Valley (Houghton, 1994).

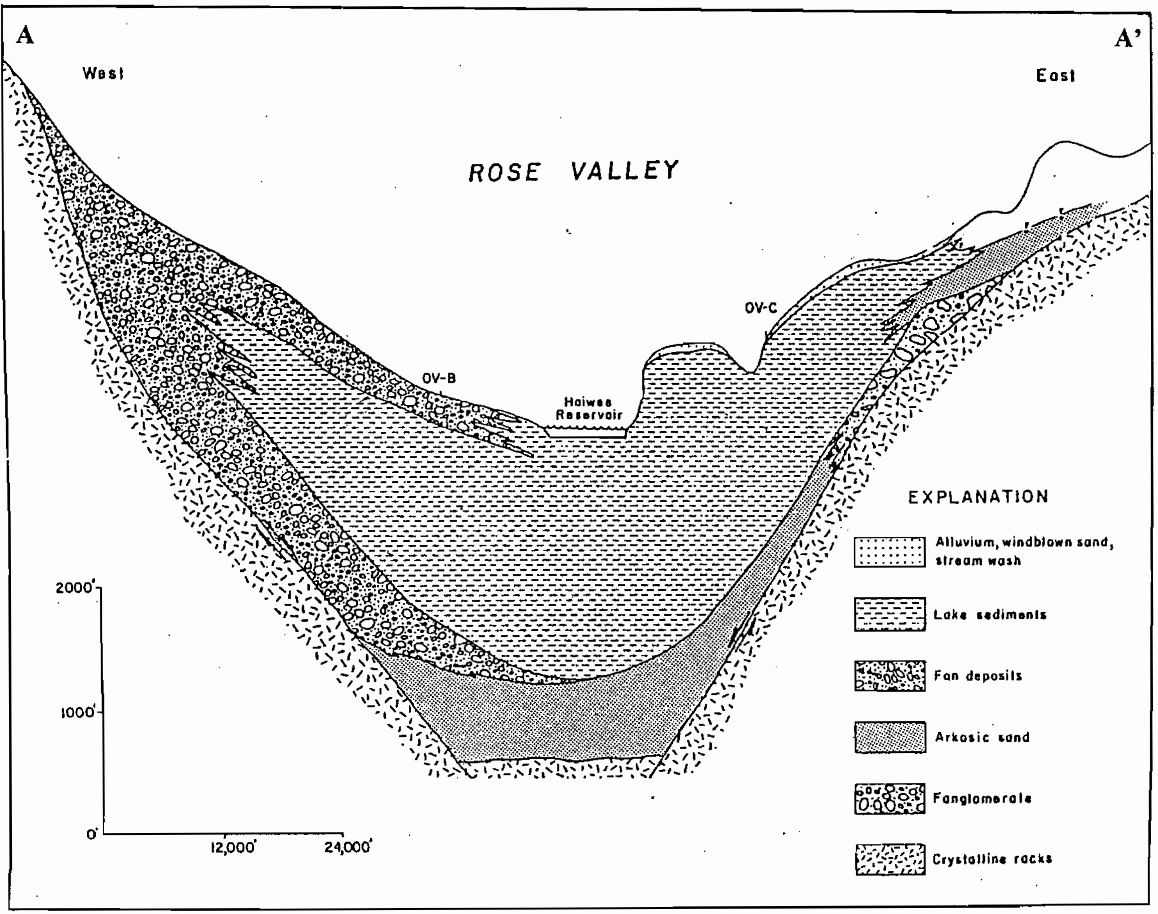


Figure 9. West to east cross section (A - A') from the Sierra Nevada Mountains to Haiwee Ridge in the Coso Range through the Coso Formation in the vicinity of Haiwee Reservoir. (Schaer, 1981). The Dunmovin Hill alluvial deposits below the Coso Lake Beds (lake sediments) are composed of older Sierra Nevada-sourced alluvial/debris flow deposits. The deposits west of and above the Coso lake sediments are considered to be recent Sierra Nevada-sourced alluvial deposits. Location of cross section is shown in Figure 5.

In the northern Rose Valley, the Coso Lake Beds range from depths of 294 to 3,000 feet with an approximate maximum thickness in OV-A of 2,150 feet (Schaer, 1981) (Figures 6 & 8). Schaer's borehole OV-B, west of Haiwee Reservoir, reveals the lithology of the Coso Lake Beds (Figure 7). The subsurface stratigraphy of this member is composed of alternating beds of fine-to coarse-grained sand, arkosic sand, green clay with interspersed volcanic ash flows, and thin-bedded white rhyolitic tuffs containing pumice fragments (Figure 7) (Schaer, 1981; Power, 1958).

d. The Owens Lake Sand and Owens Lake Bed Members

In the southern Owens Valley, the Owens Lake Sand and Owens Lake Bed Members form a thick sequence of unconsolidated sedimentary lacustrine deposits that are laterally equivalent to the Coso Sand and Coso Lake Bed Members of the Coso Formation located in the northern Rose Valley (Schaer, 1981). The Owens Lake Bed Member overlies the Owens Lake Sand Member in the southern Owens Valley. These members are both late Tertiary in age and are well developed along the west and east portions of the southern Owens basin beneath Owens Dry Lake (Power, 1958) (Figure 10). The lithologic description of these members is based upon Schaer's wells OV-D and OV-E located in the southern Owens Valley (Figures 11 and 12).

The Owens Lake Sand Member's stratigraphic sequence is defined in Schaer's well OV-D from approximately 200 to 3,500 feet below ground surface with a cumulative thickness of 3,300 feet (Figure 11). At these depths, the lithology is a mixture of unconsolidated medium to coarse-grained light brown, gray, and red sands (Schaer, 1981).

Stratigraphic Cross Section E-E'
Southern Owens Valley

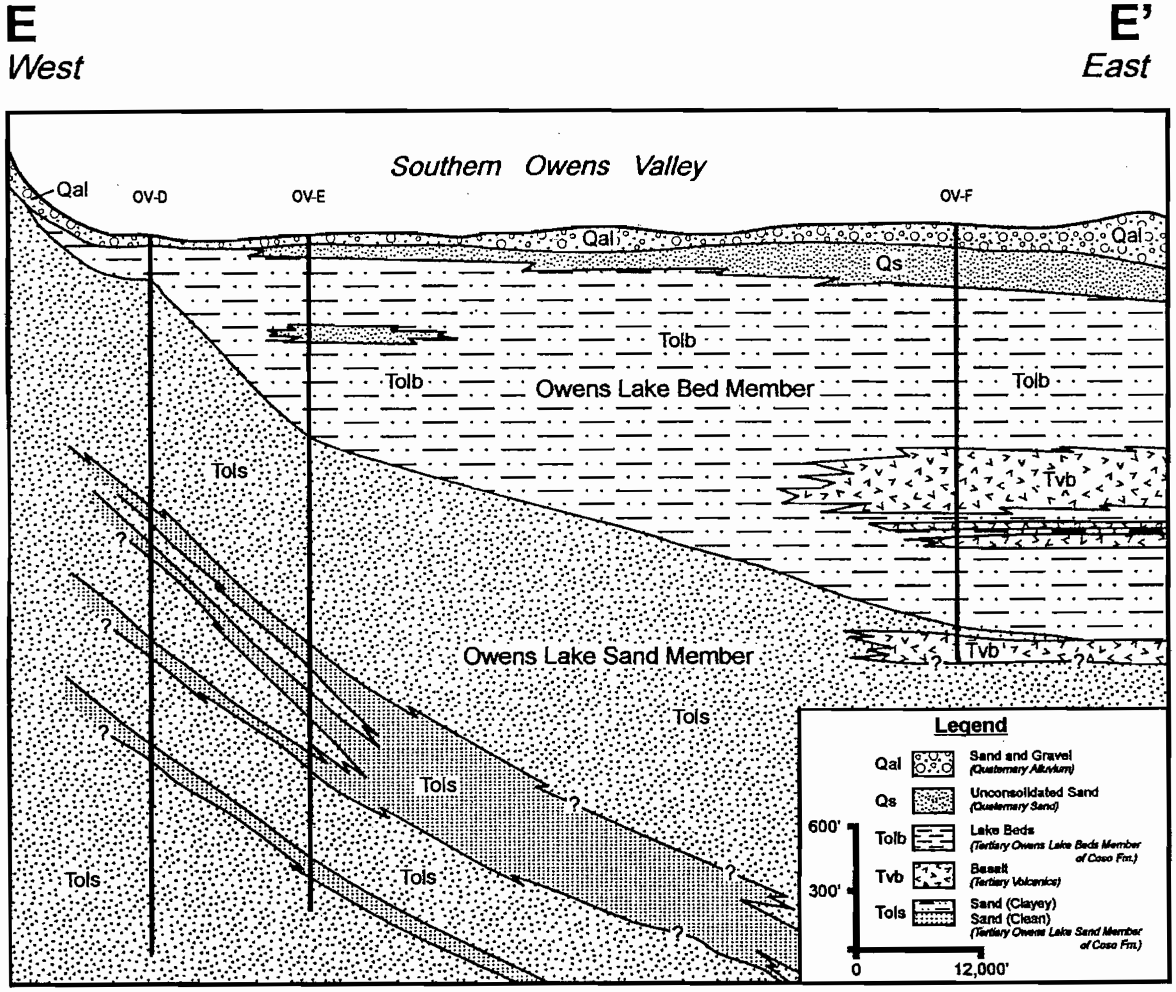


Figure 10. West to east cross section (E-E') in the southern Owens Valley showing the Owens Lake Beds and Sand Members. (Schaer, 1981). Location of cross section is shown in Figure 5.

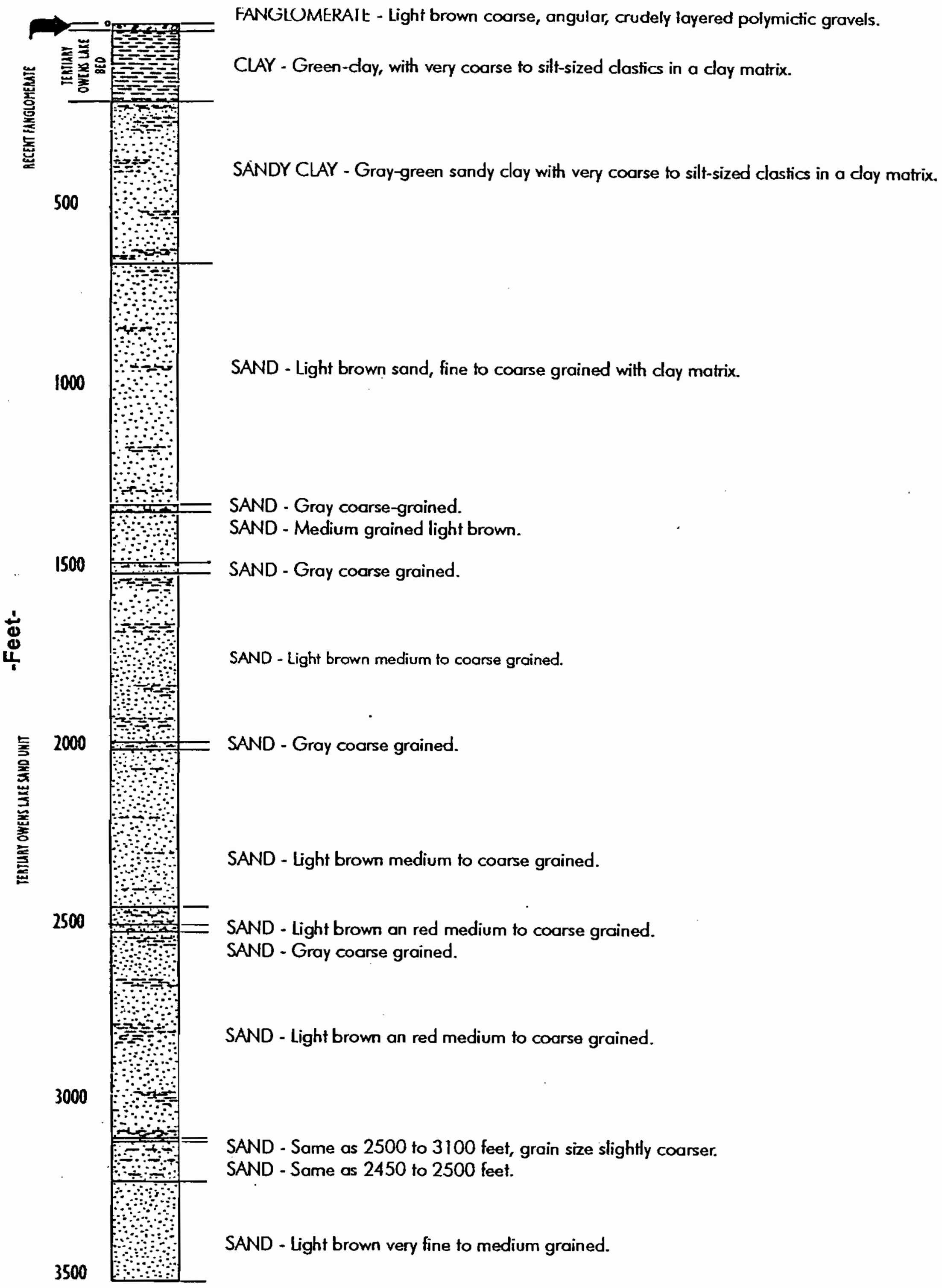


Figure 11. Owens Lake Beds and Sand Members, Schaer drill hole OV-D, north of north Haiwee Reservoir, southern Owens Valley, Inyo County, California. (Schaer, 1981). Location of OV-D is shown in Figure 5.

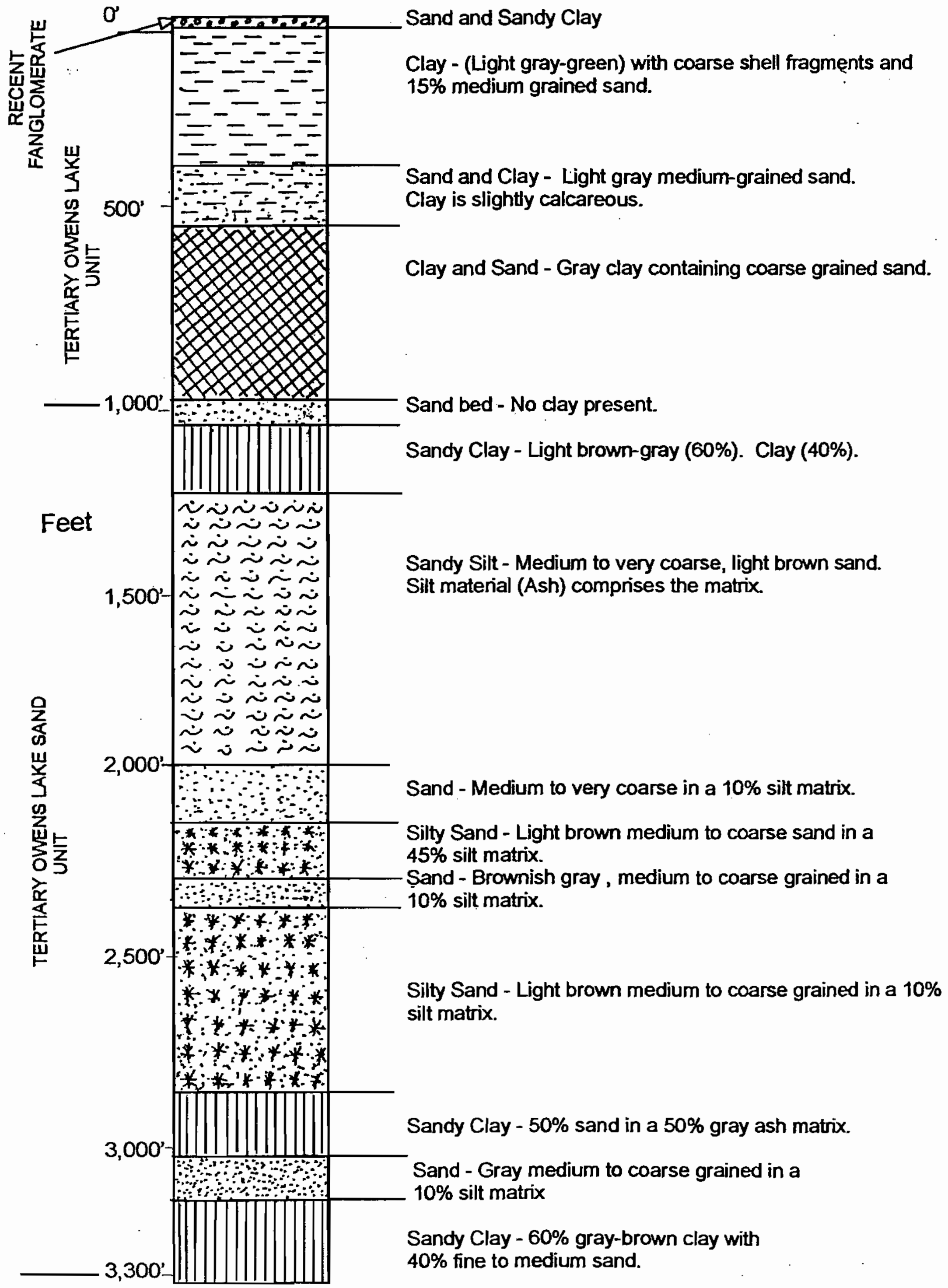


Figure 12. Owens Lake Beds and Sand Members, Schaer drill hole OV-E, on the southern shore of Owens Lake, southern Owens Valley, Inyo County, California. (Schaer, 1981). Location of OV-E is shown in Figure 5.

The overlying Owens Lake Beds Member extends westward in the southern Owens Valley where it is overlain by alluvial fan deposits of the Sierra Nevada (Power, 1958). The lakebeds maximum thickness (~1,000 feet) is greatest on the eastern side of the southern Owens basin. In borehole OV-E, from depths of 50 to 500 feet below Owens Dry Lake, the Owens Lake Beds Member is comprised of thick lacustrine clays and thinner fluvial coarse sands to silt-sized clastics in a matrix of gray-green clay (Schaer, 1981) (Figure 12). From depths of 500 to 1,000 feet below Owens Dry Lake, the lithology consists of unconsolidated, homogeneous strata of oxidized to very coarse-grained, brown arkosic sands and gravels containing minor amounts of clay (Figure 12). The clays of this member thin to the west, where they are replaced by the underlying sands of the Owens Lake Sand Member (Figure 10).

e. Rhyolite Tuff Member

The Rhyolite Tuff Member of the Coso Formation deposits occur along the east side of south Haiwee Reservoir Dam from about one mile north of the south dam, south into the northern Rose Valley along the western slopes of the Coso Range. They interfinger and lie above the Coso Lake Beds Member in this area. Schaer (1981) does not distinguish between the Coso Lake Beds and the Rhyolite Tuff Members in his cross sections or lithologic logs as Power (1958) does. This study follows Power's (1958) convention and separates the Coso Lake Beds Member from the Rhyolite Tuff Member of the Coso Formation.

Interstratified, massive beds of upper Pliocene to Pleistocene rhyolite tuff, vitric-ash tuff, and pumice-lapilli tuff (collectively called Rhyolite Tuff) from 1 to 400+ feet thick are common throughout the Coso Formation (Power, 1958). Due to uplift of the Coso block, the thickest deposits of Rhyolite Tuff are exposed both above and within the upper portion of the

Coso Lake Beds Member along the west-facing slopes of the Coso Range, from east of south Haiwee Reservoir south to the eastern Rose Valley (Power, 1958; Bacon et al., 1982) (Figure 3). The exposed tuffs on the southern portion of Haiwee Ridge are not fused (Power, 1958). This is an important point for future consideration of this member as a potential aquifer.

2.3.3 Younger Volcanic Units of the Rose Valley

Volcanic eruptions in the Coso Range began about four million years ago and have occurred as recently as the late Pleistocene (Duffield and Smith, 1978). Many of these eruptions flowed into the Owens River channel, altering its course or temporarily damming it (Duffield and Smith, 1978). Volcanic rocks derived from the Coso Range east of central and northern Rose Valley are in the north predominately rhyolitic, dacitic, and andesitic in composition (Duffield and Smith, 1978); whereas, volcanic rock units derived from the southern Coso Range (southeast of the southern Rose Valley) and from Red Hill, located in the southern Rose Valley are predominately basaltic in composition (Duffield and Smith, 1978).

Most of the Coso Range east of the southern Rose Valley is covered by basalt flows that originated from volcanic fissures and vents southeast of Red Hill. These basaltic flows form much of the eastern boundary of northern Little Lake Ranch (Figure 13 and Plate III). It is quite possible that a buried basalt flow is partially responsible for the formation of the current aquifer architecture in the southern Rose Valley and the creation of Little Lake.

a. Basalt of Southern Little Lake Ranch

The vent for the basalt of southern Little Lake Ranch (termed basalt of lower Little Lake Ranch by Duffield and Smith (1978)) is located below a cinder cone on the Little Lake fault at the southeast corner of Little Lake Ranch (Figure 13). Potassium-argon (K-Ar) age

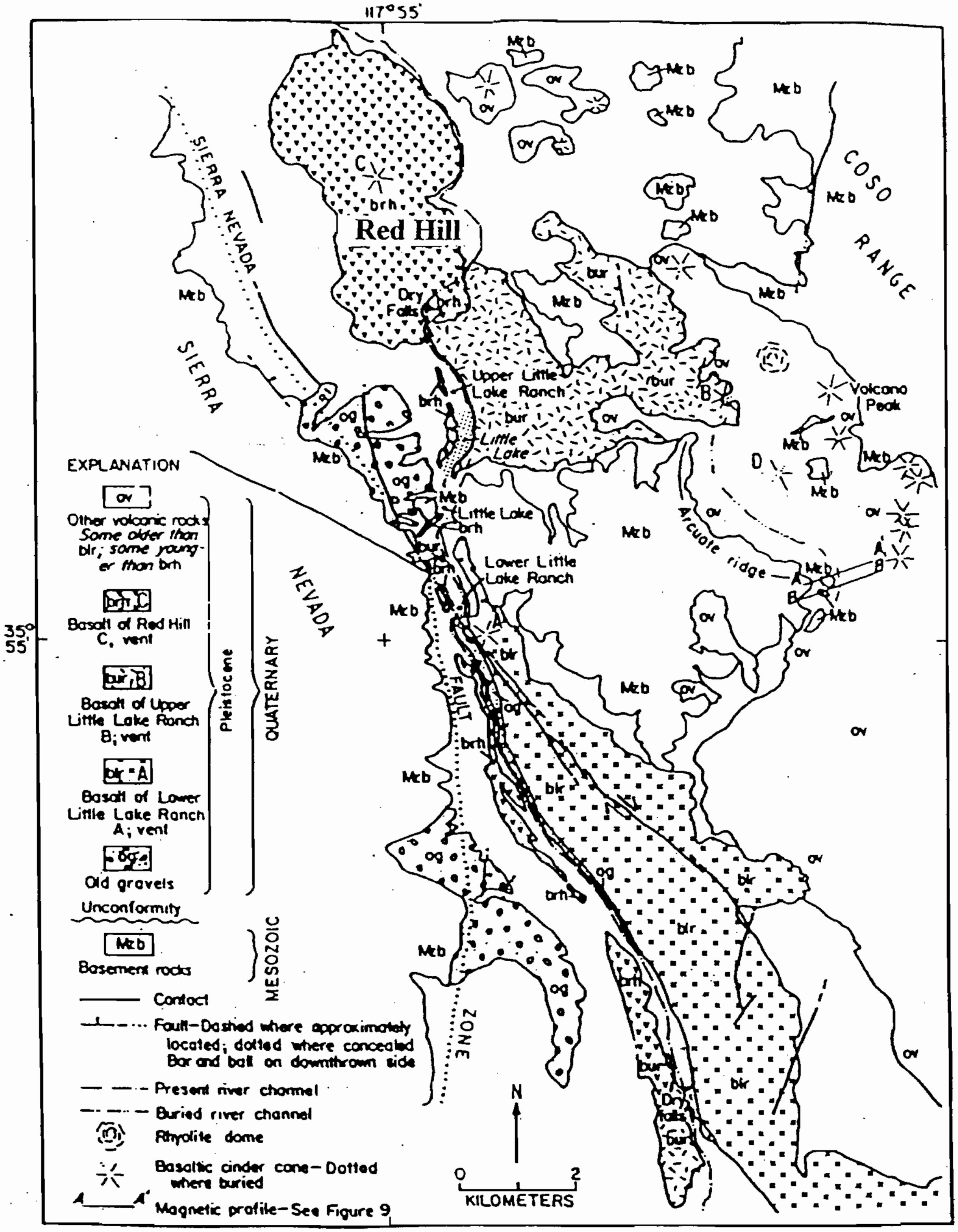


Figure 13. Geology of Little Lake, southern Rose Valley, and northwestern Indian Wells Valley. (Duffield and Smith, 1978).

dating reveals that there were two distinct eruption episodes. The older eruption (486,000 ± 108,000 years BP) flowed about 0.5 mile north covering the summit of the Coso Range to a depth of nine to fifteen feet, while the younger flow (399,000 ± 45,000 years BP) spread more than 1.25 miles laterally as it moved down a south-dipping Coso Range alluvial fan slope towards Indian Wells Valley (Duffield and Smith, 1978).

b. Basalt of Northern Little Lake Ranch

The basalt flow located east of Little Lake (named basalt of upper Little Lake Ranch by Duffield and Smith (1978)) flowed from a vent approximately three miles northeast of Little Lake and west of Volcano Peak (Duffield and Smith, 1978) (Figure 13). This flow forms an impressive 210-foot cliff containing columnar jointed basalt that forms the eastern backdrop of northern Little Lake Ranch and Little Lake. This basalt is sparsely porphyritic, containing 1% to 2% phenocrysts of olivine and plagioclase (Duffield and Smith, 1978). The probable age of this basalt has been estimated by potassium-argon dating to be 140,000 ± 89,000 years BP (Duffield and Smith, 1978). This Pleistocene age flow extended west, completely covering the bedrock and alluvial fans of the Coso Range and partially covering the massive alluvial fans of the Sierra Nevada (Duffield and Smith, 1978). It erupted as a single flow, spreading north and west until it reached the Pleistocene Owens River (Duffield and Smith, 1978). The lava flow advanced down-stream into the Owens River channel and flowed south at least 10 miles into the Indian Wells Valley (Duffield and Smith, 1978).

c. Basalt of Red Hill

Red Hill, a Pleistocene volcanic cinder cone, and the small hydrolaccoliths surrounding it, lie three miles north of Little Lake (Figure 13). The basalt of Red Hill is moderately porphyritic, containing phenocrysts of plagioclase, olivine, and pyroxene

(Duffield and Smith, 1978). Repeated attempts using K-Ar age dating have proven to be futile, because no radiogenic argon has been recovered (Duffield and Smith, 1978). Consequently, the glacial events in the Sierra Nevada and related lacustrine deposits at Searles Lake were used to provide some broad constraints on the age of the Basalt of Red Hill (Duffield and Smith, 1978). According to a Searles Lake stratigraphic study by Smith (1962), the lacustrine deposits in Searles Lake indicate that water began to flow through the Little Lake area about 130,000 years ago. Between 10,000 to 130,000 years ago, the water at Searles Lake remained at a high level (Duffield and Smith, 1978). Based on the constant rate of canyon downcutting at Fossil Falls (which is comprised of basalt of Red Hill) and the rate of sedimentation at Searles Lake, Duffield and Smith (1978) ascribe a probable age of 22,000 years BP to the basalt of Red Hill.

After entrenchment of the Pleistocene Owens River channel into the basalt of northern Little Lake Ranch, an intra-canyon lava flow erupted from Red Hill (Duffield and Smith, 1978). Red Hill basalt lava ponded around its vent and fed a single flow that advanced 10 miles down the Pleistocene Owens River channel into the Indian Wells Valley (Duffield and Smith, 1978). At Little Lake, the basalt of Red Hill stayed well below the rim of the pre-existing canyon walls (Duffield and Smith, 1978).

After the emplacement of Red Hill basalt, the Pleistocene Owens River reestablished a stream channel east of Red Hill and sculpted a 75-foot high waterfall known as Fossil Falls (Figure 1). These falls (termed dry falls in Figure 13) are located approximately two miles upstream from Little Lake (Duffield and Smith, 1978).

d. Igneous Rocks of the Northern Rose Valley

Northeast of Dunmovin and south of Haiwee Reservoir's south dam, in the path of the Pleistocene Owens River, Sharp (1976) described a bisected, highly fractured, porphyritic rhyodacite flow (Figure 14) known as "The Narrows." Stinson (1977) ascribed an age range for this flow of late Pliocene to early Pleistocene. At the base of the western half of this volcanic flow is the site of the Los Angeles Department of Water and Power (LADWP) aqueducts pumping plant.

This volcanic deposit's exposed vertical thickness is approximately 400 feet. The intact pre-eroded horizontal width was approximately 2,000 feet. The below ground dimensions have not been ascertained. The volcanic flow originated from a now buried vent in the Coso Range to the east (Power, 1958: Sharp, 1976) (Figure 3). The surface of this volcanic flow deposit is well weathered, highly jointed and cross-jointed, and appears rubbly at first inspection (Power, 1958).

2.3.4 Alluvial Deposits

Rose Valley is a graben filled with 3,000 feet (along the west side) to 5,600 feet (along the eastern side) of alluvium above a granitic basement (Rockwell Report, 1980, and Schaer, 1981). The basin fill consists of lacustrine deposits of the Pliocene Coso Formation, Pleistocene and Holocene alluvial fan and debris flow deposits from the bordering Sierra Nevada and Coso Range, Pliocene to Pleistocene volcanic rock flows, and recent sedimentary lacustrine deposits (Schaer, 1981; Rockwell Report, 1980; Powers, 1958; Duffield and Smith, 1978). The late Pleistocene to Holocene age recent alluvial deposits, depending upon location, usually occur from 0 to 840 feet below the surface and consist of a mixture of polymictitic sands and gravels (Schaer, 1981) (Figures 7, 8, and 15).

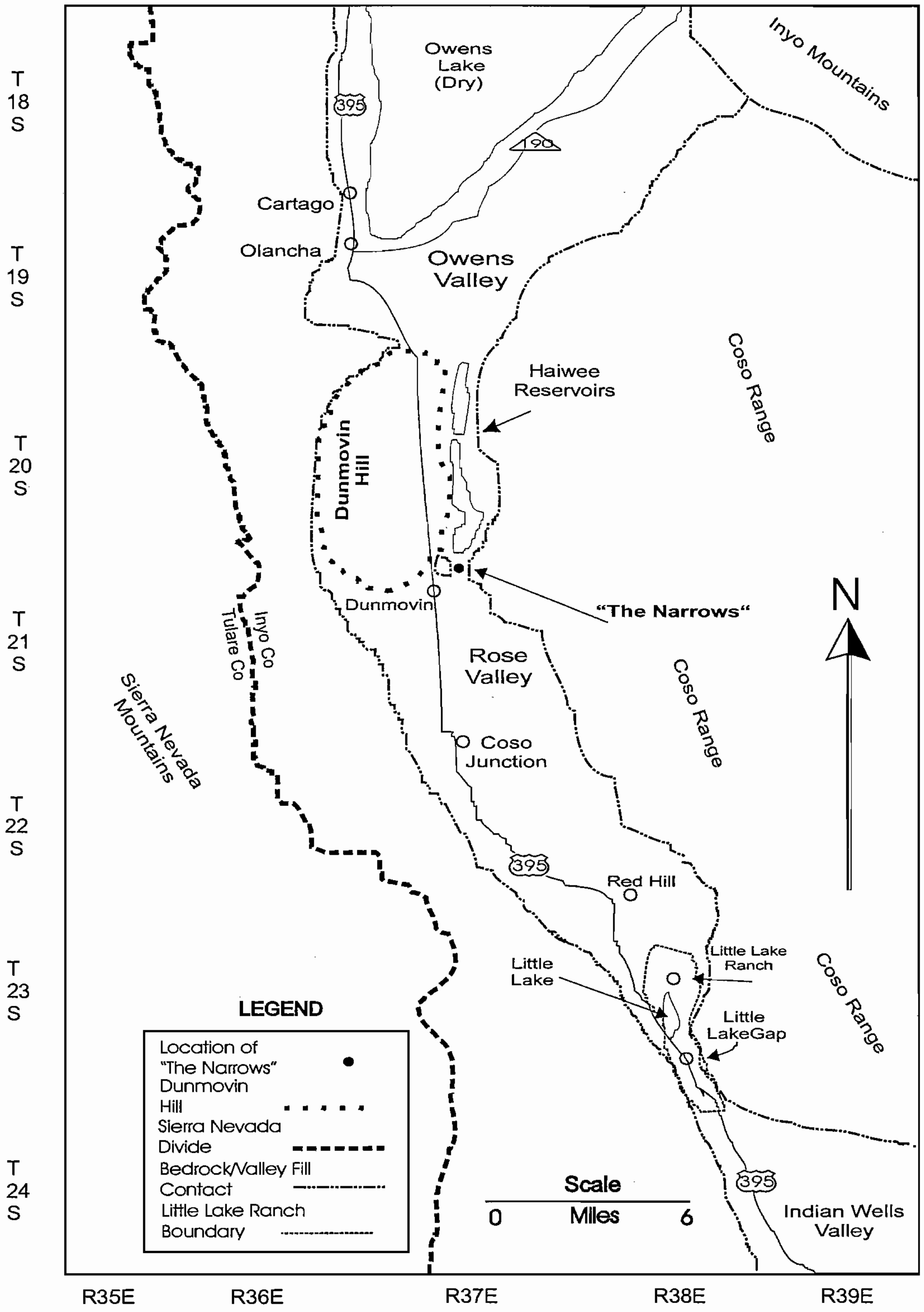


Figure 14. Location of "The Narrows" and Dunmovin Hill, both located in northern Rose Valley, Inyo County, California. (Sharp, 1976).

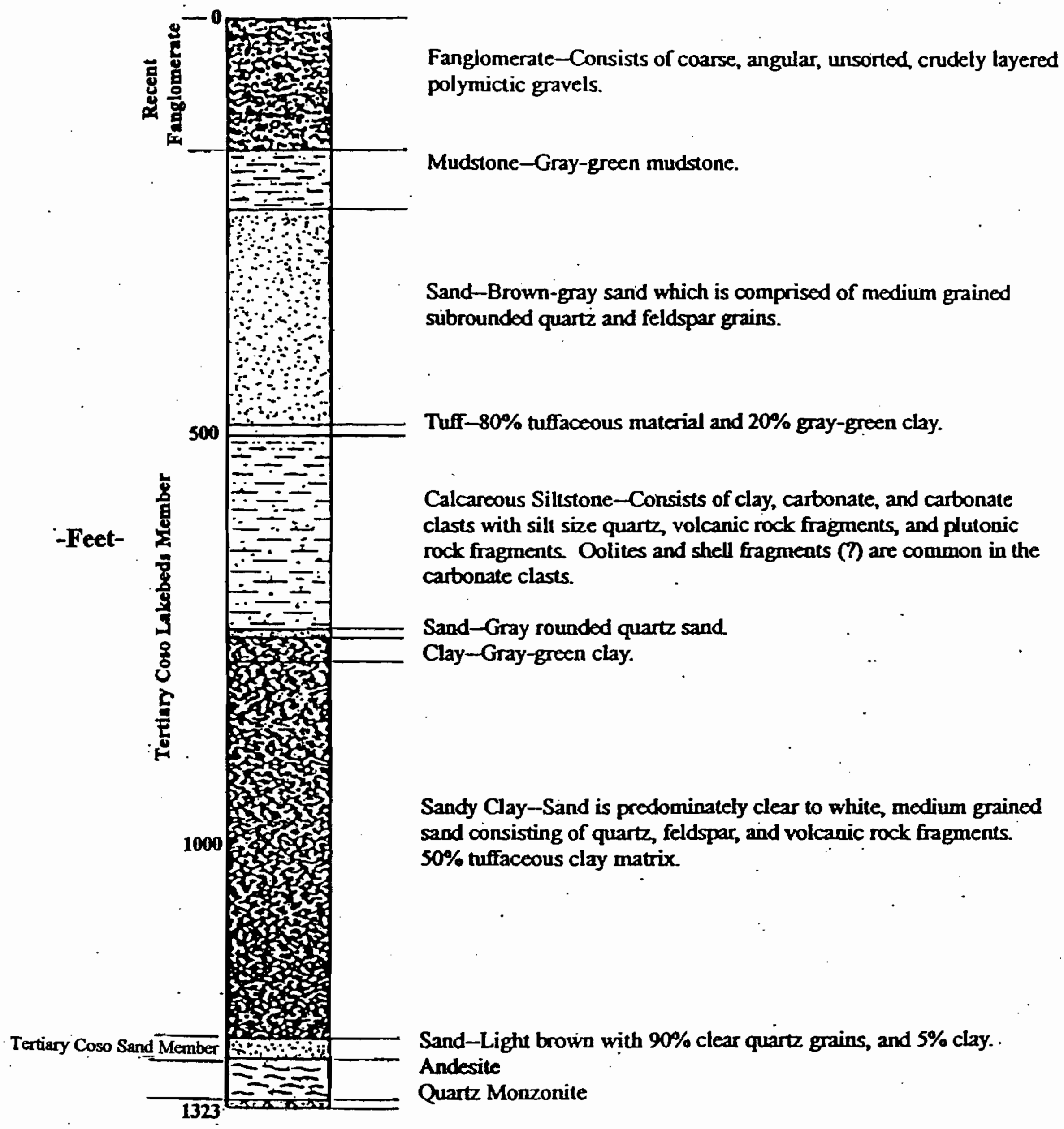


Figure 15. Interpretive lithologic log OV-H of alluvium in the Rose Valley, Inyo County, California. (Schaer, 1981). For the location of OV-H see Figure 5.

Based on degree of weathering and clay percentages, the alluvial fan deposits are divided into older and recent fan deposits. Since most of the water wells in the study area are completed in aquifers located 700 feet or less below ground surface, it will be assumed that the upper 700 feet of the subsurface alluvial deposits are potential aquifers. Both recent and older alluvial deposits are considered to be water-bearing.

The following geologic units will be described in the forthcoming sections: older alluvium, recent alluvium (lumped together with recent fanglomerates by Schaer (1981)), debris flows and debris avalanches, and recent lake deposits. In addition, the erosional and depositional effects of the Pleistocene Owens River within the Rose Valley will be described.

a. Older Alluvium

This section will characterize, within the study area, the older alluvial fan gravels of Pleistocene age. The age of the alluvial fans in Owens and Rose Valleys is directly tied to the uplift of the Sierra Nevada which began in the Miocene (Harden, 1998). Another major uplift of the eastern Sierra Nevada Mountains occurred at the close of the Pliocene, imparting new erosive energy to the streams that built the great alluvial fans (Chase and Wallace, 1986).

Well-developed and highly dissected Pleistocene age alluvial fan gravel deposits occur adjacent to the Sierra Nevada in both the Rose Valley and northwestern Indian Wells Valley (Duffield and Smith, 1978). These older fan gravel deposits were derived primarily from eroded basement rocks from the adjacent Sierra Nevada and secondarily from the Coso Range (Duffield and Smith, 1978). The older alluvial fan deposits of the Sierra Nevada can be distinguished from younger alluvial fan deposits by their advanced degree of dissection and advanced stages of soil development. In addition, mineral grains in these older fans are either cemented by silica or calcium carbonate, and feldspar minerals have been or are in the process of being altered to clays (Rockwell Report, 1980). The combination of these near surface factors result in low infiltration, low permeability, and lower porosity. Consequently, surface runoff on these older alluvial fan slopes is high due to the presence of water restrictive horizons at depths of two to four feet below the surface.

In the southern Rose Valley, the oldest post-Mesozoic alluvial fan gravel deposits occur west and southwest of Little Lake (Duffield and Smith, 1978). These older alluvial fan gravels once formed a continuous apron of coalescing alluvial fans at the base of the Sierra Nevada escarpment east to the smaller alluvial fans of the Coso Range (Duffield and Smith, 1978). These old fan gravel deposits consist of poorly-sorted, moderately to well-rounded weathered granitic clasts ranging in size from 0.05 inches sized clasts to boulders as large as 9 feet in diameter (Duffield and Smith, 1978). The Pleistocene Owens River has eroded most of these older fans, leaving behind hanging truncated fan remnants.

In the southern Rose Valley, old alluvial fan gravels are represented by three isolated erosional remnants: one overlies granitic basement rocks immediately northwest of Little Lake, another lies south of Little Lake Ranch on the west side of Highway 395 in the northwestern Indian Wells Valley, and the third deposit underlies basalt of southern (lower) Little Lake Ranch east of the present abandoned Pleistocene Owens River channel (Figure 13) (Duffield and Smith, 1978). These three erosional remnants represent vestigial parts of a single massive alluvial fan complex that grew eastward from the base of the Sierra Nevada several hundred thousand years ago (Duffield and Smith, 1978).

Mature soil horizons found on top of these remnant fan gravel deposits south and west of Little Lake indicate a long period of non-deposition and suggest an age of hundreds of thousands of years (Duffield and Smith, 1978). The alluvial fan gravels located on the east side of the Pleistocene Owens River channel in the northwestern Indian Wells Valley overlain by 440,000 year-old basalt, are consistent with such an age (Duffield and Smith, 1978). These alluvial fan gravels are poorly exposed and crop out as loose, granitic sand, and cobbles mixed with volcanic talus from the overlying basalt flow (Duffield and Smith, 1978).

b. Recent Alluvium

In the Rose Valley and southern Owens Valley, recent alluvial deposits of less than 850 feet, derived from alluvial fans on the basin margins are considered by Schaer (1981) to be recent fanglomerates (Figure 15). [Note: Schaer (1981) does not differentiate between recent fanglomerate from Sierra Nevada or Coso Range and recent alluvial fan or debris flow deposits]. This study refers to recent fanglomerates and recent alluvial fan deposits collectively as recent alluvium. Debris flow deposits will be treated separately in a different section.

Sierra Nevada-derived recent alluvial fans occur along the west side and at the center of the Rose basin primarily in two areas within the study area: from Little Lake Gap north to Dunmovin Hill, and in the southern Owens Valley north of Dunmovin Hill. The lithology of these recent deposits ranges from boulders, to gravels, to coarse sands and lesser amounts of silt and clay. Subsurface thicknesses of up to 600 feet of these recent alluvial deposits occur along the west side of the southern Owens basin (Well Logs #21 - #34, Appendix 8). The recent alluvial fans cover the floor and flanks of the Rose Valley. They are composed of unconsolidated, coarse, angular, unsorted, crudely layered sands and gravels (Schaer, 1981). The maximum drilled thickness of 800 feet of these deposits is located at Schaer's (1981) drillhole OV-A near the center of the Rose Valley (Figure 8). These alluvial fans are still very active with large amounts of sand and gravel deposits being added to their surface during and shortly after intense precipitation events. From their Sierra Nevada canyons, these fans extend approximately two to four miles into the Rose and southern Owens Valleys. They are distinguished from the older alluvial fans by a lack of appreciable soil development on their surfaces, absence of carbonate cementation or clay formation at shallow depths, and active depositional surfaces containing numerous gullies and active stream channels. The lithology of Sierra Nevada-sourced recent alluvial deposits consist of eroded angular to sub-rounded granitic and metamorphic rocks of various sizes embedded in a matrix of fine to coarse sands and gravels.

Coso Range-derived, recent alluvial fans occur both in the Rose Valley and the southern Owens Valley. In the eastern Rose Valley and in the southern Owens Valley, recent alluvial deposits consists of a combination of eroded Coso Range granitic basement rocks, andesitic and basaltic poorly-sorted, sub-rounded gravels, coarse sands, tuffaceous limestones, and limestones in a matrix of fine sand and silt with minor amounts of clay. Usually these deposits do not extend very far into their respective basins before being overtaken by the larger alluvial fan or debris flow deposits of the Sierra Nevada. Coso Range fans tend to be minimally dissected with fewer gullies than their Sierra Nevada counterparts. Mineral components of the rocks on these fans exhibit little to no weathering. Consequently, there are usually no well-developed soil horizons present on their surfaces. In the central Rose Valley, recent alluvial material constitutes a mixture of Sierra Nevada and Coso Range alluvium, basaltic gravel, fine sand and silty lacustrine deposits of ancestral Rose Lake, and coarse fluvial channel deposits of the Pleistocene Owens River.

c. Debris Flows and Debris Avalanches-Dunmovin Hill, Rose Valley

A massive debris flow or debris avalanche in northern Rose Valley known as Dunmovin Hill forms a rectangular topographic high, approximately eight miles long from north to south and three miles wide from east to west (Figure 14). It extends north from the town of Dunmovin nearly to Olancha in the southern Owens Valley, and from the base of the Sierra Nevada east to the west shore of Haiwee Reservoir (Figure 14). This debris flow had its origins in the Sierra Nevada to the west, and extended east to the base of Haiwee Ridge. The distal portion of the flow has been truncated by the Pleistocene Owens River, forming Haiwee Gorge. The total areal extent of Dunmovin Hill is approximately twenty-four square miles. Its subsurface thickness at the southern extent is at least 400 feet at the town of Dunmovin, based on Well Log #14 (Appendix 8) and well OV-B found on Figure 7, Schaer, 1981, [Note: Schaer refers to the debris flow deposit of Dunmovin Hill as recent fanglomerate]. A well-developed paleosol is found on the surface of this debris flow, indicating that it is most likely at least Pleistocene in age. The surface is made up of Sierra Nevada-derived, poorly sorted, moderately weathered, granitic cobbles, gravels, and coarse-grained sands, in a matrix of fine sands, silts, and clays.

The subsurface lithological sequence of Dunmovin Hill is defined as alternating zones of sand and gravel separated by boulders to a depth of 400 feet (Well Logs #14, #17, Appendix 8). It is possible that some sand and gravel deposits found at depth are relic deposits of the meandering Pleistocene Owens River channel that existed prior to the emplacement of Dunmovin Hill.

d. Recent Lake Deposits in the Rose Valley

In the south-central Rose Valley, southeast of Coso Junction, recent lacustrine deposits are visible both in the field and on aerial photographs. These clay and silt deposits, separated by islands of basalt of Red Hill flows, occur in irregular patches from 0.5 miles to 2 miles east and northeast of Red Hill. These lacustrine deposits appear to be remnants of a small lake, known as Lake Rose, that formed here during the late Pleistocene or early Holocene (Saint-Amand, 1980).

Little Lake, a shallow lake 4 to 5 feet deep, contains a sequence of lacustrine beds. A study of a 35-foot core of these lakebed sediments by Mehringer and Sheppard (1978) provided data on the lake's age and sub-surface lithology. Their findings reveal abundant sands, silts, and clays along with silt-size carbonates in a matrix of organic plant remains known as chara ooze. Chara is an algal vascular plant that grows in slow-moving shallow water. Carbon-14 age-dating of chara remains reveals that the oldest lake sediments in the 35-foot core are 5,000 years before present (BP) (Mehringer and Sheppard, 1978). Interpretation of the sedimentary and fossil record of the core suggests alternating grassy meadow and marshy environments between 5,000 to 3,000 years BP and the presence of a shallow lake since 3,000 years BP (Mehringer and Sheppard, 1978).

e. Erosional Effects of the Pleistocene Owens River

During the Pleistocene, the Owens River, spanning more than 175 miles, connected a string of lakes. The northernmost lake was Lake Russell in the Mono Lake Valley (Figure 16). The Pleistocene Owens River flowed south into Lake Owens located in the southern Owens Valley, Lake Rose in the Rose Valley, Lake China in the Indian Wells Valley, Lake Searles in the Searles Valley, and ended with Lake Panamint and Lake Manly in the

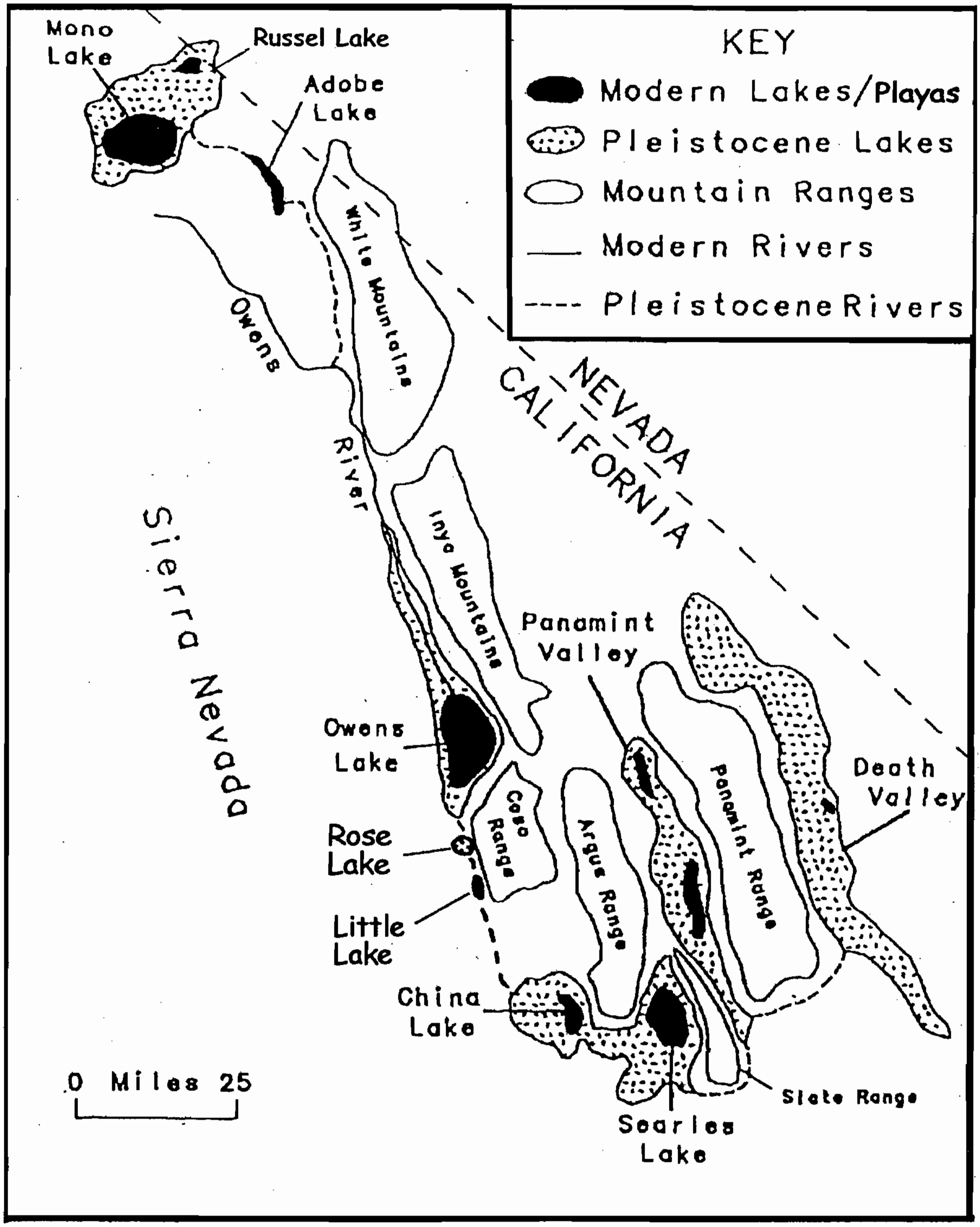


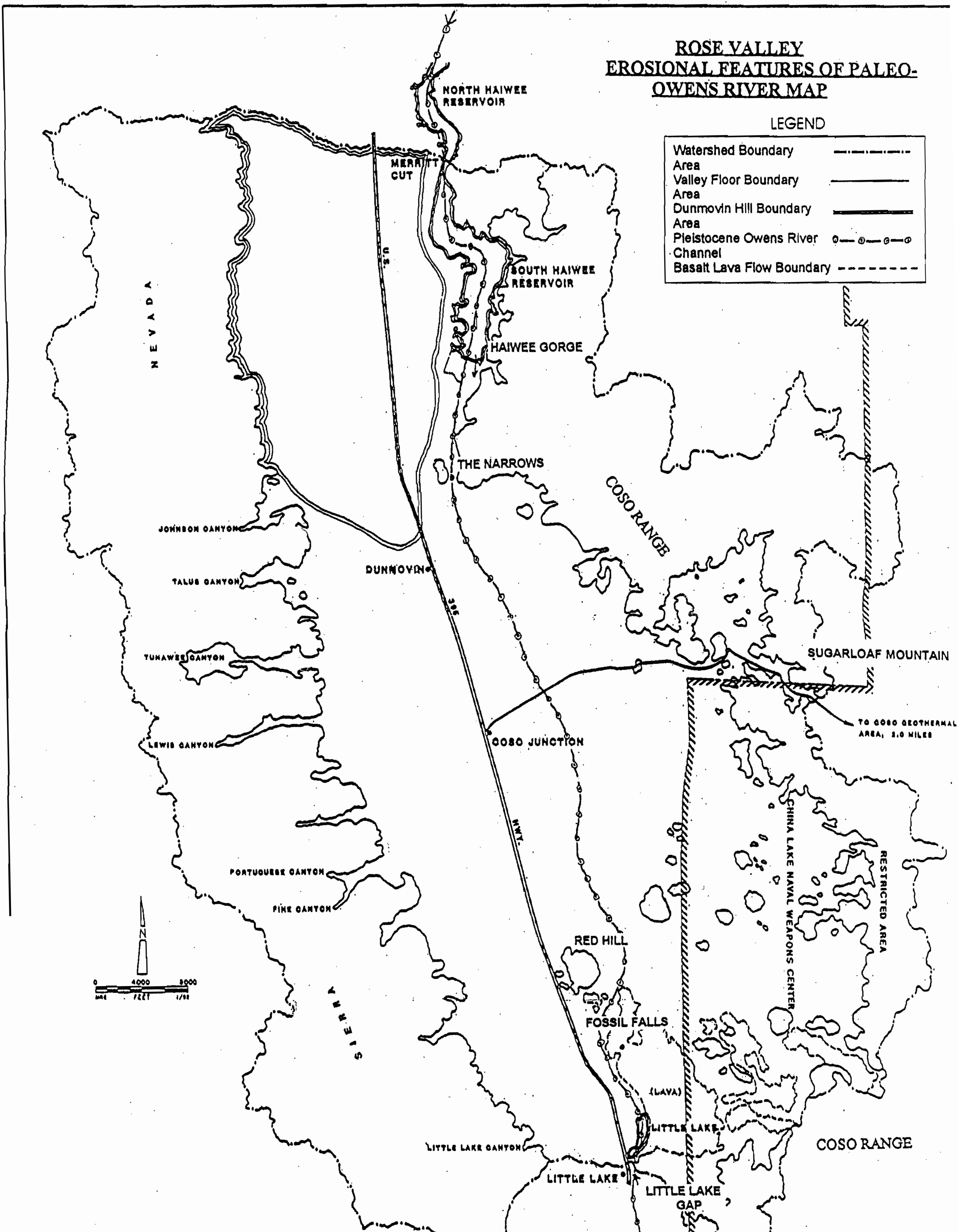
Figure 16. Pleistocene lakes of the western Great Basin. (Map modified after Grayson, 1993).

Panamint and Death Valleys, respectively (Grayson, 1993 and Smith and Street-Perrot, 1983). During this time, Pleistocene Lake Owens had a depth of 220 feet, a maximum surface area of 205 square miles, and a drainage basin area of 4,235 square miles (Gale, 1915). After the end of the Pleistocene, the Mojave and Great Basin deserts became increasingly arid. Most of these lakes disappeared, leaving behind dry stream courses, hanging lakeshores, and playas composed of various salt deposits.

The Pleistocene Owens River was responsible for eroding and depositing large amounts of geologic material in the southern Owens and Rose Valleys. The erosive action of the river is evident in several locations in the region, including the eastern eroded margin of Dunmovin Hill, the abandoned channel known as Haiwee Gorge that now contains Haiwee Reservoirs, water gaps cut at the Narrows, Fossil Falls, and Little Lake Gap, and the abandoned stream channel that contains Little Lake (Figure 17).

Dunmovin Hill's eastern extent and the surface outcrop of the Coso Formation were both eroded by the Pleistocene Owens River. The eroded portion of Dunmovin Hill and the exposed Coso Lake Beds left a channel, known as Haiwee Gorge, from approximately 100 to 150 feet deep by 1,000 to 1,500 feet wide (Figure 17). This abandoned stream-carved channel now contains both north and south Haiwee Reservoirs and Merritt Cut (Merritt Divide) (Figures 1 and 17). Merritt Divide is the currently held groundwater and watershed boundary between the Owens Valley and the Rose Valley (Danskin, 1988).

Erosion through a rhyodacite flow by the Pleistocene Owens River at the southern end of Haiwee Gorge created a gap approximately 1,000 feet wide known as "The Narrows" (Figures 14 and 17). The depth of further downcutting by the river and subsequent fluvial and alluvial infilling in this part of Haiwee Gorge is believed to range from 150 to 200 feet (L.A.



ROSE VALLEY
EROSIONAL FEATURES OF PALEO-OWENS RIVER MAP

Jackson, LADWP geologist, personal communication, March, 1999). A landslide visible on the east side of "The Narrows" is probably the result of over-steepening at the base caused by Pleistocene Owens River erosion (Sharp, 1976). From here, the Pleistocene Owens River flowed south through the Rose Valley.

In the northern Rose Valley, the Owens River meandered to the east. Evidence of the depth of erosion is not available for this portion of the valley floor. However, shallow subsurface evidence for the meandering river's existence is found in the form of coarse river deposits to be discussed further in the following section. Southeast of Coso Junction, the Pleistocene Owens River flowed to the east of Red Hill cinder cone, eroded the basalt flows of this volcano, and created a deep gorge which includes Fossil Falls, a series of waterfalls and cliffs carved out of basalt by the glacial runoff of this river (Figure 17).

From Fossil Falls, the channel that contains Little Lake was created by fluvial erosion and downcutting of both the overlying basalt of northern Little Lake Ranch and the underlying Sierra Nevada and Coso Range older alluvial fans. The Pleistocene Owens River then eroded the basement rocks of the Coso Range, south of Little Lake, creating Little Lake Gap (Figure 17). This gap marks the southern boundary and surface watershed boundary of Rose Valley. At Little Lake Gap, exposed Coso Range basement rocks are separated by an east-west distance of approximately 1,000 feet. Therefore, only a narrow conduit of alluvial fill connects the Rose and Indian Wells Valleys in this area. The subsurface geology of Little Lake Gap comprises a critical piece of the puzzle in understanding the distribution and retention of groundwater, and the creation of Little Lake within the southern Rose Valley. The extent of possible downcutting by the river here is unknown, however, wells in the area have been drilled to depths of 100 to 125 feet and have not reached bedrock (Karl

Kirschenmann, personal communication Nov., 1998; Well Log #2, Appendix 8). Another plausible explanation is that this fill may be due to faulting and subsequent alluvial and fluvial infilling with little or no erosion being needed.

f. Depositional Effects of the Pleistocene Owens River

Deposits of the Pleistocene Owens River are readily observed in Haiwee Gorge. The total thickness of the deposit in this area is at least 175 feet (L.A. Jackson, LADWP geologist, personal communication, 1999). In the east central Rose Valley, along the Pleistocene Owens River's meander zone, surface deposits of the river occur in a band approximately one-eighth mile wide. The deposits are clearly visible as a river meander zone on aerial photographs of the study area. These surface sand and gravel deposits exhibit fining-upward sequences and cross-bedding characteristics of river-laid deposits rather than alluvial fan or debris flow deposits. The hydrogeologic significance of these buried river deposits will be investigated in a future section.

2.4 Hydrological Overview

The watershed area of the Rose Valley encompasses approximately 112,000 acres (175 square miles) (Figure 17). The western watershed boundary is the crest of the Sierra Nevada, and its eastern boundary trends approximately north and south of Sugarloaf Mountain connecting the scattered higher volcanic peaks of the Coso Range (Figure 17). The southern boundary of the Rose Valley watershed is Little Lake Gap and the northern boundary lies between north and south Haiwee Reservoirs and is known as Merritt Divide or Merritt Cut (Figure 17) (Rockwell Report, 1980; Danskin, 1988; LADWP, 1992).

2.4.1 Climate

The climate of Rose Valley and Little Lake Ranch is arid, with hot, dry summers and cold, relatively dry winters. In the winter, snow generally falls above 5,000 feet while rain falls below this elevation. Since Rose Valley and the Coso Range lie within the rain shadow of the Sierra Nevada Mountains, precipitation is sparse on both the valley floor and the Coso Range. The average annual precipitation in Rose Valley ranges from 5 to 7 inches, mostly occurring in the late fall and winter months from November to March (California Department of Water Resources, 1975). Annual average precipitation in the Coso Range varies from 4 to 6 inches (Lager and Johnson, 1997). Effectively negating the annual precipitation and potential to recharge local aquifers in the Rose Valley and the Coso Range is the area's annual evapotranspiration rate of 75 to 80 inches (California Department of Water Resources, 1975).

Summer thunderstorms typically occur between July and September. They tend to be very areally restricted, but can drop considerable amounts of precipitation over a short period of time with a high amount of runoff. Consequently, on the valley floor, this water is not entirely utilized as recharge because of the low soil moisture conditions at the time of these events. However, due to the minimized soil infiltration on the upper mountain slopes as well as the high degree of porosity and permeability found in the stream channels of the proximal portion of the recent alluvial fans bordering the Rose basin, runoff from precipitation falling on the mountain slopes of the Sierra Nevada and Coso Range can recharge the valley's groundwater basin.

2.4.2 Potential Aquifers and their Properties

The primary aquifer within the study area is the recent buried alluvium fan deposits that were sourced from the Sierra Nevada and the Coso Range. Other potential aquifer units within the study area include: 1) older debris flow deposits of Dunmovin Hill; 2) possibly one or more Members of the Coso Formation including the near-surface Rhyolite Tuff Member and possible permeable and porous zones within either the Coso Sand Member or Coso Lake Beds Member; 3) the sand and gravel channel and overbank deposits of the Pleistocene Owens River channel in the southern Owens and Rose Valleys; and to a lesser extent 4) fractured bedrock of the Sierra Nevada and Coso Range.

The earliest investigations of the region's hydrogeology were conducted south of Owens Lake in the Pleistocene Owens River channel at Haiwee Meadows (Lee, 1912). Haiwee Meadows was a wetland located in the middle of Haiwee Gorge, (later to become the location of north and south Haiwee Reservoirs). Lee (1912) believed that bedrock of the Coso Formation in this area prevented any substantial surface water and subsurface groundwater flow to the south. Lee's conclusion established the currently-held belief by Danskin, 1988, Hollett et al., 1991, and Rogers, 1987 among others, that there is no surface water or groundwater connection between the Owens and Rose Valleys (Lee, 1912). As a result, Merritt Divide (Merritt Cut), from this time forward, became both the watershed and groundwater boundary between Rose and Owens Valleys (Figure 17).

Knopf (1918) concluded that the Coso Formation at the southern end of the Owens Valley is consolidated bedrock and, therefore, acted as a subsurface dam for Pleistocene Owens Lake. He stated that the lithologic character of the rocks (referring to the Coso Lake Beds Member of the Coso Formation) that formed the bedrock dam of Owens Lake at its maximum expansion has determined the length of time since the lake last overflowed (Knopf, 1918). His assumption that the bedrock is impermeable implied that evaporation alone, not groundwater outflow, balanced all the lake's inflow (Knopf, 1918). He did not take into account any possible groundwater outflow either above the proposed Coso Formation subsurface dam within the Pleistocene Owens River deposits or within porous and permeable zones of the Coso Formation. However, he added that porous tuffs and breccia of rhyolite pumice formed an important part of the bedrock dam of Pleistocene Owens Lake, and that these lithological components, unless choked by silt, could permit a considerable subsurface flow to the south (Knopf, 1918). This observation was later verified when Haiwee Reservoirs began to fill in 1913. The eastern abutment of the south dam, composed of rhyolite tuff, leaked freely, and prolific springs issued along its base (Knopf, 1918). Knopf concluded that as long as the water of Pleistocene Owens Lake was above the level of the Coso Lake Beds, groundwater could flow through the overlying Rhyolite Tuff Member deposits of the Coso Formation. Knopf never characterized the width or depth of the Coso Formation's potential bedrock barrier below the Merritt Divide area. Consequently, this omission has lead later investigators to conclude that the Coso Formation forms a continuous east-west groundwater barrier from the basement rock of the Coso Range west to the Sierra Nevada basement rock. Knopf (1918) also never discussed the possibility of groundwater flowing through either the buried stream deposits of the Pleistocene Owens River or the debris flow deposits of Dunmovin Hill.

2.4.3 Aquifer Transmissivity

Aquifer transmissivity is the capacity of an aquifer to transmit groundwater horizontally through a unit width by the full-saturated thickness of the aquifer under a unit hydraulic gradient. The units of transmissivity are measured in square feet per day (ft^2/day) or gallons per day per foot (gpd/ft). Transmissivity within the alluvial aquifer of the Rose Valley, for the purposes of this investigation, is assumed to be similar to transmissivity of the alluvial aquifer found in the Owens Valley, due to similar climate, sediment source, and depositional environment.

The coefficient of transmissivity is most accurately determined via pump step-drawdown tests in wells that completely penetrate the aquifer. If this method is not possible, empirical techniques are available for determining an approximate transmissivity by utilizing the specific capacity. Razack and Huntley (1991) modified an equation from Theis (1963) for estimating an aquifer's transmissivity from a well's pumping rate divided by the drawdown (specific capacity). They analyzed 215 data set pairs where transmissivity and specific capacity values were known (Razack and Huntley, 1991). These authors discovered an empirical relationship between the two parameters which can be expressed in the following mathematical model:

$$T = 33.6(Q/h_0 - h)^{0.67}$$

where $T =$ Transmissivity (ft^2/day),
$Q =$ Pumping Rate (ft^3/day),
$h_0 - h =$ Drawdown (ft)

Groundwater yields and specific capacity for five wells in the Rose Valley are used here to estimate an average transmissivity for the Rose Valley (Appendix 10) (Moyle, 1977; Southern California Edison (SCE), 1977). Neither Moyle (1977) nor SCE (1977) specified the aquifer(s) in the Rose Valley from which these values were derived. However, an average pumping water level from the wells from which the data was derived is 148 feet below the surface (Rockwell Report, 1980). Transmissivity estimates for the five wells in the Rose Valley range from 9,000 gpd/ft to 69,800 gpd/ft with an average of 38,240 gpd/ft.

Western Water Company (1999) determined and compiled transmissivity data using monitoring wells within the southern Owens Valley (Western Water Company, 1999, Appendix 3). Their transmissivity values within the saturated deposits in the southern Owens Valley, range from 9,328 gpd/ft to 150,000 gpd/ft (Western Water Company, 1999, Appendix 3). The depths of the wells from which the southern Owens Valley transmissivity values were derived range from 30 to 700 feet.

By using data from aquifer tests, driller's logs of wells, and selected specific capacity tests, transmissivity of the alluvium in the Little Lake Gap area has been estimated by Dutcher and Moyle (1973) to be between 10,000 and 25,000 gpd/ft. The amount of groundwater leaving the Rose Valley through Little Lake Gap would be limited by the constraining width of the aquifer's cross-sectional area which is approximately 1,000 to 1,500 feet, and by the hydraulic conductivity of the aquifer material (Rockwell Report, 1980). The hydraulic conductivity of the alluvial aquifer materials may be high due to the presence of porous and permeable deposits of sand and gravel in the shallow subsurface (Rockwell Report, 1980). In a future section of this report, the hydraulic conductivity of the shallow sediments in the Little Lake Gap area will be described and characterized.

2.4.4 Aquifer Specific Yield

Specific yield is the ratio of the volume of water that a given mass of saturated rock or soil will yield when drained by gravity to the total volume of reservoir material that is being pumped (Jackson, 1997). This ratio is often stated as a percentage. Specific yield values decrease with poorer sorting, decreasing grain size, increased cementing material, and increased compaction (Rockwell Report, 1980). Specific yield values estimated for the Rose Valley for the total saturated alluvium is estimated to range from 10 to 15% (Rockwell Report, 1980).

The volume of saturated fill within the Rose Valley was computed using the edge of the alluvium as the reservoir boundary (minimum 3,000 feet thick) and an average depth to water of 125 feet (Rockwell Report, 1980). The resulting total volume of saturated alluvial fill is estimated to be 33 million acre-feet (Rockwell Report, 1980). Assuming an unconfined aquifer with a 10 to 15% specific yield, the total water in storage is estimated to be 3.3 to 5 million acre-feet, and of this total, 1.4 to 2.2 million acre-feet are estimated to be within 800 feet of the surface (Rockwell Report, 1980). Most of the water is believed to be usable, except Little Lake water, which is too saline for potable water purposes. In addition, geothermal fluids may occur at depth in the alluvial materials in the vicinity of Red Hill.

2.4.5 Recharge and Discharge

Relatively few studies have discussed recharge and discharge of groundwater into and out of the Rose Valley area (Rockwell Report, 1980, Dutcher and Moyle, 1973). Rainfall on the Rose Valley floor is considered to be too sparse and erratic to contribute significant recharge to the groundwater aquifer (Rockwell Report, 1980). Consequently, recharge to the Rose Valley is presumed to be distributed among the following four sources: 1) runoff from heavy precipitation in the Sierra Nevada and Coso Range, 2) canyon stream water infiltration into the eastern slope of the Sierra Nevada and its associated proximal alluvial fans, 3) groundwater inflow from the Owens Valley to the north, 4) leakage from the Los Angeles Department of Water and Power aqueducts (Rockwell Report, 1980). Leakage from the LADWP aqueducts will not be investigated in this study. A fifth potential recharge source that needs to be investigated in future studies is fracture flow from the Sierra Nevada and Coso Range. Two authors have investigated discharge of surface water and groundwater from the Rose Valley and their findings will be presented here (Rockwell Report, 1980, Dutcher and Moyle Jr., 1973).

The total quantities of groundwater recharge to the Rose Valley have not been definitively established. Investigators' estimates vary widely regarding the possibility and the amount of underflow from the north and the contribution from precipitation in the Sierra Nevada. Precipitation runoff from the Coso Range is considered to be negligible, due to the rain shadow effect of the Sierra Nevada. The Naval Weapons Center (1979), using a method to determine groundwater recharge described by Spane (1978), estimated a value of 611 acre-feet/year (ac-ft/yr) for groundwater recharge to the Rose Valley from the combined precipitation in the Sierra Nevada and the Coso Range (Rockwell Report, 1980). The Los Angeles Department of Water and Power (LADWP) (1976) estimated the subsurface underflow component of recharge from the deeper aquifer in the Owens Valley at 10,680 acre-feet/year. This estimate was based upon an estimated cross sectional area, permeability, and hydraulic gradient. However, LADWP never identified the aquifer through which water is transferred from the Owens to the Rose Valley. Hollett et al. (1991) do not know the exact quantity of groundwater underflow from the Owens Valley to the Rose Valley, however, Darcy's law calculations to determine underflow produced a range from 5,000 to greater than 50,000 acre-feet/year. A water budget developed by Lopes (1987) for the area surrounding Owens Dry Lake gives a value of 15,000 acre-feet/year as underflow across the southern Owens Valley boundary.

The Rockwell Report (1980) and (Western Water Company, 1999 personal communication) concluded that no subsurface underflow occurs to Rose Valley from the aquifer of Owens Valley due to the presence of a groundwater divide (Merritt Divide) which separates south Haiwee Reservoir from north Haiwee Reservoir (Figure 17). Their interpretation of the shallow groundwater contours showed that the groundwater table slopes away from the Rose Valley on the north side of this divide (Rockwell Report, 1980, and Western Water Company, 1999, personal communication). They did not address the possibility or existence of a deeper ground-water connection in either the Coso Sand or Coso Lake Beds Members, or a shallow groundwater connection in the Sierra Nevada-sourced alluvial fan deposits, fluvial deposits of the Pleistocene Owens River, and/or Rhyolite Tuff Member volcanic deposits of the Coso Formation.

Other studies have addressed groundwater discharge from the Rose Valley to the Indian Wells Valley (Dutcher and Moyle Jr., 1973; Saint Amand, 1980). These authors conclude that a limited amount of surface runoff and groundwater underflow comes from Rose Valley into the Indian Wells Valley, and that the Rose Valley is essentially a closed basin.

3.0 Methods and Materials

3.1 Geology, Lithology, and Stratigraphy

This section outlines the procedures used to accomplish the objectives of this study. It is divided into four categories: lithology and stratigraphy; hydrology; hydrogeochemistry; and soils and hydraulic conductivity analyses. The results of these procedures and their interpretations will be presented in subsequent sections.

The objectives for investigating the geology, lithology, and stratigraphy are: 1) to determine if aquifer units exist which could potentially transmit groundwater between the southern Owens and Rose Valleys, and 2) to explore the mechanism(s) that result in the presence of Little Lake in the southern Rose Valley. Using information derived from literature review, aerial photographs, hydraulic conductivity determinations, and field observations; a geologic map and cross section of the southern Owens Valley and the southern Rose Valley were constructed (Plates I and V). In addition, a soils map was constructed for Little Lake Ranch (Plate IV).

a. Geologic Map of Southern Owens and Rose Valleys

Utilizing a geologic map constructed by California Division of Mines and Geology and field observations by the author, a geologic map of the southern Owens Valley south to the Little Lake Gap area in the Rose Valley was compiled (Stinson, 1977) (Plate I). Aerial photographs provided by the USGS were used to define the geology of the southern Owens and Rose Valleys, and to locate and characterize the most recent location of the Pleistocene Owens River channel within the study area. Both field observations of abandoned stream channels and lighter rock color on aerial photographs were used as criteria to define the most probable location of the Pleistocene Owens River. Surface geologic control of the Coso

Formation was obtained by taking field attitudes of the Coso Lake Beds Member east of Haiwee Reservoir. These beds were measured with a Brunton pocket transit.

b. Geologic Cross Section in Northern Rose Valley

Subsurface geologic control for stratigraphic columns and geologic cross sections was obtained from well log data supplied by Inyo County Environmental Health Department and from data published in a report by Schaer (1981). Surface geologic control for the cross section located in the Merritt Divide area was undertaken utilizing a Brunton compass to determine the dip of the Coso Lake Beds Member of the Coso Formation.

c. Little Lake Ranch Geology and Soils Maps

Previous mapping of the geology of Little Lake Ranch and the southern Rose Valley was documented by Duffield and Smith (1978). The geology of Little Lake Ranch was mapped from aerial photographs and from field observations by the author (Plate III). The paleosols occurring at Little Lake Ranch were first observed by Duffield and Smith (1978). They also recognized that there may be five different soil families in the Little Lake Ranch area. Utilizing aerial photographs supplied by the USGS, the five potential soil families of Little Lake Ranch were mapped by the author (Plate IV). These soil families were then field surveyed and mapped utilizing soil field tests, soil cores, and soil trenches excavated to depths of up to fifteen feet.

Hydrology

a. Water Budget Determination

A water budget was calculated for Little Lake in order to quantify probable recharge and discharge in the Rose Valley, and to determine the most probable source for groundwater in the Rose Valley and Little Lake. Climatological data for Rose Valley and the Coso Range were obtained from data published by the California Department of Water Resources (1975) and Edwards and Condon (1989).

In Little Lake Ranch, five water discharge sites were monitored on a quarterly basis for a one and one-half year period using a Stevens Model 2100 current velocity meter. A figure showing the stream gaging locations is presented in Section 4.4.1- Hydrologic Investigations at Little Lake Ranch Overview. These measurements were used to calculate the amount of water discharge in the southern Rose Valley.

The daily fluctuation of the water level of Little Lake was monitored for a period of thirteen months using a HERMIT Model SE 1000C Environmental Data Logger and a pressure transducer. A figure showing the transducer locations is presented in Section 4.4.3- Little Lake's Water Budget. The hydraulic pressure was converted to a head value using a mathematical formula programmed into the data logger. The change in elevation of the water over this time period was recorded once every twenty-four hours. The lake level and the groundwater table in a nearby well were simultaneously monitored to assess the relationship between groundwater and lake levels. Transducer sites and top of well casing elevations located on Little Lake Ranch were field-surveyed using a Nikon AX-1 Automatic Engineer's Level. Measured survey points were based on USGS benchmarks and field checked daily for accuracy.

b. Equipotential Map of Southern Owens Valley and Rose Valley

Depth to groundwater was measured by the author in twenty-three wells in southern Owens Valley, Dunmovin Hill, and in Rose Valley, using a Solinst 300 foot electric well sounder. A figure of the depth to groundwater measurement locations will be presented in Section 4.1.- Equipotential Map for the Southern Owens Valley South to Rose Valley. Depth to groundwater measurements were used to determine groundwater elevations and to construct a potentiometric surface map of the study area (Plate II), and a north to south groundwater table elevation cross-section (Plate V).

c. Evaluation of Potential Aquifers

California state well log completion reports and geologic cross sections from Schaer (1981) and Stinson (1977) were used to determine the existence of potential aquifers within the study area. Using data from twenty-eight California state well drillers' logs, six lithologic logs from Schaer's report, and cross sections of the southern Owens Valley from Stinson (1977), potential aquifer units were defined. Previous studies on the type and depth of potential aquifers in the Rose Valley is limited to the Rockwell Report (1980). Los Angeles Department of Water and Power supplied groundwater table elevation data in the Haiwee Reservoir area, and Danskin (1988) supplied information on the aquifer system in the Owens Valley.

3.3 Hydrogeochemistry

Thirty water samples from both surface and groundwater sources were collected in 250-milliliter high-density polyurethane (HDPE) bottles. A figure showing the water sample locations is presented in Section 4.2.- Hydrogeochemistry. All well-water samples were secured from pumping wells at the wellhead. No chemical additions or treatments were used on any of the wells sampled. Each sample was tested in the field for pH, alkalinity, temperature, total dissolved solids (TDS) (as calculated from the electrical conductivity), and electrical conductivity (EC). An Orion pH meter was utilized to measure pH and water temperature. A Hach portable TDS meter was used to measure TDS and EC. Alkalinity was measured by titration in the field using a Hach portable microtitrator with sulfuric acid as the titrating acid. The water sample was pumped through a 0.45 micron filter with a Master Flex sampling pump, packed and chilled to 4^{o} C, and shipped to the Colorado School of Mines for chemical laboratory analysis. The major ions analyzed were: potassium, sodium, calcium, magnesium, bicarbonate, sulfate, and chloride.

Fingerprint plots (Mazor, 1991) of the aqueous geochemical data were used to characterize the relationships between water samples. These graphs allow comparison of water samples based on their cation-anion ratios using pattern similarity recognition techniques. A fingerprint plot is composed of an x-axis showing the major ions and a y-axis depicting the concentration of these ions in millequivalents per liter (meq/L) plotted on a logarithmic scale. The patterns of water types with similar or contrasting geochemical evolutionary pathways can often be readily recognized in a fingerprint plot. Consequently, the pattern of a particular unknown groundwater being investigated in a region can often be matched to similar known groundwater, suggesting possible hydraulic connections.

3.4 Soils and Hydraulic Conductivity Analyses at Little Lake Ranch

a. Soils Investigation

Using a first order soil survey, the soils of Little Lake Ranch were mapped at a scale of 1:24,000 on a Little Lake 7.5 minute U. S. Geological Survey (USGS) quadrangle map (Soil Survey Manual, 1993). Individual soil map units were described and classified utilizing soil trenches excavated to depths of four to six feet and soil cores augered from five to fifteen feet. A representative soil sample was obtained from each soil horizon and sieved utilizing an ASTM number 10, 2.0-mm soil sieve. The soil texture of each sieved soil sample was determined by the feel method. The feel method is a qualitative field technique utilized by soil scientists to determine the percentage of sand, silt, and clay (soil texture) of a particular soil. In addition, the following soil properties were determined by standard soil field observations techniques: soil structure, soil horizon boundaries, soil color (Munsell Color Chart, 1994), and the amount and type of rock fragments greater than 2.0 mm in diameter. The latter was determined by visual inspection of a soil trench or augered soil material (Soil Survey Manual, 1993). Soil pH and the presence of carbonates were tested using bromcresol green indicator solution and 10% hydrochloric acid (HCl), respectively (Soil Survey Manual, 1993).

A soil profile description includes: vegetation present, depth to groundwater, thickness of each soil horizon, slope and drainage class determinations, soil parent material, percent coarse fragments > 2.0 mm, soil color, soil texture, soil temperature, percent soil organic matter, depth to root and water restricting zones, estimated soil porosity, and presence of mottles. The existence of mottles usually indicates the presence of shallow and/or fluctuating groundwater tables (Soil Survey Manual, 1993).

b. Hydraulic Conductivity Measurements

Hydraulic conductivity is dependent on the porosity, grain size, type of grain sorting, pore distribution, tortuosity of the soil/sediments, and the density and viscosity of the fluid (Hillel, 1980). Hydraulic conductivity can be estimated using Darcy's law:

$$Q = -KA(dh/dl)$$

where Q = discharge (cm^3/s),
K = hydraulic conductivity (cm/s),
A = cross-sectional area (cm^2),
and dh/dl = hydraulic gradient.

Hydraulic conductivity of the soils and sediments of Little Lake Ranch was measured using a Guelph Constant Head Permeameter (Figure 18). The Guelph Constant Head Permeameter operates according to the Mariotte Principle. The Mariotte Principle provides

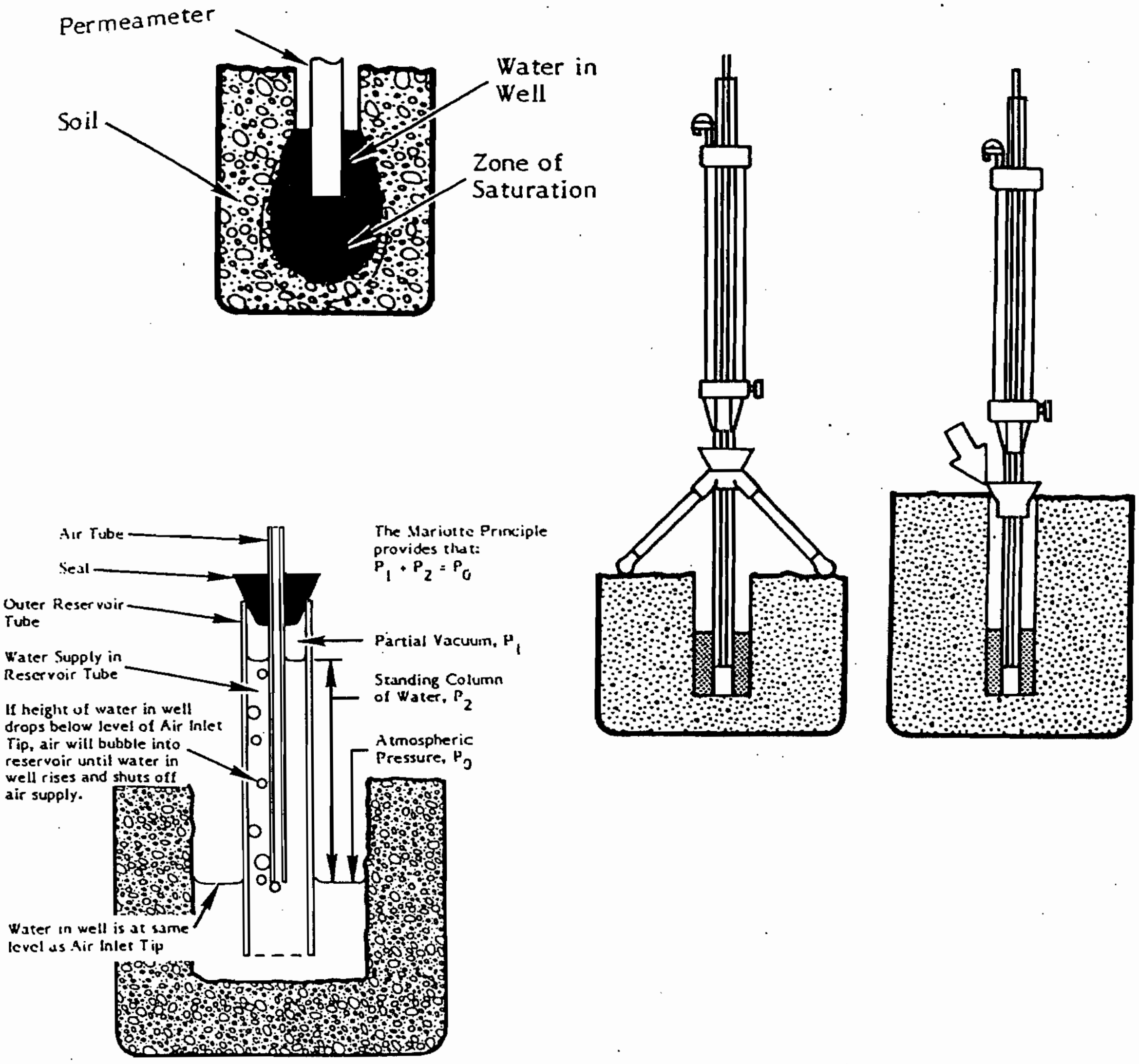


Figure 18. Guelph Constant Head Permeameter and method of operation, (Soilmoisture Equipment Corp., 1986).

that the pressure from the partial vacuum above the reservoir plus the head of the standing water column within the instrument's plastic cylinders equals the atmospheric pressure on the water surface in the well at a predetermined head (Figure 18). A numerical scale on the permeameter reservoir measures the rate of recharge required to maintain a constant head within the well (Moody, 1989). The Mariotte Principle can be expressed by the equation (Soilmoisture Equipment Corp., 1986):

$$P_1 + P_2 = P_0$$

where: P_1 is the partial vacuum within the plastic outer reservoir,
P_2 is the standing water column within the outer reservoir,
and P_0 is the atmospheric pressure within the augered well.

Hydraulic conductivity values obtained from the permeameter were corrected using an equation which incorporates the Marriotte Principle with the specific permeameter tube diameter (Soilmoisture Equipment Corp., 1986). Mathematical equations known as the Glover and Standard methods were used to convert the raw field data to hydraulic conductivity values.

At Little Lake Ranch, twenty-nine boreholes were augered to a depth of 2 to 5 feet, depending upon the soil texture. A figure showing the hydraulic conductivity determination locations is presented in Section 4.4.2 - Hydraulic Conductivity Determinations of the Shallow Soil at Little Lake Ranch. The permeameter was installed in each of the augered wells and water was added to the permeameter, which then drained into the well while maintaining a constant head. The rate at which the water flowed from the permeameter's graduated cylinders to the well to the saturated three-dimensional soil column was recorded every minute. When three or more readings were identical in their flow rates, equilibrium was assumed, i.e., a constant flow of groundwater within the saturated soil had been attained. These values were then used to characterize the hydraulic conductivity of the soils and aquifer materials at Little Lake Ranch.

I. Potential Subsurface Groundwater Flowpaths

4.0 Discussion and Results

4.1 Equipotential Map for the Southern Owens Valley South to the Rose Valley

In order to determine potential groundwater flow directions within the study area, depth to groundwater was measured in several wells in both the southern Owens Valley and the Rose Valley (Figure 19) (Appendix 2). An equipotential surface map was constructed from water level measurements made by the author and from well drillers' reports (Plate II).

The following assumptions and limitations apply for the construction of the equipotential map:

1) All the water levels used to construct the equipotential surface map were not determined at the same time nor by the same individual; hence, seasonal, annual, or long-term variations are likely to introduce some distortion into the interpretations.

2) Well head elevations (except for the surveyed Little Lake Ranch wells) were determined directly from USGS 7.5 minute topographic maps with 40 or 80-foot contour intervals. These values were field-checked with a Thommen TX mechanical altimeter with an accuracy of ± 20 feet. The altimeter was field- checked daily at a USGS benchmark.

3) The groundwater level measurements were not corrected for temperature or barometric pressure.

The equipotential map suggests that groundwater in the southern Owens Valley north of Sageflat Road Divide is flowing north (Plate II). South of Sageflat Road Divide, the groundwater is flowing south. This indicates the presence of a partial groundwater divide at Sageflat Road (Figure 19). Sageflat Road Divide runs east to west along the northern terminus of Dunmovin Hill along an east-trending ridge of Sierra Nevada granodiorite. This granitic bedrock outcrop terminates at a north-striking fault scarp approximately one-eighth

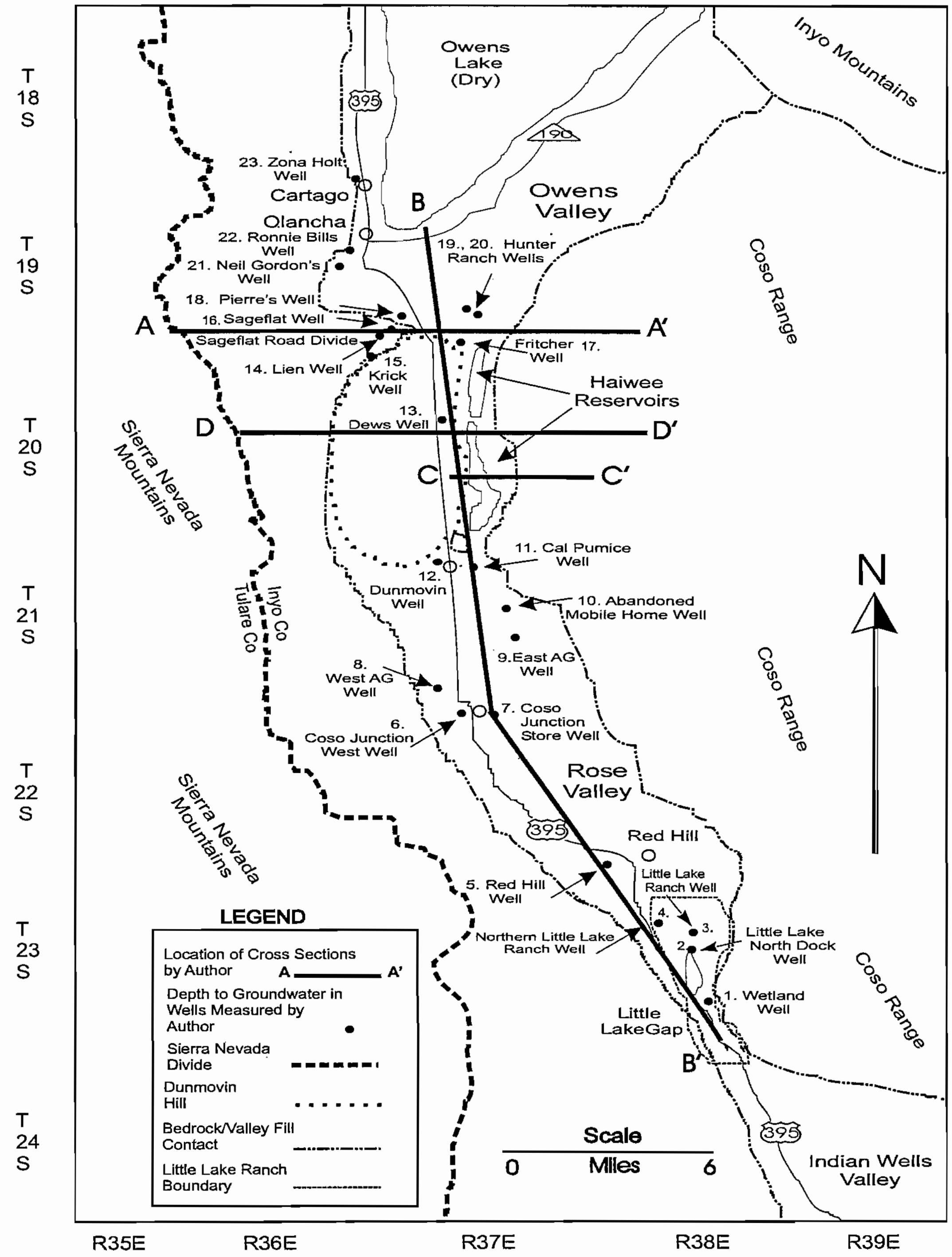


Figure 19. Locations of depth to groundwater measurements by author in the Rose and southern Owens Valleys, Inyo County, California. Also locations of east-west cross sections: A-A' alongSageflat Road Divide; D-D' Dunmovin Hill; C-C' Coso Lake Beds; and B-B' north to south cross section through study area for Plate V.

mile west of Highway 395, along the west side of the southern Owens Valley (Figure 20). This highly-fractured, granitic extension of the Sierra Nevada appears to be acting as a partial groundwater barrier between the southern Owens Valley and the Rose Valley. In the area between the Sageflat Road Divide fault and north Haiwee Reservoir, alluvial fill approximately 500 feet in thickness extends in an arcuate pattern east to north Haiwee Reservoir, south to Rose Valley, and northeast to the southern Owens Valley (Stinson, 1977).

East of Sageflat Road Divide, the groundwater flows northward into the southern Owens Valley, and appears to be the result of north Haiwee Reservoir water infiltrating directly into the alluvial and fluvial deposits comprising the base of North Haiwee Reservoir (Plate II). This surface water has a higher elevational head than the groundwater within the Owens Valley to the north. North Haiwee Reservoir water also appears to be flowing west and southwest within the alluvium south of Sageflat Road Divide (Plate II). Infiltrating runoff from perennial creeks draining the Sierra Nevada north of Sageflat Road Divide also becomes shallow groundwater flowing east and northeast into the southern Owens Valley. Groundwater south of Sageflat Road Divide flows south into the Rose Valley through the Rhyolite Tuff Member deposits of the Coso Formation and through the Sierran-sourced alluvial deposits west of Haiwee Reservoirs.

The equipotential surface map also reveals that the groundwater flow direction south of Sageflat Road Divide is primarily from the west, north, and east sides of the basin towards the center of Rose Valley and then south to Little Lake (Plate II). Sierra Nevada canyon stream runoff and subsequent infiltration into the alluvial fans recharges the aquifers of the Rose Valley from the west and northwest. Groundwater originating from the north enters the Rose Valley through alluvium derived from Sierra Nevada and Coso Range canyons and

Southern Owens Valley West to East Cross Section
Sage Flat Road Divide to Coso Range

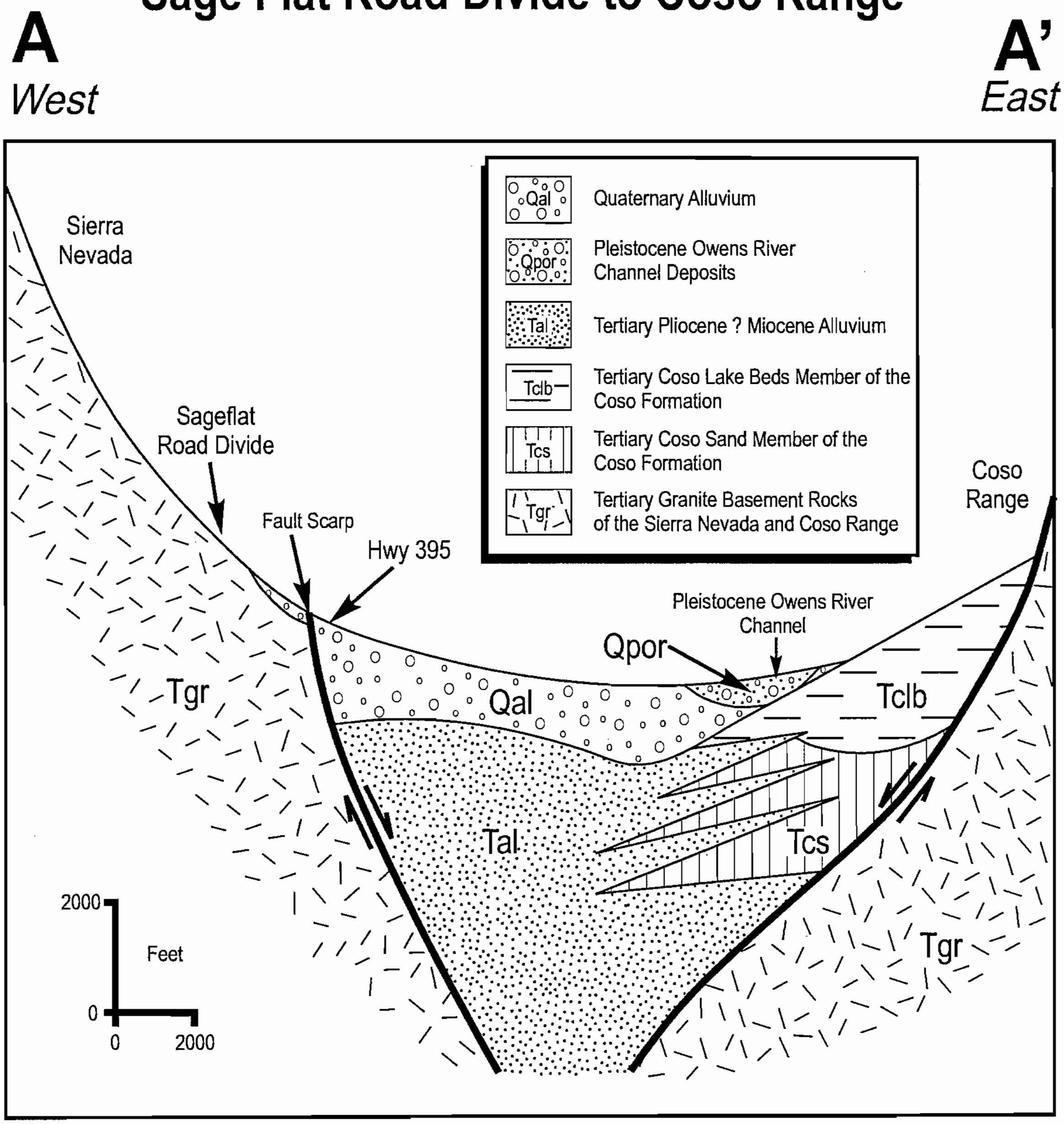


Figure 20. West to east cross section (A-A') through Sageflat Road Divide area. This area is the location of a partial groundwater divide in the study area (see Plate II), southern Owens Valley, Inyo County, California. See Figure 19 for location of cross section.

sediments located beneath south Haiwee Reservoir. This groundwater flows south within the Rose Valley through the alluvial basin fill. Along the east side of Rose Valley, the Coso Range contributes groundwater on an ephemeral basis primarily after heavy precipitation events when the soil can no longer hold any additional soil moisture. Springs near Little Lake in the southern Rose Valley suggest that the area north of Little Lake Gap appears to be a primary discharge point for Rose Valley groundwater (Plate II). Stream gaging on Little Lake outflow creek in the Little Lake Gap area indicates that as much as 5,300 ac-ft/yr. is being discharged into the Indian Wells Valley.

4.2 Hydrogeochemistry

4.2.1 Water Sample Locations

The chemical composition for water within the study area was investigated in order to identify and compare major water types, and to determine the possible origins for water found at Little Lake. Water samples were collected from 18 wells, 7 springs, 4 streams, south Haiwee Reservoir, and Little Lake located in the southern Owens Valley, the Coso Range, the Sierra Nevada, and the Rose Valley (Figure 21). Water sample locations are shown on Figure 21 and listed in Table 1. Depth to groundwater in wells sampled ranged from 15 feet to 200 feet below ground surface. Springs sampled in the study area occur in both the Sierra Nevada and Coso Range from Sageflat Road Divide south to Little Lake Ranch. Streams sampled in the study area drain either the Sierra Nevada batholith east of the Sierran crest or Little Lake and its associated ponds. No perennial surface streams drain either the Coso Range north of Little Lake or the southern Inyo Mountains located on the eastern margin of the southern Owens Valley. All well-water samples were secured from pumping wells at the well head. No chemical additions or treatments were used on any of the wells sampled.

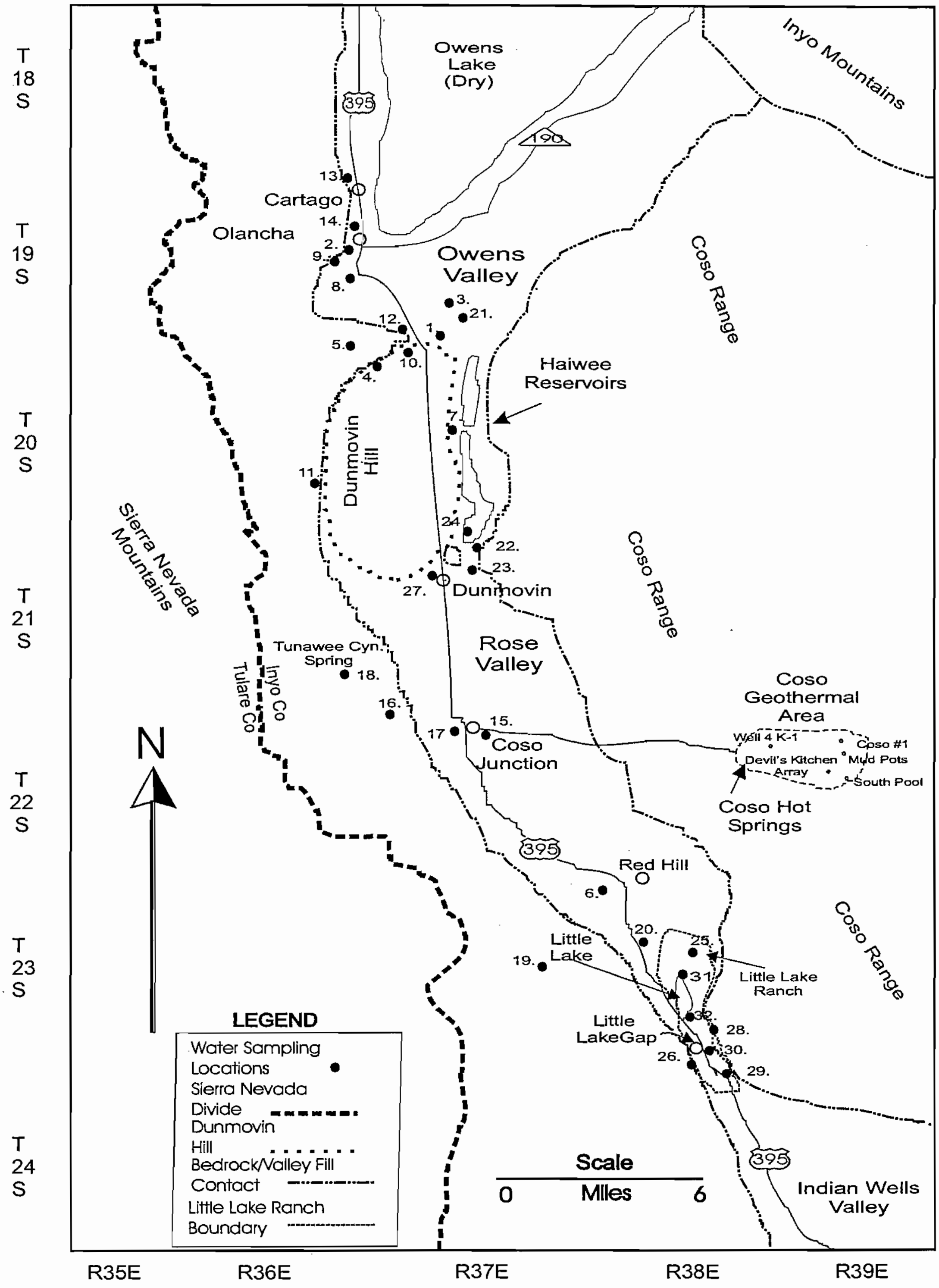


Figure 21. Chemical water sampling locations within the Rose and southern Owens Valleys. For locations of sampling point numbers, see Table 1.

TABLE 1 Water Sample Locations and Water Groups in Southern Owens and Rose Valleys

Map Number	Location	Water Group
1	20S/37E-04B1, Olancha, Owens Valley	I
2	19S/37E-18K02, Olancha, Owens Valley	I
3	19S/37E-33H01, Olancha, Owens Valley	I
4	20S/37E-07J01, Sageflat Road Divide, Dunmovin Hill	I
5	VP Spring, Sageflat Road Divide, Dunmovin Hill	I
6	22S/37E-36B01, Red Hill Road, Rose Valley	I
7	20S/37E-21L01, Enchanted Lake Village, Dunmovin Hill	I
8	19S/37E-18P05, Olancha, Owens Valley	I
9	19S/37E-18L02, Olancha, Owens Valley	I
10	20S/37E-08K01, Sageflat Road Divide, Dunmovin Hill	I
11	Haiwee Creek, Haiwee Canyon, Sierra Nevada	I
12	19S/37E-32G01, Olancha, Owens Valley	I
13	18S/36E-36Q01, Cartago, Owens Valley	Ia
14	Cartago Creek, Cartago, Owens Valley	Ia
15	22S/37E-02R01, Coso Junction Store, Rose Valley	II
16	Portuguese Bench Spring, Rose Valley	II
17	22S/37E-02Q01, West Coso Junction, Rose Valley	II
18	Tunawee Canyon Spring, Sierra Nevada	II
19	Little Lake Canyon Spring, Sierra Nevada	II
20	23S/38E-06R01, Northwest Little Lake Ranch, Rose Valley	II
21	19S/37E-33H02, Olancha, Owens Valley	III
22	Haiwee Ridge Spring, Rose Valley	III
23	Haiwee Pump Station Stream, Rose Valley	III
24	Haiwee Reservoir, South Dam, Rose Valley	III
25	23S/38E-05N01, Little Lake Ranch House, Rose Valley	IIIa
26	Little Lake Fault Spring, Rose Valley	IIIa
27	21S/37E-22R03, Dunmovin, Rose Valley	IIIa
28	Coso Spring, Little Lake Ranch, Rose Valley	IV
29	Little Lake Outflow Creek, South Culvert, Indian Wells Valley	IV
30	23S/38E-17D01, Little Lake Ranch, Artesian Well, Rose Valley	IV
31	Little Lake, North Dock, Rose Valley	IV
32	Little Lake, South Dock, Rose Valley	IV

Table 1. Location of water sample groups within the southern Owens and Rose Valleys, Inyo County, California. Note: Abbreviations are wells numbered by the California State Well Numbering System (refer to Appendix 8 (A-8-21) for definition).

4.2.2 Field and Laboratory Water Sample Data Analyses

The results of both field and laboratory water sample data will be discussed in this section. The geochemical water analyses consisted of the following field determined parameters: pH; total dissolved solids (TDS) expressed as mg/L; electrical conductivity (EC) measured in μS/cm; alkalinity expressed as mg/L of HCO_3 ; and temperature measured in degrees Centigrade (^oC). Measured values for pH, TDS, alkalinity, EC, and temperature for the four major groups and two subgroups of water found within the study area are listed in Table 2.

Results of the laboratory chemical analysis of the water samples are found in Appendix 4. The aqueous chemical data were interpreted using fingerprint plots of the major cations and anions. Based on the similarity of fingerprint patterns, the results suggest that there are four major water groups in the study area, labeled I to IV with two subgroups labeled Ia and IIIa.

Group I water is a calcium bicarbonate water. Group Ia water is also a calcium bicarbonate water related to Group I water, but has a lower chloride concentration, either less than or equal to 0.10 meq/L. Group II water is a calcium bicarbonate water with distinctly higher sulfate concentrations than Group I water. Group III water is a sodium bicarbonate water, while Group IIIa water is a sodium bicarbonate water with distinctly higher magnesium concentrations than other Group III water samples. Group IV water is a sodium bicarbonate water with still higher magnesium concentrations than Group IIIa water. The locations of the water samples are listed in Table 2.

		TABLE 2. Water Sample Field Data						Sample
	Major	Southern Owens and Rose Valleys						Location
Map	Water		Alkalinity	pH	Temp	TDS	EC	Elevations
Number	Group	Location	mg/L HCO3		°C	mg/L	US/cm	Feet
1	I	20S/37E-04B01, Olancha, Owens Valley	150	7.4	20	190	380	3,900
2	I	19S/37E-18K02, Olancha, Owens Valley	127	8	18	290	570	3,650
3	I	19S/37E-33H01, Olancha, Owens Valley	257	7.6	16	380	780	3,680
4	I	20S/37E-07J01, Sageflat Road Divide, Dunmovin Hill	280	7.7	17	430	870	4,000
5	I	VP-Spring, Sageflat Road Divide, Dunmovin Hill	166	7.6	18	200	400	4,200
6	I	22S/37E-36B01, Red Hill, Rose Valley	204	7.5	19	288	570	3,344
7	I	20S/37E-21L01, Dunmovin Hill	144	7.4	17	310	610	3,800
8	I	19S/37E-18P05, Olancha, Owens Valley	79	7.6	18	90	180	3,760
9	I	19S/37E-18L02, Olancha, Owens Valley	101	7.5	17	80	180	3,760
10	I	20S/37E-08K01, Sageflat Road Divide, Dunmovin Hill	89	7.6	19	120	250	3,860
11	I	Haiwee Creek, Haiwee Cyn., Sierra Nevada	233	8.5	7	270	560	5,300
12	I	19S/37E-32G01, Olancha, Owens Valley	128	7.7	19	240	480	3,480
13	Ia	18S/36E-36Q01, Cartago, Owens Valley	67	7.3	18	57	113	3,680
14	Ia	Cartago Creek, Cartago, Owens Valley	35	7.3	14	23	48	3,770
15	II	22S/37E--02R01, Coso Junction Store, Rose Valley	303	7.4	24	480	970	3,370
16	II	Portugese Bench Spring, Rose Valley	190	7.7	20	220	450	3,800
17	II	22S/37E-02Q01, West Coso Junction, Rose Valley	179	7.7	22	340	680	3,395
18	II	Tunawee Cyn. Spring, Sierra Nevada	312	8.1	17	230	620	4,500
19	II	LL Cyn. Spring, Sierra Nevada	251	8	26	400	810	3,800
20	II	23S/38E-06R01, Northwest LL Ranch, Rose Valley	517	6.6	24	670	1350	3,244
21	III	19S/37E-33H02, Olancha, Owens Valley	174	7.9	21	260	550	3,680
22	III	Haiwee Ridge Spring, Rose Valley	142	8.1	18	200	400	3,700
23	III	Haiwee Pump Station Stream, Rose Valley	37	8.2	16	190	380	3,560
24	III	Haiwee Reservoir, South Dam, Rose Valley	39	8.2	8	153	300	3,740
25	IIIa	23S/38E-05N01, LL Ranch House, Rose Valley	312	7.6	21	660	1330	3,162
26	IIIa	Little Lake Fault, Spring, Rose Valley	143	7.9	20	550	1110	3,200
27	IIIa	21S/37E-22R03, Dunmovin, Rose Valley	229	8	30	630	1280	3,480
28	IV	Coso Spring, LL Ranch, Rose Valley	953	7.3	21	931	1250	3,760
29	IV	LL Outflow Creek, South Culvert, Rose Valley	916	8.8	22	1010	2030	2,960
30	IV	23S/38E-17D01, LL Artesian Well, Rose Valley	545	6.8	22	922	1830	3,120
31	IV	Little Lake, North Dock, Rose Valley	396	8.4	8	900	1800	3,145
32	IV	Little Lake, South Dock, Rose Valley	218	9.9	18	750	1470	3,145

Table 2. Field measured results of pH, TDS, EC, Alkalinity, and Temperature for water samples. LL = Little Lake. For definitions of the California well numbering system, see Appendix 8.

4.2.3 Analysis of Water Groups

a. Group I, $Ca\text{-}HCO_3$ Water: Ca>Na & Cl>SO_4

Group I water is a $Ca\text{-}HCO_3$ water derived from twelve sources in the southern Owens Valley, Dunmovin Hill, and the Rose Valley (Figure 22). The twelve water samples were taken from the following geographic locations: six wells within the southern Owens Valley (1,3,8,9,10,12); a spring which discharges from a fractured granitic bedrock outcrop at the northern terminus of Dunmovin Hill along Sageflat Road Divide (5); a well on Sageflat Road Divide (4); from wells located on Dunmovin Hill in the northern Rose Valley (2,7); surface water draining the Sierra Nevada into northern Rose Valley (11); and a well within the southern Rose Valley (6).

Water samples in this group had field pH values that ranged from 7.4 to 8.5. Measured TDS values ranged from 80 to 430 mg/L. The electrical conductivity values ranged from 180 to 870 μS/cm. Alkalinity ranged from a low of 79 mg/L HCO_3 at well (8) in Olancha to a high of 280 mg/L HCO_3 at well (4) in Dunmovin Hill, northern Rose Valley. Temperatures for eleven of the water samples were between 16 and 20° C. Haiwee Canyon Creek water (11), flowing from the Sierra Nevada before infiltrating into the alluvium of Dunmovin Hill, was the coldest at 7° C.

The Group I water fingerprint plot shows the similar fingerprint patterns for all twelve water samples (Figure 22). The chemical composition of Group I water in the wells in the southern Owens Valley area is similar to that of the groundwater found at Dunmovin Hill and groundwater in a well at Red Hill in the southern Rose Valley. The relatively low ionic concentrations of potassium, sodium, magnesium, sulfate, and chloride suggest a short

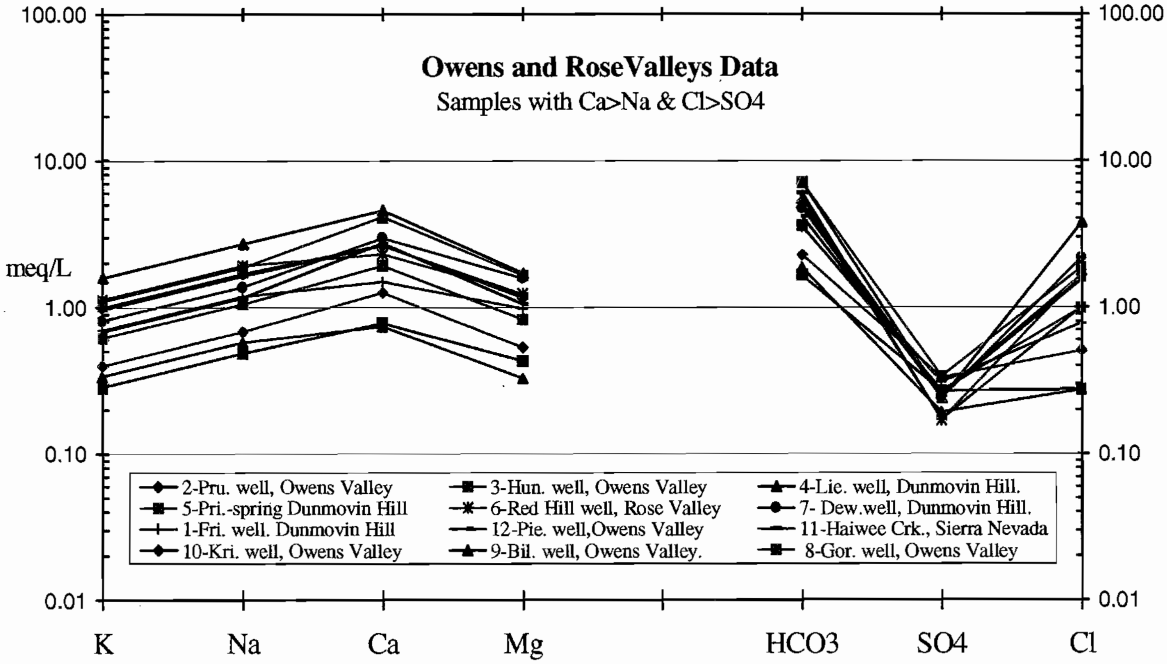


Figure 22. Group I Water. Fingerprint plot of Group I water samples from the southern Owens Valley, Dunmovin Hill, and Rose Valley, Inyo County, California.

residence time in the watershed with only minor dissolution.

b. Group Ia, $Ca\text{-}HCO_3$ Water: $Ca>Na$ & $HCO_3>Cl<1.0$ meq/L

Group Ia water is also a $Ca\text{-}HCO_3$ water. Water samples from Group Ia came from a well and a creek both located in Cartago (13, 14) in the southern Owens Valley (Figure 23). Samples in this group were both taken from sites located on the proximal portion of the alluvial fan of Cartago Creek, a perennial stream that drains the Olancha Peak watershed area in the Sierra Nevada. Water was sampled within one-half mile of the Sierra Nevada's east facing edifice. There is a vertical drop of nearly 7,000 feet from Olancha Peak to these sampling locations.

The two water samples had identical pH values of 7.3. Measured TDS values ranged from 23 mg/L for Cartago Creek (14) to 57 mg/L for the Cartago well (13). The alkalinity as expressed in mg/L HCO_3 ranged from 35 mg/L at Cartago Creek to 67 mg/L at the Cartago well and indicates a relatively pure water close to its source. The electrical conductivity (EC) values varied from 48 to 113 μS/cm. These low TDS and EC values indicate that the water's residence time in the watershed is short, or that the rocks that the water comes in contact with are not very reactive. Temperatures for these two water samples were 14° C for Cartago Creek (14) and 18° C for Cartago well (13).

The fingerprint plot of Group Ia water reveals nearly identical patterns for these two samples (Figure 23). These waters have relatively low concentrations in all major cations and anions. They are especially low in magnesium and chloride ions. Potassium values range from 0.09 to 0.22 meq/L; sodium values range from 0.15 to 0.37 meq/L; magnesium values range from 0.05 to 0.12 meq/L; bicarbonate values range from 0.47 to 1.06 meq/L; and chloride values range from 0.03 to 0.10 meq/L. These values are among the lowest ionic

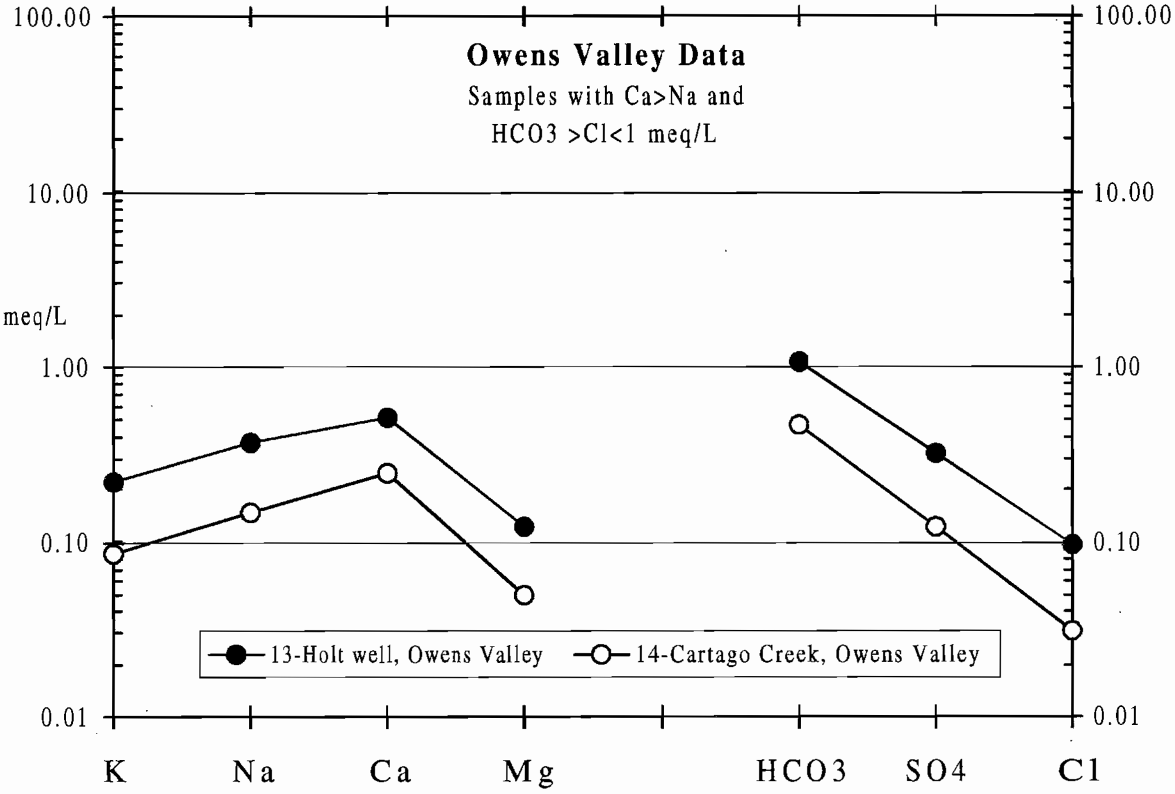


Figure 23. Group Ia water. Fingerprint plot of Group Ia water samples from a shallow well and a stream located in southern Owens Valley, Inyo County, California.

concentrations for all the water samples within the study area. Group Ia water is related genetically to Group I water, but warrants a separate subdivision due to the low concentrations, particularly of chloride.

c. Group II, Ca-Na-HCO_3 Water: Ca>Na & HCO_3>Cl<1.0 meq/L

Group II water is a Ca-Na-HCO_3 water with bicarbonate concentrations greater than chloride concentrations, which are less than 1.0 meq/L, but have significantly greater SO_4 concentration compared to Group I samples (Figure 24). There are six water samples within this group, all taken from within the Rose Valley watershed. Samples in this group include: three wells located in the Rose Valley (15, 17, 20), two springs draining the Sierra Nevada (Tunawee Canyon Spring (18) and Little Lake Canyon Spring (19)), and a spring discharging at the Portugese Bench fault scarp east of the Sierra Nevada frontal fault zone (16).

Group II water samples displayed field pH values from 6.6 to 8.1. The measured TDS values for this group ranged from 220 mg/L to 670 mg/L. The lower TDS values were derived from shallow or surface sources and were found closer to the Sierra Nevada mountain front, whereas the water with the higher TDS values were located in the central and southern portions of the Rose Valley. Temperatures for five of the six water samples ranged from 20 to 26° C. The temperature for Tunawee Canyon Spring (18) was 17° C. Alkalinity for the water group ranged from a low of 179 mg/L HCO_3 at the Coso Junction west well (17), to a high of 517 mg/L HCO_3 at the northern Little Lake Ranch well (20). The electrical conductivity values ranged from 450 to 1,350 µS/cm. Potassium ion concentrations ranged from 0.01 to 0.23 meq/L. These values are lower than the well water samples found in the southern Owens Valley (Group I Water) with the exception of the two Cartago water samples (Group Ia Water). The fingerprint plot of Tunawee Canyon (18) and Little Lake Canyon (19),

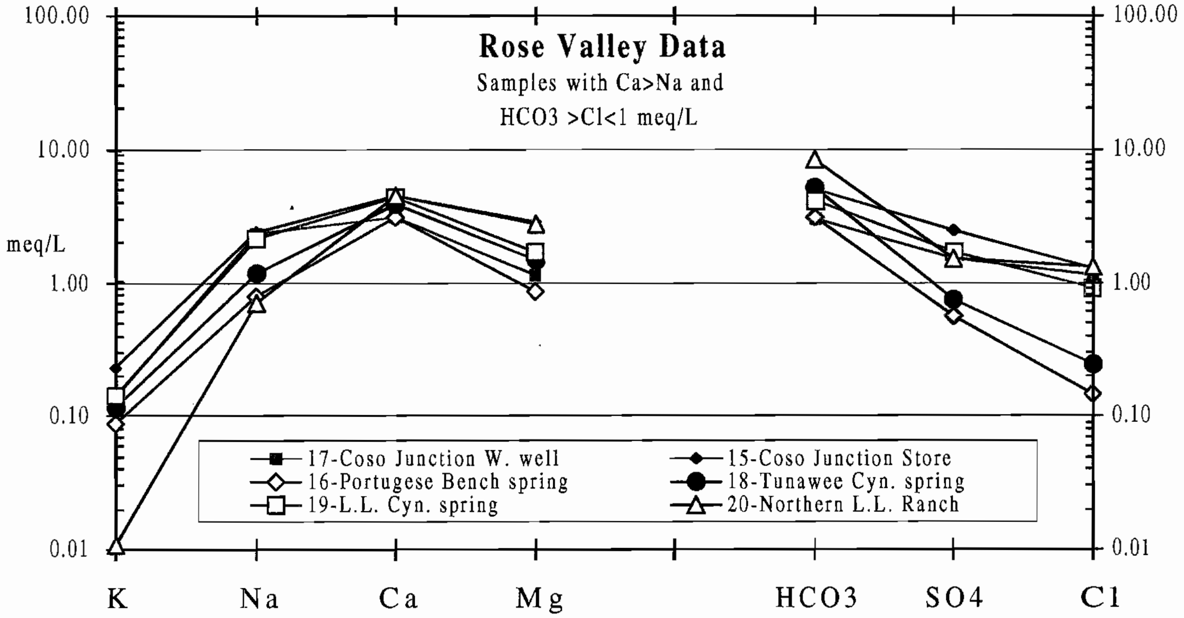


Figure 24. Group II water. Fingerprint plot of Group II water samples from the Rose Valley and Sierra Nevada Mountain canyons entering the Rose Valley, Inyo County, California.

two effluent streams draining the Sierra Nevada into the Rose Valley, shows identical cationic patterns. The Portugese Bench sample (16) resembles water from Tunawee Canyon Spring (18), which lies to the northwest of the Portugese Bench fault scarp.

d. Group III, Na-HCO_3 Water: Na>Ca

The samples that comprise this group are Na-HCO_3 waters (Figure 25). Group III water samples were derived from the northern Rose Valley and the southern Owens Valley. These four water samples came from the following locations: 1) south Haiwee Reservoir (24); 2) a spring located along the west-facing slope of Haiwee Ridge below the eastern abutment of south Haiwee Reservoir Dam (22); 3) a stream draining south Haiwee Reservoir at Haiwee pump station in the northern Rose Valley (23); and 4) an agricultural well located in the southern Owens Valley approximately two miles north of north Haiwee Reservoir within the Pleistocene Owens River channel (21). This latter well penetrates four aquifers (one unconfined and three confined) to a total depth of 700 feet below ground surface.

The pH values for Group III waters ranged from 7.9 to 8.2. The TDS measured values ranged from a low of 153 mg/L at south Haiwee Reservoir (24) to 260 mg/L at the Pleistocene Owens River channel well (21). Alkalinity values ranged from a low of 37 mg/L HCO_3 at the Haiwee pump station (23) to a high of 174 mg/L HCO_3 at the Pleistocene Owens River channel well (21). Electrical conductivity values ranged from 300 to 550 μS/cm. Temperatures for Group III waters ranged from 8 to 21° C.

The Group III water fingerprint plot revealed that these waters are all enriched in sodium. The higher sodium ion concentration relative to calcium ion concentration of Haiwee Reservoir water could either be due to cation exchange, or indicate that the samples are derived from other sources including deep and shallow aquifers or surface water sources

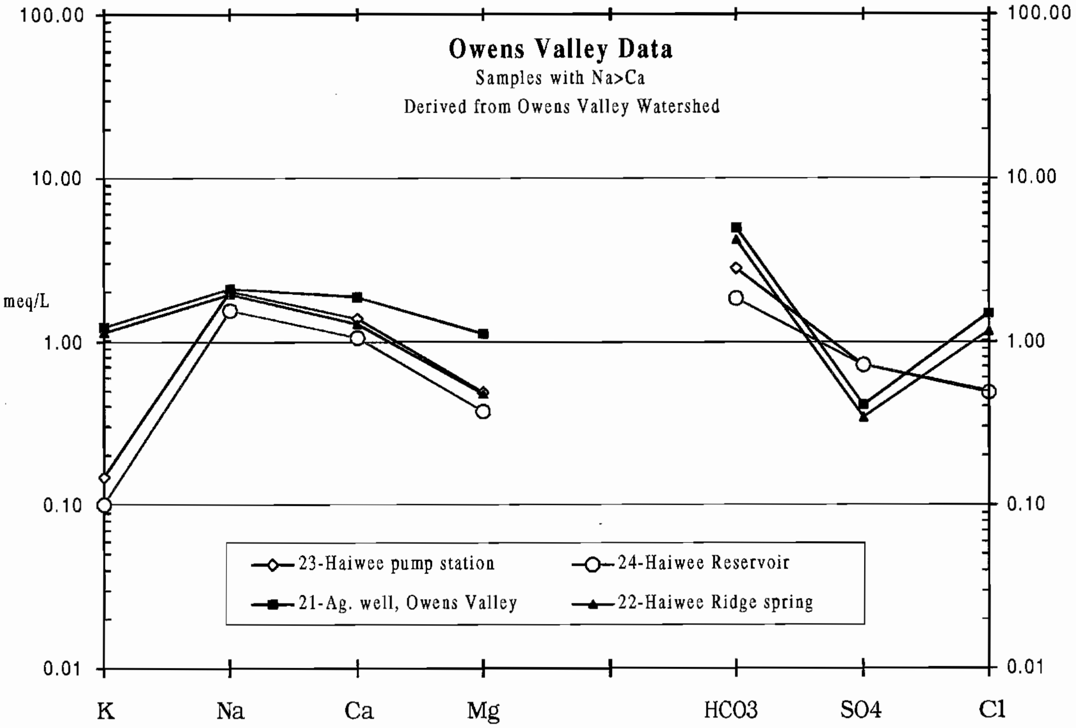


Figure 25. Group III water. Fingerprint plot of Group III water. Samples were derived from a well located in the southern Owens Valley, along the Pleistocene Owens River channel, Haiwee Reservoir toe drain, a spring, and South Haiwee Reservoir located in the northern Rose Valley, Inyo County, California.

draining into the Owens Valley watershed, primarily from the Sierra Nevada. These waters are stored briefly in Haiwee Reservoir for aeration purposes before being transported to Los Angeles for municipal and industrial water use. Water from Haiwee Ridge spring is chemically similar to south Haiwee Reservoir water with the exception of an elevated potassium ion concentration of 1.14 meq/L for Haiwee Ridge spring water vs. 0.10 meq/L for south Haiwee Reservoir water.

e. Group IIIa, Na-SO_4-HCO_3 Water: $SO_4 > Cl$

Group IIIa water is a Na-SO_4-HCO_3 water (Figure 26). Group IIIa water samples were taken from three locations: two in the Rose Valley (25, 27), and one on the Little Lake fault south of Little Lake Gap, in the northwestern Indian Wells Valley (26). Water in Group IIIa water occurs at: 1) a spring (26) on the Little Lake fault north of Wickline Canyon; 2) a shallow well (25) (groundwater table at 15 feet below ground surface) located in northern Little Lake Ranch; and 3) a deep well (27) (groundwater table at 300 feet below ground surface) located in the northern Rose Valley at the town of Dunmovin. Water in this subgroup contains a higher concentration of sulfate ions than in other Group III water (Figure 25).

Field determined pH values for Group IIIa water ranged from 7.6 to 8.0. The measured TDS values for this water ranged from 550 mg/L to 660 mg/L, while Group III water's TDS values ranged from.153 to 260 mg/L. Alkalinity values ranged from 143 to 312 mg/L HCO_3. Electrical conductivity values ranged from 1,100 to 1,300 µS/cm. Two of the three water temperatures were almost identical at 20 and 21° C. The water at the town of Dunmovin (27) had the highest temperature of all the 32 water samples at 30° C.

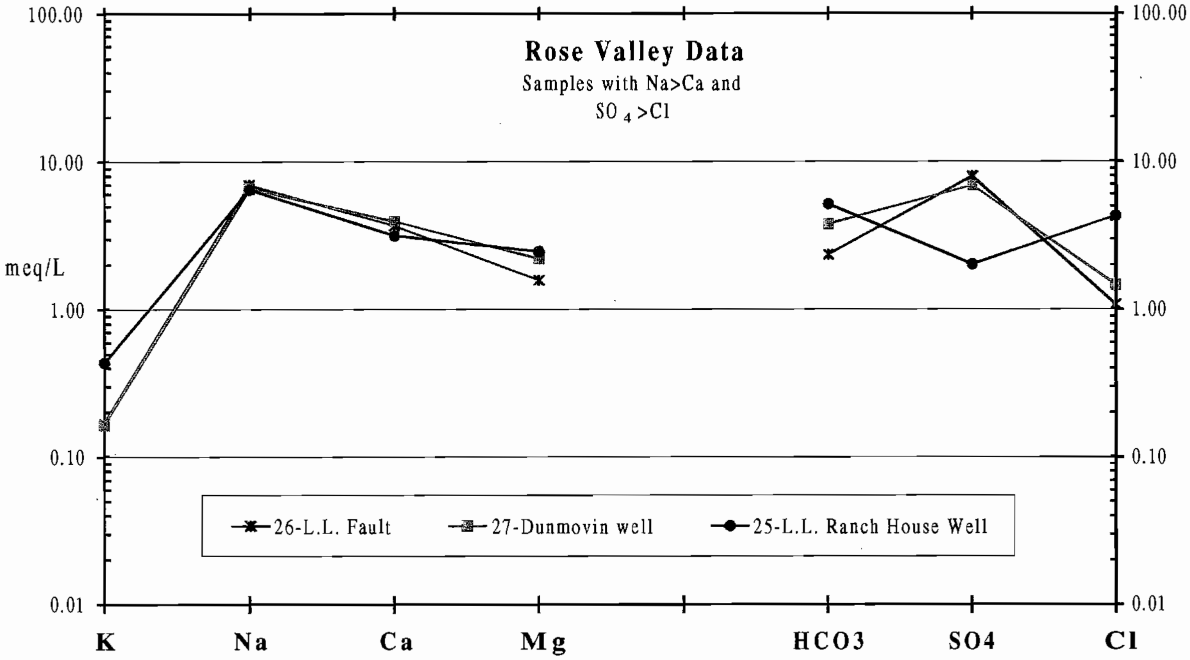


Figure 26. Group IIIa Water. Fingerprint plot of Group IIIa water derived from sources in the Rose Valley and northwestern Indian Wells Valley, Inyo County, California.

f. Group IV, Na-HCO_3 Water: Na>>Mg>Ca

Group IV water is a Na-HCO_3 water. Water samples in this group come from the southern Rose Valley at the following Little Lake Ranch locations: Little Lake (31,32); an artesian well (30) that supplies water to the second pond (P-2) located south of Little Lake; and a Coso Range Spring (28) located approximately 800 feet southeast of the artesian well (30). Group IV fingerprint plot is similar to Group III fingerprint plot with the exception that in group IV water the amount of bicarbonate and chloride are elevated and the amount of calcium is reduced (Figure 27).

This water group displayed pH values that varied widely, ranging from 6.8 to 9.9. The measured TDS values ranged from 750 to 1,010 mg/L. Alkalinity varied from a low of 218 mg/L HCO_3 at the south dock of Little Lake (32) to a high of 953 mg/L HCO_3 at the Coso Spring (28). Electrical conductivity ranged from 1,250 to 1,830 µS/cm. Temperatures for three of the five samples range from 21 to 22° C. These latter three samples were taken from groundwater, while the remaining two were taken from surface water. Temperatures for Little Lake surface water ranged from 8° C in winter to 18° C in autumn.

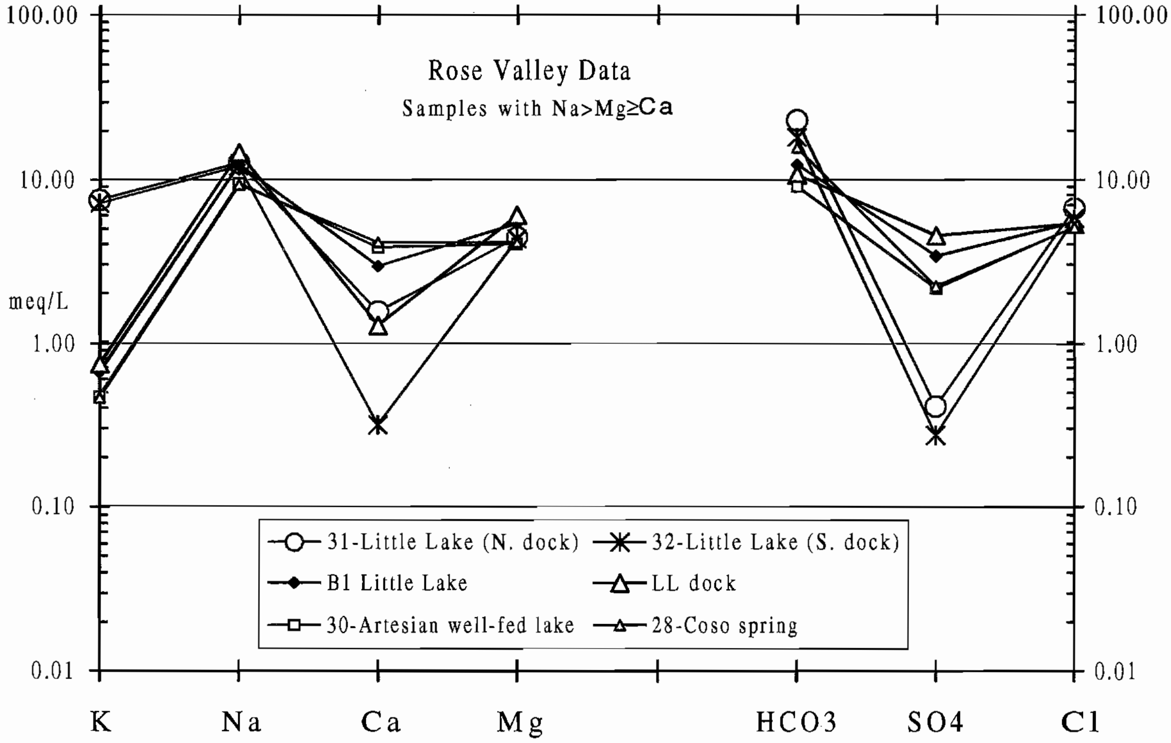


Figure 27. Group IV water. Fingerprint plot of Group IV water derived from sources in the southern Rose Valley, specifically Little Lake Ranch, Inyo County, California.

g. Coso Geothermal Area Water Chemistry, Coso Range: NaCl & $CaSO_4$ Waters

The Coso Geothermal Area (CGA) is located in the Coso Range approximately six miles east of Coso Junction (Figure 21). In order to determine if groundwater from Coso Geothermal Area (CGA) is supplying groundwater to the Rose Valley, aqueous geochemical data from five water samples from Edwards and Condon (1989) were plotted and compared with surface and groundwater found in the Rose Valley. A fingerprint plot of the CGA water is found in Figure 28. This plot suggests that there are two water groups in this area: a high TDS sodium chloride water group, and a lower TDS calcium sulfate water group. Neither of these water groups occurs in the water sampled from the southern Owens Valley or the Rose Valley. The following paragraphs compare and contrast the major ionic species beginning with the cations and then the anions, pH, TDS, and EC of CGA water with the water occurring in the southern Rose Valley at Little Lake Ranch.

The cation fingerprint plots for CGA water slightly resembles Little Lake fault cation fingerprint patterns (Figures 26 and 28). Potassium concentrations of four of the five CGA water samples are similar to Little Lake Ranch potassium values in that they are between 0.10 and 1.0 meq/L, however, the potassium ion value for Coso #1 well is more than 100 meq/L. Water from this well shows no geochemical resemblance to Little Lake Ranch water as far as major ionic concentrations or fingerprint patterns (Figure 28). Sodium ion concentration values of the other CGA samples resemble Little Lake Ranch water with similar concentrations between 1.0 and 10.0meq/L. CGA calcium concentrations also resemble Little Lake water calcium concentrations CGA magnesium ion values for three of the five samples, Coso #1, 4K-1, and Red Mud Pots do not resemble magnesium values found at Little Lake. Two samples, Devil's Kitchen Array and south Pool West Edge, do

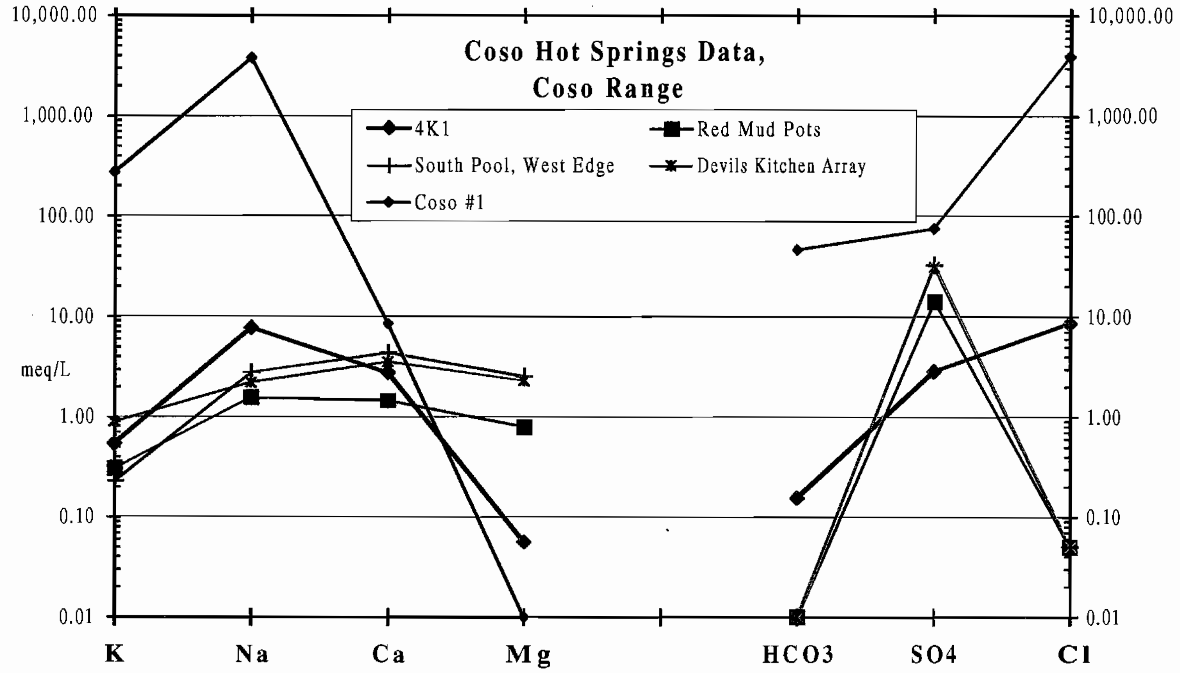


Figure 28. Fingerprint plot analysis of water sampled from the Coso Geothermal Area (CGA) located east of Rose Valley in the Coso Range, Inyo County, California. Water Chemistry Data in Appendix 4. (Edwards and Condon, 1989).

resemble magnesium values found at Little Lake. Magnesium concentrations for three of the five CGA water samples are less than 1.0 meq/L, whereas Little Lake Ranch water magnesium concentrations are all greater than 1.0 meq/L.

The anion fingerprint pattern for CGA water does not resemble the anion fingerprint pattern for Little Lake Ranch water (Figures 27 and 28). Four of the five bicarbonate values for CGA water range between 0.01 meq/L and 0.20 meq/L. This is in contrast to Little Lake bicarbonate ion values which are all between 9.0 meq/L and 30 meq/L (Figure 27). A high bicarbonate value of 46.33 meq/L for Coso #1 at CGA is also outside of the bicarbonate range found at waters derived from Little Lake. CGA sulfate ion values range between 2.88 to 75.42 meq/L, whereas Little Lake's sulfate ion values occur from 0.27 to 2.94 meq/L. CGA chloride ion values are also not consistent with Little Lake's chloride values. CGA chloride ion values range from a high of 3,500.00 meq/L for Coso #1 to a low of 0.40 meq/L for Red Mud Pots, South Pool West Edge, and Devils Kitchen Array. This is contrasted with chloride ion concentrations of 4.0 meq/L to 8.0 meq/L for Little Lake Ranch-derived water. The pH of the CGA water is strongly too slightly acidic with pH values ranging from 2.0 to 6.6 (Appendix 4). In contrast, the pH of Little Lake Ranch water is near neutral to strongly alkaline with pH values ranging from 6.8 to 9.9 (Table 2).

TDS values for Little Lake Ranch water ranges from 660 to 1,010 mg/L, whereas TDS values for CGA waters are all greater than 1,100 mg/L. The lowest EC value for CGA water occurred at well 4 K-1 and is 1,525 µS/cm. The rest of the water samples from CGA have EC values ranging from 3,100 to 130,800 µS/cm. Little Lake Ranch water has EC values from 1,330 to 2,030 µS/cm. Only the EC value of CGA water from well 4K-1 falls within the range of Little Lake water with an EC value of 1,525 µS/cm.

4.2.4 Comparison of Southern Owens Valley Water with Little Lake Water

Chemistry data from wells in the southern Owens Valley sampled by Lopes (1987) were plotted to determine if a similarity exists between groundwater from the aquifers in southern Owens Valley (Figure 29) and water found at Little Lake Ranch in the southern Rose Valley. Water samples taken by Lopes (1987) were directly north and east of this study's sample locations. In addition, Lopes' (1987) water samples were all derived from within the southern Owens Valley, very near or beneath Owens Lake.

The water samples from the southern Owens Valley are highly elevated in concentrations of sodium ion over calcium ion, and chloride ion concentrations are either equal to or greater than sulfate ion concentrations. This strongly resembles the chemical signature for water found at Little Lake (Figure 27). The major chemical difference is that the Owens Valley groundwater contains higher sodium ion concentrations than Little Lake samples. The combined fingerprint plots of the Little Lake water samples and the water found in the southern Owens Valley aquifer by Lopes (1987) suggest that groundwater from the southern Owens Valley appears to be genetically similar to the water found at Little Lake (Figure 29). This points to the possibility of a hydraulic connection between the aquifer(s) of the southern Owens Valley and the aquifer(s) of the Rose Valley.

4.2.5 Summary and Conclusions of Hydrogeochemistry of the Study Area

The interpretation of the hydrochemical data suggests that there are four major water groups with two subgroups within the study area, excluding the Coso Geothermal Area Water. Of the five Coso Geothermal Area (CGA) groundwater samples analyzed, none of the water samples resemble the water samples from Owens and Rose Valleys. In addition, deep groundwater from the Coso Geothermal Area is not likely to enter Rose Valley due to

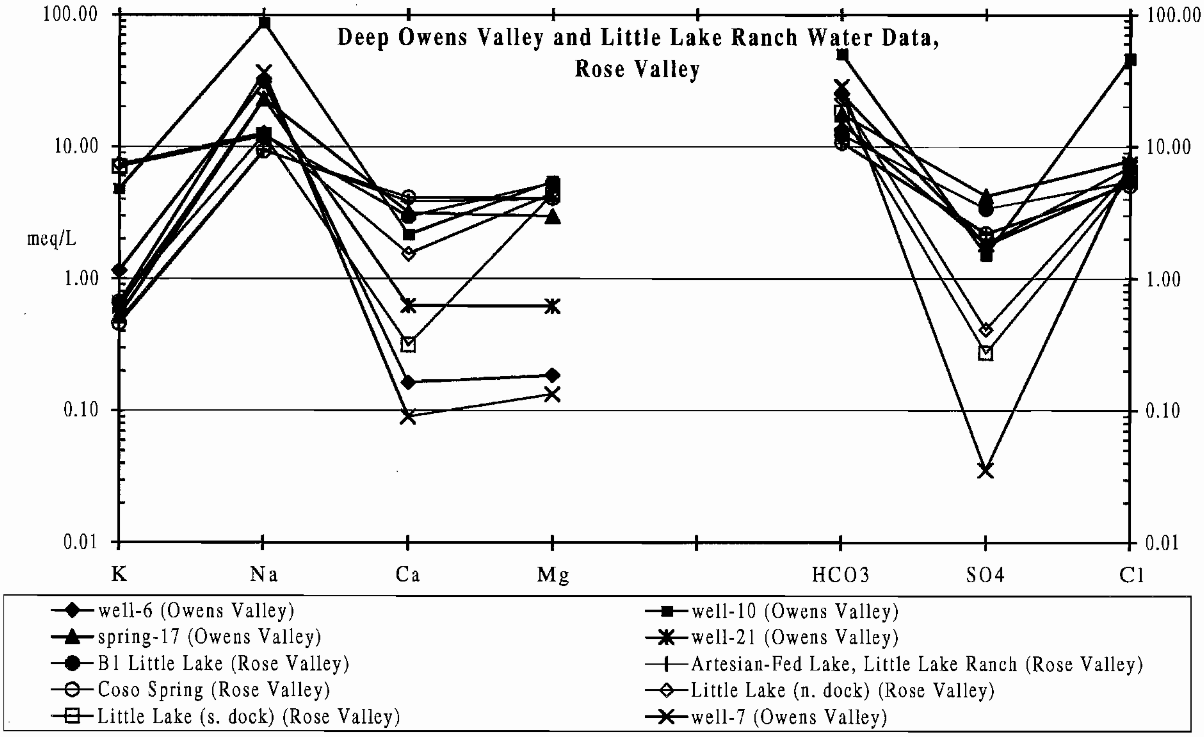


Figure 29. Fingerprint plot of water derived from five sources in the southern Rose Valley and five aquifer sources (groundwater at > 95 feet below ground surface) in the southern Owens Valley drainage area, Inyo County, California. (Southern Owens Valley deep water chemical data, (wells 6, 7, 10, 21, and spring-17) from Lopes, 1987).

the presence of a normal fault (Rose Valley fault) west of CGA, which acts as a groundwater barrier (Frank Monastero, PhD, China Lake NAWS, personal communication, 1997).

If groundwater recharge from Sierra Nevada runoff within the Rose Valley watershed is entirely responsible for the origin of Little Lake water, then Little Lake should exhibit similar geochemical signatures to water derived from the Sierra Nevada. Water samples from streams and springs draining the Sierra Nevada all have greater calcium ion concentrations than sodium ion concentrations (Figures 22 & 23). However, the water sampled at Little Lake, artesian well-fed lake (P-2), and the Coso Spring all have sodium ion concentrations higher than calcium ion concentrations (Figure 27). Based on this data, it appears that Sierra Nevada runoff water, within the Rose Valley watershed, is not the only source for water found at Little Lake. Instead, the aqueous geochemistry of Little Lake strongly resembles groundwater found in the aquifer(s) within the southern Owens Valley by Lopes (1987). Based on these chemical similarities, Little Lake's artesian water is hydraulically connected to the groundwater aquifer(s) in the southern Owens Valley.

The TDS values of the water samples are another useful tool. The TDS values of the Rose Valley water samples varies from north to south and to a lesser extent from west to east (Table 2). TDS values tend to be low in both the wells of the southern Owens Valley and in the springs and streams of the Sierra Nevada. In contrast, the TDS values are highly elevated for water derived from both the deeper wells sampled by Lopes (1987) in the southern Owens Valley and Little Lake.

Haiwee Reservoir contains water that is a mixture from many sources within the Owens Valley watershed. The water found at Haiwee Reservoir is a combination of shallow and deep Owens Valley groundwater sources and Sierra Nevada stream runoff from Mono

Lake south to Lone Pine. A portion of south Haiwee Reservoir water is flowing south to the Rose Valley within the underlying coarse Pleistocene Owens River channel deposits (Tim Thompson, Western Water, personal communication, 1999). South Haiwee Reservoir water is a sodium bicarbonate water like that found at Little Lake. However, the TDS values of Haiwee Reservoir water range from 153 to 190 mg/L, while the TDS values for water at Little Lake Ranch range from 660 to 1,010 mg/L. Based on TDS, leaking south Haiwee Reservoir water does not seem to be a major component of water found at Little Lake and may point to a possible separation of two or more aquifers in the Rose Valley, a shallow aquifer and a deeper aquifer. It is also possible that the water at Little Lake is being concentrated by evaporation. This would provide a possible mechanism for similar chemistry to Haiwee Reservoir along with a higher TDS.

The southern Rose Valley's artesian well that supplies water to the second pond (P-2) south of Little Lake has the same chemical fingerprint (Group IV water) as waters from Coso Spring and Little Lake (Figure 28). The confined aquifer below the Little Lake area may be deeper than 125 feet, based on the presence of clay beds below this depth at the Little Lake Hotel located west of Little Lake (Karl Kirschenman, Kirschenman Drilling contractors, personal communication, 1999) (Well Log #2, Appendix 8). However, the exact depth of the artesian well that penetrates this confined artesian aquifer is unknown due to the loss of the original well log.

The 80 inches per year of average evapotranspiration is another environmental mechanism that could explain the chemical signature for water in Little Lake. It is possible that the evaporative concentration of minerals occurs as a result of the desert's high evaporation potential. However, groundwater at Little Lake Ranch is also a sodium bicarbonate water that has not yet been exposed to evaporation. Therefore, it is improbable that the observed geochemical signature for Little Lake water is due solely to evaporative concentration of water in Little Lake.

4.3 Hydrogeological Investigations of Little Lake Ranch

4.3.1 Geology of Little Lake Ranch, southern Rose Valley

The geology of the Little Lake Ranch area was mapped in order to define the major rock units and their relationship to the hydrogeologic features of Little Lake (Plate III). Little Lake Ranch is divided hydrogeologically into a northern and a southern portion as a result of a water-carved gap in Coso Range bedrock forming Little Lake Gap (Figure 19). The predominant geology north of the gap is composed of alluvial fan material that is saturated at shallow depths. The predominant geology south of the gap is also alluvial fan deposits that are not saturated at shallow depths. The western boundary of northern Little Lake Ranch, from south to north, is composed of Coso Range bedrock in the south near Little Lake Gap and Sierra Nevada-derived truncated older alluvial fans in the north (Plate III). The eastern boundary of northern Little Lake Ranch is composed of Coso Range bedrock covered by thick basalt flows. The western boundary of southern Little Lake Ranch is composed of recent alluvial fans and the Sierra Nevada mountain front. The eastern boundary of southern Little Lake Ranch is composed of Coso Range bedrock that is capped by a thin basalt flow originating from a vent located at the southeast boundary of southern Little Lake Ranch (Plate III).

a. Basement Rocks

Coso Range basement rocks crop out approximately 1,000 feet apart on either side of Little Lake Gap. The outcrops consist of undifferentiated igneous and metamorphic rocks

(Plate III). On the east side of the gap, these basement rocks continue south through the gap to the southeastern boundary of southern Little Lake Ranch (Plate III). Southwest of Little Lake Gap, Coso Range basement rocks appear to have been eroded and buried by gravelly alluvial fan deposits originating from Wickline Canyon in the Sierra Nevada.

Directly east of Little Lake, Coso Range bedrock is buried by approximately one hundred feet of basalt originating from a vent located to the east (Duffield and Smith, 1978) (Figure 13). Approximately one-quarter mile southeast of Little Lake Gap, Coso Range basement rock outcrops are covered with approximately 10 feet of basalt that erupted from a cinder cone located at the ranch's southeastern boundary (Figure 13).

Sierra Nevada basement rocks exposed in the southern Rose Valley are primarily granodiorite and quartz monzonite (Duffield and Smith, 1978). Sierra Nevada granitic bedrock outcrop located southwest of Little Lake Gap are also comprised of granodiorite rocks and quartz monzonite. On the west side of the gap, the contact between Sierra Nevada bedrock and Coso Range bedrock is covered by older, Sierra Nevada-sourced alluvial fans.

b. Alluvial Deposits

Older, Sierra Nevada-derived, truncated alluvial fan deposits occur both north and south of Little Lake Gap (termed old gravels in Figure 13) (Plate III). They are exposed approximately five miles north of the gap before being covered by the younger alluvial fans along the west side of Rose Valley. To the south, they occur approximately four miles south of the gap in the northwestern Indian Wells Valley. In the Little Lake Gap area, these old alluvial fan deposits cover outcrops of Coso Range basement rocks. The exposed older alluvial fan deposits are approximately 100 feet thick, friable, poorly sorted, and well weathered. Grain size in these fan deposits ranges from clay to fine sands, gravels, and scattered cobbles. The shapes of the gravels and cobbles are sub-angular to sub-rounded and exhibit moderate weathering surfaces. These older truncated fans have well-developed paleosols on their surfaces. For example, they have noted increases in clay content in their subsoil horizons. The color of the soil fraction formed on these fans is reddish brown. This advanced degree of soil development detected by color, mineral weathering, and subsoil clay increase is in sharp contrast to the younger soils formed on the more recent alluvial fan deposits which lack all of these soil morphological characteristics.

Younger, Sierra Nevada-derived, alluvial fan deposits occur south of Little Lake Gap and north and east of the older truncated alluvial fan deposits in northern Little Lake Ranch. These young alluvial fan deposits cover most of northern Little Ranch and occur in the Little Gap area and most of southern Little Lake Ranch (Plate III). The younger alluvial fan deposits are completely unconsolidated, poorly sorted, and generally lack an appreciably weathered surface. Grain size in these fan deposits ranges from fine to coarse sands, abundant gravels, and scattered cobbles. The shapes of the gravels and cobbles are sub-angular and exhibit unweathered fresh mineral surfaces. In contrast to older fans, these younger fans lack well-developed soil horizons and no increase in clay content at depth. The color of the young soil fraction formed on these fans is 10 YR 5/2 (grayish brown). This early stage of soil development is in contrast to the paleosols formed on the older alluvial deposits previously discussed.

c. Fluvial Deposits

Along the base of the east side lava flows, in both northern and southern Little Lake Ranch, are fluvial-derived deposits of sands and gravels (Plate III). These coarse deposits show fining upward sequences and are better sorted than the alluvial fan deposits located to the west. It is probable that both exposed and buried portions of these fluvial deposits may in part be remnant channel deposits of the Pleistocene Owens River. North of Little Lake, a stratified, fining upward sequence was also encountered to depths of fifteen feet. The subsurface lithology of this deposit is composed of alternating beds of unconsolidated, well-sorted, sub-rounded granitic sands and gravels. South of Little Lake Gap, a six-foot augered hole also shows a fining upward sequence. However, the lithology here is composed of fine sands near the surface and very coarse sands at depth. No gravelly layers were found in the southern fluvial deposit. Groundwater in the northern deposit occurs at a depth of fourteen feet, whereas groundwater in the southern deposit was not encountered at a depth of six feet (unable to auger deeper due to looseness of dry sand). It is possible that buried portions of this porous and permeable fluvial deposit at Little Lake Ranch is transmitting groundwater south from the southern Rose Valley through Little Lake Gap to the Indian Wells Valley.

d. Volcanic Rocks

The geology of Little Lake Ranch includes basalt flows derived from the east, north, and south. The majority of the basalt encountered at Little Lake Ranch in the Pleistocene Owens River channel and at Fossil Falls was derived from Red Hill (Figure 13). The basalt forming the eastern escarpment of northern Little Lake Ranch and Little Lake had its origin in a vent located to the east (approximately 1.5 miles west of Volcano Peak) (Vent B in Figure 13). The basalt capping the eastern canyon wall in southern Little Lake Ranch and northwestern Indian Wells Valley came from an isolated cinder cone above the Little Lake fault (Cinder cone 'A' in Figure 13).

Basalt of Red Hill occurs as three isolated erosional remnants in Little Lake Ranch: west of Little Lake, Little Lake Gap, and southern Little Lake Ranch (Plate III). West of

Little Lake, basalt of Red Hill occurs as a thin raised ridge that strikes parallel to the west shore of Little Lake. It ranges from 10 to 25 feet high and 150 to 300 feet wide. In the Little Lake Gap area, remnant basalt of Red Hill occurs along the western side of the gap buttressed against Coso Range bedrock. In this area, numerous springs emanate from cooling cracks in the basalt. In the central portion of southern Little Lake Ranch, remnant basalt of Red Hill reappears as a rectangular, slightly-raised plateau (Plate III).

Basalt of Red Hill is important because it has preserved a paleosol that has formed in-place on its protected, elevated alluvial fan surface both west of Little Lake and in the central portion of southern Little Lake Ranch. This is important for three reasons: first this preserved paleosol, west of Little Lake, has nearly identical soil-development properties to the truncated older alluvial fans located further west, inferring that these are the same units; secondly due to its elevated position, this basalt preserved a remnant portion of a once extensive Sierra Nevada fan system that extended east across the southern end of the Rose Valley, but has been almost completely obliterated by the Pleistocene Owens River; and finally the existence of the basalt of Red Hill in this narrow portion of the southern Rose Valley may be important due to the possibility that buried portions of this or other earlier flows, or other buried paleosols with increases in clay content could slow groundwater flow causing the water to come to the surface as Little Lake and/or the wetlands at Little Lake Ranch.

e. Faults and Lineaments

South of Wickline Canyon, the Little Lake fault strikes southeast from the Sierra Nevada Frontal Fault Zone through southern Little Lake Ranch (Figure 2 and Plate III). This is an active right-lateral, left-stepping, strike-slip fault that extends southeast through the

Indian Wells Valley (Zellmer, 1988). This fault has a minimum slip rate of approximately 0.6 mm./yr. (Roquemore, 1981). Roquemore (1981) has documented at least 250 meters of right-slip along the Little Lake fault during the last 400,000 years. A possible fault-gouge zone within southern Little Lake Ranch has a surface expression as a 60 to 80 foot wide band of clay parallel to the fault trace. West of southern Little Lake Ranch, numerous springs are found along the trace of the fault on the southeast-facing slope of Wickline Canyon in the Sierra Nevada. Southeast of Wickline Canyon, in a railroad cut through a small hill, exposures of offset Sierran bedrock are visible. At the southeast boundary of Little Lake Ranch, a prominent cinder cone lies upon the Little Lake Fault Zone (A in Figure 13).

It is possible that the subsurface effects of the fault may be partly responsible for the current hydrogeologic conditions found in the southern Rose Valley and the northwestern Indian Wells Valley. The Little Lake fault may be acting as a partial barrier for Rose Valley groundwater flowing south through Little Lake Gap. A possible consequence of this fault on the groundwater system in the southern Rose Valley is the slowing of groundwater flow and building up of hydraulic pressure within the confined aquifer, possibly resulting in the formation of springs along both the west and east sides of the southern Rose Valley. Some of these springs feed Little Lake and the other ponds to the south. South of Little Lake Gap, the Little Lake fault may also be directing groundwater to deeper aquifers in the northwest Indian Wells Valley. This is suggested by the observation that the depth to groundwater in the northwestern Indian Wells Valley is measured at 300 feet below ground surface six miles south of Little Lake Gap, compared to groundwater at or near the surface directly north of the gap (Kern County Water Agency, 2000).

An east-west striking lineament is visible on high altitude photographs of the Little Lake area (Figure 30). The lineament extends from the Kern Plateau in the Sierra Nevada west of Little Lake Gap to the Coso Range. This lineament may have the potential to transmit groundwater from the uplands of the Sierra Nevada to the Rose Valley or to the northwest Indian Wells Valley. However, aqueous geochemical data from Little Lake Ranch does not indicate that this is occurring. The lineament may also act as a groundwater barrier to south-flowing groundwater. In Little Lake Ranch, the lineament occurs slightly north of Little Lake Gap very close to the location of the Coso Spring (Figure 30). No field expression of this lineament was observed.

f. Summary of Geologic Conditions Affecting the Hydrogeology of Little Lake

There appears to be a number of geologically-related factors (near-surface basement rocks of the Coso Range constraining basin width and depth at Little Lake Gap, buried basalt lava flows, fault displacement effects, and the presence of an east-west striking lineament) that may play a role in the current hydrogeology of the Little Lake Ranch area. Whether these individual entities work in concert or independently is left to further research.

4.3.2 Soil Investigation Results and Discussion

a. Shallow Deposits of Little Lake Ranch - Overview

This section characterizes the shallow subsurface deposits to depths of ten to fifteen feet at Little Lake Ranch (Plate IV). The soil study was performed in order to characterize and identify the shallow aquifer materials (generally less than 10 feet) and their distribution within the southern Rose Valley. A soil pedon extends down to the lower limit of a soil usually 6 feet or bedrock whichever is shallower (United States Department of Agriculture, Handbook Number 18, 1975). A soil pedon as used here is a three-dimensional soil body

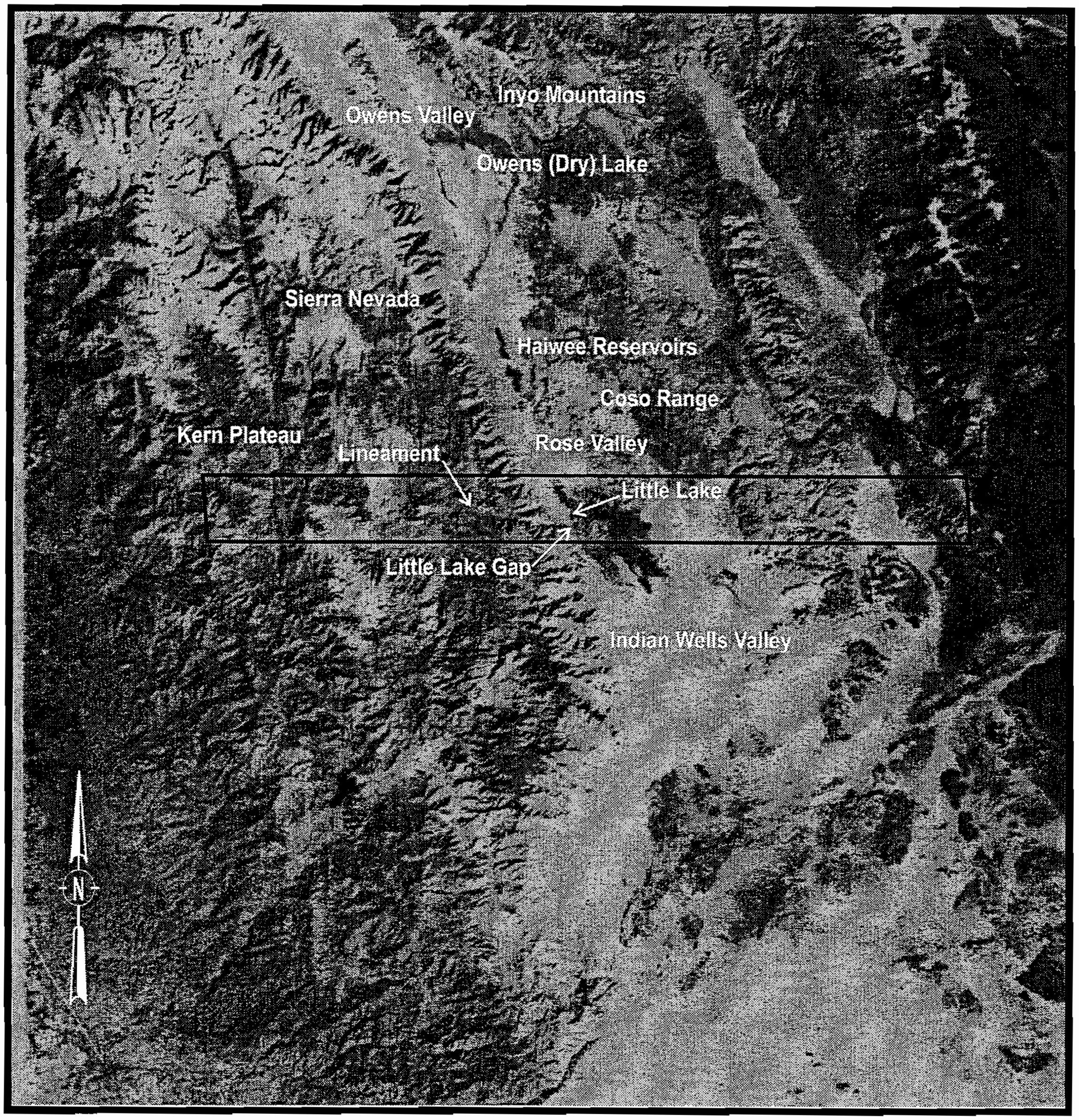


Figure 30. Expression of a possible fracture system represented by a lineament trending east from the Sierra Nevada Mountains, west of Little Lake, to the Coso Range, Inyo County, California. (NASA ERTS Satellite Photo, October 1972).

(approximately 10 to 30 cubic feet) whose lateral dimensions are large enough to allow study of its horizons and of its chemical and physical properties (Brady, 1984).

Most of Little Lake Ranch (> 75%) is composed of recent fluvial, alluvial, and debris flow deposits. These recent deposits were derived primarily from sediment-loaded runoff, debris flows and mass wasting events originating in adjacent canyons located in both the Sierra Nevada and the Coso Range. These coarse, surficial deposits are made up primarily of poorly sorted sands and gravels with cobbles and boulders usually making up less than 20% of the total. The surface soil layer, from northern Little Lake Ranch south to Little Lake Gap, was formed in a fairly continuous gravel and coarse sand deposit from one-quarter to one-half inch thick. Most of the fine-grained clastic surface deposits (< 0.5 mm) have been eroded either by wind or by overland sheet-flow. Below this thin surface horizon are poorly sorted coarse sands and gravels, with clays and silts making up usually less than 30% of the total soil pedon. This subsurface coarse sand and gravel layer typically extends to a depth of eight feet or more. Its thickness is fairly uniform throughout the area both north and west of Little Lake (Appendix 7).

In the subsurface, north of Little Lake Gap, a fairly uniform layer of cobbles and boulders is present. This deposit, located at a depth of eight to nine feet, presents a barrier to deeper auger investigation. Immediately south of Little Lake, the soil contains a porous but indurated calcium carbonate layer (calcrete) that occurs near the surface or at depths of four feet or more, implying reworking in a lacustrine shoreline environment, or recent shallow groundwater tables coupled with a high degree of near-surface evapotranspiration.

South of Little Lake Gap, in the northwestern part of southern Little Lake Ranch, the surface soil down to eight feet is dominated by soils composed primarily of coarse sands, gravels, and cobbles. These soils formed in Sierra Nevada-sourced debris flow and alluvial fan parent materials of granitic origin. Wickline Canyon is the major source for these recent alluvial fan and debris flow deposits. Grain sizes range from minor amounts of silt to increasing amounts of sand, gravels, pebbles, cobbles, and scattered boulders up to three feet in diameter. The larger rock sizes decrease in abundance from west to east. South of Little Lake Gap, in the northeastern part of southern Little Lake Ranch, the soil contains clast sizes that are predominantly gravels and coarse sands with moderate amounts of pebbles from the surface down to a depth of more than six to eight feet. The major sources for these recent alluvial fan deposits are the canyons of the Coso Range.

Along the base of the basalt-capped, Coso alluvial fans and Coso bedrock, located along the eastern boundary of southern Little Lake Ranch, are remnant coarse fluvial sands probably deposited from the Pleistocene Owens River (Plate IV). These fluvial deposits differ from the Coso and Sierra Nevada-sourced alluvial fan deposits of southern Little Lake Ranch in that the grains are better sorted, subrounded to rounded, and predominately sand-sized.

In September 1997, Little Lake Ranch experienced a two hundred year storm event. This unusual summer thunderstorm dropped 2 inches of precipitation in 45 minutes. Highway 395 was closed for a day while Caltrans crews removed four feet of accumulated mud, debris, and boulders from the highway and the town of Little Lake. This storm was confined to the southern Rose Valley area. Torrents of water flowed over Fossil Falls south to Little Lake during and after the storm event for several days. According to eye witnesses (George and Sheila Salteros, personal communication, Sept., 1997), debris and boulders up to three feet in diameter were rafted effortlessly across Highway 395 from Little Lake

Canyon to Little Lake Ranch. The eastern part of the ranch along the base of the basalt scarp became a raging river 3 feet deep and 500+ feet wide. Along the west side of Highway 395, the western extension of Little Lake and the town of Little Lake were completely filled in by 4 feet of mud and debris. Similar, localized, intense storms over recent geologic time probably deposited the alluvial and debris flow materials that are currently found in the shallow subsurface at Little Lake Ranch.

b. Soils Analysis of Little Lake Ranch

A soil survey of first-order intensity, as defined by the USDA Soil Survey Manual (1993), was performed at Little Lake Ranch during the summer of 1997. The soil survey of the ranch was carried out by excavating soil trenches and augering soil holes to depths of six to fifteen feet. Utilizing toposequences from north to south and east to west across the ranch, the soil profiles were described and correlated to construct a soil map of Little Lake Ranch (Plate IV). The minimum size of mapping unit delineations for this survey was approximately 2 acres. In addition to soil characterizations, observations and recordings were made on vegetation type, depth to groundwater, and geomorphology of Little Lake Ranch (Appendix 6). Based upon the underlying geology and hydrogeology, the ranch can be divided into roughly six soil mapping units (Plate IV). Soil boundaries were delineated on a 1:24,000, 7.5 minute USGS Little Lake quadrangle enlarged to 200% (Plate IV). The location of the soil pits are located in Appendix 5. The field data was interpreted and the soils were taxonomically classified to the family level (Appendix 5).

The rationale for characterizing the soils of Little Lake Ranch was to define the physical, chemical, and hydrogeological properties of the deposited geologic materials from the surface down to, and including, the shallow aquifer (Appendix 6). The outcome of this portion of the study revealed the nature of the shallow subsurface deposits at Little Lake Ranch and the physical propensity of these sediments to transmit groundwater. Appendix 7 contains detailed soil profile field descriptions of the soils of Little Lake Ranch.

The soils for most of Little Lake Ranch are similar to those of the Rose Valley (Rockwell Report, 1980). However, the Little Lake Ranch area has a shallow groundwater table which is absent in the rest of the Rose Valley. This perennial shallow groundwater presence has changed the nature of soil formation in an arid environment to an almost humid environment. In northern Little Lake Ranch, groundwater typically occurs at depths of less than fifty feet and to the southeast the depth decreases steadily to zero at and around Little Lake and the other ponds (P-1 and P-2). South of Little Lake, the depth to groundwater varies from at or very near the surface to approximately five feet below the surface immediately north of Little Lake Gap. Depth to groundwater is greater than twelve feet below the surface south of the gap.

The six major soils found at Little Lake Ranch include: 1) alkaline, wetland, "hydric" soils formed from saturated lacustrine and alluvial/fluvial sediments adjacent to Little Lake and the other ponds (P-1 & P-2); 2) recent, volcanic, basalt rock-derived soils found along the eastern shore of Little Lake which are sourced primarily from volcanic rock and secondarily from aeolian dust; 3) petrocalcic soils in the area immediately south of Little Lake to, and including, Little Lake Gap; 4) recent coarse-grained, sandy soils southeast of Little Lake and the other ponds in central Little Lake Ranch with parent-material sourced from the Coso Range; 5) recent coarse-grained, sandy soils west of Little Lake and south of Little Lake Gap with parent-material sourced from granitic debris flows and alluvial fans of the Sierra Nevada; and 6) paleosols with distinct claypans in the subsurface horizons that formed on Red Hill basalt-capped Sierra Nevada-sourced alluvial fans immediately west of Little Lake and in the central, slightly raised portion of southern Little Lake Ranch (Plate IV and Appendix 7).

The dominant textural characteristics of the majority of the soils of Little Lake Ranch, not influenced by shallow groundwater, are either coarse sandy loams, very coarse sands, or loamy sands formed primarily from granitic parent material derived from debris flow, alluvial fan, and stream deposits. Gravel content within these soils ranges widely from 1 to 50%, while clay content ranges from <5% north and south of Little Lake. The clay content increases to > 35% in the wetland "hydric" soils surrounding Little Lake and in the paleosols formed on the basalt-capped alluvial fans and abandoned stream terrace of northern and southern Little Lake Ranch. Sorting of these granitic and undifferentiated metamorphic rock parent material soils range from poor to moderately well-sorted, and most of the grains less than 2.0 mm in diameter are subangular to subrounded.

North of Little Lake Gap, in northern Little Lake Ranch and Rose Valley, soils are derived predominantly from recent debris flows and alluvial fans sourced from steep sloped canyons of the eastern Sierra Nevada and from more shallowly sloped canyons of the western Coso Range. For soils derived from the Sierra Nevada, grain sizes decrease from west to east towards the center of the Rose Valley, and from east to west for soils derived from the Coso Range. In the southern Rose Valley, the soil directly west of the eastern basalt scarp of both northern and southern Little Lake Ranch is fluvially-derived. These soils are composed of deep, layered sands and gravels. The sand and gravel deposits found at augered subsurface depths of fourteen feet or more, in the Little Lake Ranch area, may be deposits of the Pleistocene Owens River overlying more recent flash-flood deposits. Soils formed on these coarse deposits, differ from the alluvium and debris flow-derived soils in that they are well sorted, evenly layered with alternating beds of medium to fine sands, and contain a fining-up sequence. In contrast, debris flow-derived soils are poorly sorted with sands and gravels of all sizes and subangular to angular cobbles spaced randomly throughout the soil profile.

4.3.3 Soils of Northern Little Lake Ranch - Dunmovin, Arizo, and Aquic Torrifluvents

Soils of northern Little Lake Ranch, north of Little Lake Gap, may be found on Plate IV. In northern Little Lake Ranch, north of Little Lake, there exist three mappable soil mapping units: Dunmovin soil series (Typic Torrispsaments), Arizo soil series (Typic Torrifluvents), and Aquic Torrifluvents.

The existing landscape of Little Lake Ranch was formed primarily as a result of downcutting of bedrock and alluvial slopes by the Pleistocene Owens River (Duffield and Smith, 1978). The final channel of the Pleistocene Owens River appears to be along the base of the eroded lava flow along the eastern boundary of Little Lake Ranch. In this part of the ranch, layered stream deposits show fining upward sequences and extend south to Little Lake. In the Little Lake Gap area, these fluvial-derived sediments appear to have been buried by more recent deposits of Coso Range alluvial fan material. The paleo-stream deposits reappear along the base of the basalt-capped Coso Range bedrock located along the eastern boundary of southern Little Lake Ranch, south of Little Lake Gap.

Northern Little Lake Ranch is underlain by thick deposits of very porous and permeable sands and gravels that are a part of the distal end of Sierra Nevada-sourced recent alluvial fan deposits. The shallow groundwater table in northern Little Lake Ranch becomes shallower near the north shore of Little Lake, until it intersects the surface at the lake itself (Plate II). Shallow groundwater plays an important role in soil development in Little Lake

Ranch. Grain weathering, biological activity, and salt deposition are all increased in the subsurface by the constant presence of shallow groundwater in this arid region. These combined effects cause soils to develop at a faster rate than the surrounding, more arid desert soils with deeper groundwater tables.

a. Dunmovin Soil Series-(Typic Torripsamments)

The Dunmovin soil series typically occurs on alluvial fans and debris flows sourced from the Sierra Nevada. This soil occurs north and south of Little Lake Gap, and is the dominant soil series of Rose Valley. Dunmovin soil is composed of deep, nearly level to moderately sloping (5 to 50%) (100%=45°), well-drained sandy soils formed from granitic rock parent material. The official soil family classification is a Typic Torripsamment.

The surface texture of Dunmovin soil ranges from cobbly to bouldery close to the Sierra Nevada Mountain front to gravelly with a poorly-sorted coarse to fine sand matrix further east. No calcrete hardpan horizons were encountered on this soil. In both northern and southern Little Lake Ranch, this soil map unit is formed primarily on debris flow and alluvial fan deposits. Elevation for these soils within Rose Valley typically ranges from 3,000 to 4,200 feet. This soil series makes up about 45% of the Little Lake Ranch study area.

The soil profile of the Dunmovin soil series is characterized by calcareous loamy sands to a depth of 9.0 feet, and below this depth, sandy loams with a cobble layer comprising the greater than 2.0 mm fraction. Dunmovin soil is not well-suited for irrigated crops and is limited by its low water-holding capacity, high hydraulic conductivity, high gravel concentration, and wind erosion hazard. Its low moisture retention makes drought-resistant and forage crops the optimal choice. This area is currently being used for wildlife habitat and groundwater recharge along the Sierra Nevada and Coso Range mountain fronts.

b. Arizo Soil Series - (Typic Torrifluvents)

Minor soil inclusions within the Dunmovin soil series consist of Arizo soils (Typic Torrifluvents). Arizo soils formed in sandy well-drained river channels. Such a channel is located north of Little Lake. This channel occurs in an 800 to 1,000 foot east to west band that trends approximately north-south parallel to the western edge of the basalt flow north of Little Lake, and extends north to the base of Fossil Falls (Plate IV). An Arizo variant soil is also found south of Little Lake Gap along the base of the Coso Range. This soil also occurs in a 1,000 foot east to west band and trends parallel to the western edge of the basalt-capped Coso Range in southern Little Lake Ranch.

Arizo soils and Arizo variants are comprised of highly stratified channel sand deposits, which may in part be the last remnant channel deposits of the Pleistocene Owens River. However, during times of intense precipitation, recent canyon runoff deposits of coarse sediments from the basalt flows to the east, Fossil Falls to the north, and Little Lake Canyon Creek to the west add material to this channel. However, this is not the case for the remnant channel in southern Little Lake Ranch, which has been cut off from any recent stream flow from the Sierra Nevada due to the presence of a substantial older Coso Range derived alluvial fan. The groundwater table below Arizo soils north of Little Lake is generally found at shallow depths from nine to fourteen feet below ground surface. The groundwater table below Arizo soils in southern Little Lake Ranch was not encountered at depths of six to seven feet due to the dry, well-sorted nature of the sandy subsoil.

c. Aquic Torrifluvents (Hydric Soils)

Encompassing the shores and near shore areas of Little Lake and the smaller ponds to the south are fine-textured, hydric soils that are typically moist to wet year round. Since there is no common name for these soils, only the soil family name of Aquic Torrifluvents is used for naming purposes. These soils show redoximorphic features (mottles) from just below the moist surface down to the top of the groundwater table. The groundwater table is usually at a depth of one to two feet below the ground surface in these soils. Mottles are common in these shallow, often water-logged soils from about one-eighth of a mile north of Little Lake south to Little Lake Gap. The presence of mottles are used here as indicators of a seasonally fluctuating groundwater table of approximately ± one foot.

Characteristic native wetland vegetation associated with these hydric, alkaline, and saline soils include saltgrass (*Distichilis sp.*), pickleweed (*Salicornia sp.*), rushes (*Juncus sp.)*, sedges (*Carex sp.*), cattails (*Typhus sp.)*, willows (*Salix sp.*), and a non-native, salt cedar (*Tamarix sp.*).

Hydric soils in the wetland area around the perimeter of Little Lake, are clay loams to clays, but these soils become loamier farther south and north of the lake (Plate IV). On the south side of Little Lake, saturated clays extend to a depth of 10+ feet, alternating between coarser beds of saturated sand and gravel. It is highly possible that these deeper clay horizons are in part damming Little Lake, while the coarse zones are transmitting water south from Little Lake as groundwater in the subsurface shallow aquifer. However, the existence of a deeper, subsurface, igneous bedrock or a fault-gouge zone of either the Little Lake fault or the Sierra Frontal fault to the south and west respectively, should not be ruled out as either an additional or primary groundwater flow barrier. In the wetland north of Little Lake, coarse sands and gravels alternate between thin beds of silt and clay to a depth of nine feet. The major difference observed between soils on the north shore and soils on the south shore of Little Lake is that the latter soils contain thicker clay beds than the former soils. In addition, soils formed south of Little Lake have a thick calcrete horizon not found in the subsurface north of Little Lake.

The soils formed around Little Lake are more weathered, finer in texture, and are alternately layered: gravelly, coarse sandy clay loams, and clays than the soils formed on recent alluvial fans. The finer texture of these soils reflects that this area was either a lake, slow-moving stream, or that increased chemical weathering caused by an increase in soil moisture has reduced much of the coarse sand particles to silt and clay size.

4.3.4 Soils of Central Little Lake Ranch

a. Soils Formed on Lava Flows and Basalt-Capped Alluvial Fans - (Typic Torriorthents and Typic Haplargids)

Located on the east side of Little Lake are thin soils formed from extensive lava flows comprising the eastern boundary of northern Little Lake Ranch. Along the western shore of Little Lake are paleosols formed as a result of being protected from stream erosion by basalt of Red Hill. The soil taxonomic classification for these soils to family level is Typic Torriorthent for the soils east of Little Lake and Typic Haplargids for the soils west of Little Lake.

The volcanic/eolian soils located along the eastern boundary of Little Lake are shallow, coarse-grained, and excessively well-drained. The lighter-colored fine silts and fine sands observed in pockets and vesicles of the basalts are evidence of eolian activity. Elevations for these soils vary from 3,300 to 3,600 feet, while slopes are steep and range from 75 to 100%.

A Pleistocene (?), Sierra-sourced, remnant alluvial fan contains a paleosol that appears to have been preserved by a continuous cap of a remnant Red Hill basalt flow. This paleosol is located about twelve to twenty feet above Little Lake's western shore, west of the remnant basalt flow. This clay-rich red alluvial fan derived soil extends both parallel to Little Lake and west from the top of the basalt flow for approximately one-fourth of a mile. The soil that lies west of this paleosol, at a lower elevation, is considerably younger and belongs to the Dunmovin soil series. The Dunmovin soil series in northern Little Lake Ranch also skirts the western base of the higher and older truncated alluvial fans found on the west side of Highway 395. These older fans also have paleosols on their surface with soil properties that are nearly identical to those found directly west of Little Lake. This suggests that a large portion of a paleo-alluvial fan complex that once occupied much of northern Little Lake Ranch has been eroded away by the Pleistocene Owens River. Only the soils on the topographically higher proximal portion of the truncated alluvial fans and the higher protected basalt-capped distal fan portion located west of Little Lake are still preserved.

The paleosols located west of Little Lake have a surface texture that ranges from loam to clay loam. These soils show an increase in clay up to 25% with depth. They have well-developed argillic clay pan horizons at depths from one and a half to two feet below the surface. These soils are very poorly drained and have subangular blocky structure. The taxonomic classification of these soils is Typic Haplargid. These soils have very slow water infiltration and low internal hydraulic conductivity rates. Digging in these soils is very hard due to the indurated nature of the dry subsoil clay pan horizon. The paleosols of central Little Lake Ranch are typically reddish-brown (10YR 4/3) and contrast well with the lighter, tannish-brown (2.5 Y 3/2) younger soils of the Dunmovin soil series, found directly to the west.

west.

b. Calcareous Soils of Central Little Lake Ranch: (Typic Petrocalcids & Calcic Petrocalcids)

Calcareous soils, containing a petrocalcic horizon (calcrete hardpan) either at or near the surface or at depth, are found in the alkali wetland immediately south of Little Lake. The taxonomic classification of these soils to the family level is Typic Petrocalcid and Calcic Petrocalcid. These alkaline wetland soils only occur in central Little Lake Ranch from the south shore of Little Lake south to Little Lake Gap. They typically exhibit a thick calcareous indurated pan (calcrete) at depths ranging from just below the surface to depths of 4 feet. This hardpan layer, in places, can be as thick as five to six feet. These saline and sodic soils are probably the result of groundwater evaporation occurring near the surface rather than pedogenically derived.

The presence of the calcareous hardpan does not seem to restrict vertical upward groundwater flow. In the middle of summer, groundwater is present both in the soil immediately above the calcrete zone and within the calcrete horizon itself. In addition, the wetland soils show abundant mottling from the surface down to the top of the calcareous hardpan horizon. These conditions indicate that the groundwater table is able to rise and fall through the pores of the calcareous hardpan, and groundwater can wick through the overlying soil pores by capillarity up to the surface and evaporate. The deep calcareous hardpan zone itself is typically wet and has a porosity of about 15 to 25%, as determined by field observation. Both the calcareous zone and the overlying soil effervesce violently in 10% hydrochloric acid (HCl), indicating that these soils are moderately to strongly calcic with accompanying alkaline pH values ranging from 8.0 to 8.5.

These soils continue south downslope to the north shore of the artesian pond (P-2), which receives water from three sources: Coso Spring, an artesian well, and effluent from Little Lake outflow creek. The soil effects of the calcareous pan horizon south of the artesian pond are restricted primarily to the area west of the artesian-fed pond and along the banks and base of the south-flowing Little Lake outflow creek. From the south shore of the artesian pond, the calcic hardpan horizon extends south through Little Lake Gap primarily on the banks and in the bed of Little Lake outflow creek, then widening again through the Little Lake Gap area and ultimately confining itself to the base of the outflow creek south of the gap. The calcareous zone is discontinuous along Little Lake outflow creek south of the gap. This discontinuity most likely allows the creek water to infiltrate into the underlying coarse sand deposits of the creek bed south of Little Lake Gap in northwest Indian Wells Valley.

c. Soils Formed on Coso Alluvial Fans of Central Little Lake Ranch - (Typic Torripsamments and Typic Torriorthents)

Soils formed on Coso Range alluvial fan material are similar to soils formed on Sierra Nevada alluvial fans. The major differences are that Coso Range alluvial fan soil parent material is composed of mixed metamorphic and igneous rocks, and it does not extend as far west from the mountain front (typically 500 feet), as do the far-reaching, Sierran-derived alluvial fan soil parent material. Bedrock exposures are very common on the shallow slopes of the topographically lower Coso Range along the east boundary of Little Lake Ranch, indicating that this range does not contribute a great deal of sediments to alluvial fan formation and subsequent soil development. In contrast, the topo-graphically higher, Sierra Nevada derived alluvial fans contribute a greater sediment volume to the southern Rose Valley. These sedimentary deposits are ultimately used for both the soils and the aquifer material of Rose Valley and Little Lake Ranch. The proximity to the Coso Range bedrock soil parent material and the high gravel content of the Coso-derived alluvial fans, have caused the Coso soils to have a coarser grain size. Furthermore, the combined effects of local lava flows, Pleistocene Owens River erosion, and Sierra Nevada alluvial fans and debris flows all seem to have restricted Coso Range-derived soils to their current narrow eastside landscape position.

Both immediately north and south of Little Lake Gap, Coso Range-derived alluvial fan soils occur in a narrow area restricted to the east side of central Little Lake Ranch, along the base of the Coso Range. The taxonomic family classification for these Coso Range soils is Typic Torripsamments. Coso soils are very gravelly to sandy, deep, and very well-drained. Grain sorting is moderate. These soils typically form on slopes of 15 to 45%. They are very young in profile development and display no internal soil structure. These coarse-grained soils lack calcareous hardpans in their proximal fan portions, however, in the distal fan portions, closer to shallow groundwater conditions, calcareous hardpans can be found. These soils have field-estimated porosities as high as 45% to 60% and a low clay content of <20%. Water infiltration is moderately high while available water holding capacity is low.

d. Soils of Little Lake Gap - (Typic Petrocalcids and Typic Torripsamments)

Two soil mapping units are found in the Little Lake Gap area: Typic Petrocalcids and Typic Torripsamments. Soils formed here are either loamy soils that have a calcareous hardpan horizon close to the surface - Typic Petrocalcids, or they are very coarse sands and gravels devoid of this horizon - Typic Torripsamments. The former soil family occurs only along the north and east side of the gap east of Highway 395, while the latter more gravelly and cobbly soil family occurs along the west and south sides of the gap primarily west of

Highway 395.

Soils east of the highway may express what is occurring in the subsurface, i.e., groundwater flowing southward and upward and evaporating as it fluxes to the surface, leaving behind the calcareous hardpan deposit. The well-drained soils west of Highway 395, contain a coarse sand, gravel, and cobble content, and do not show any indication of a calcareous horizon or hardpan either at the surface or at depths up to six feet.

4.3.5 Soils of Southern Little Lake Ranch - Typic Torripsamments, Aridisols, and an Arizo Variant Soil Series

Southern Little Lake Ranch is located south of Little Lake Gap in the northwestern Indian Wells Valley. There are three soil taxonomic families located here: 1) gravelly and sandy soils belonging to the Dunmovin-Cajon soil complex - Typic Torripsamments; 2) soils with clay and silica-rich subsoils belonging to the Aridisol soil order - Typic Haplargids; and 3) sandy soils belonging to the Arizo variant soils series - Typic Torrifluvents. For this reason, the soils of the southern Little Lake Ranch will be divided into three soil mapping areas: west, central, and east sides, respectively.

a. West Side Soils: Dunmovin-Cajon Soil Complex (Typic Torripsamments)

Generally soils on the west side of southern Little Lake Ranch are predominantly derived from recent alluvial fans, catastrophic debris avalanches, and landslide deposits from the Sierra Nevada. They formed in alluvial fan slopes of 25 to 50%. While moderately to excessively well-drained, the finer surface fraction of these soils has a tendency to be easily eroded by wind, sheet, rill, and gully erosion during intense wind and precipitation events. Clay content for this soil is typically less than 10%. Taxonomic classification of this soil to the family level is Typic Torripsamment.

The Dunmovin-Cajon soil complex is an example of west side soils in the Rose Valley and northwestern Indian Wells Valley. This soil formed in southern Little Lake Ranch (about 30% of the study area). Elevations for this soil ranges from 3,000 to 3,200 feet. A typical soil profile, to a depth of nine feet, consists of gravelly, loamy sands alternating with coarse sandy loams with clay percentages less than 10%. These soils are massive and have no internal soil structure. The surface is usually cobbly, with a poorly sorted coarse to fine sand matrix. No calcareous pan horizons were encountered, however, the soils do effervesce when 10% HCl is applied.

The Dunmovin-Cajon soil complex in Little Lake Ranch has a low water holding capacity with a sandy surface texture. Depth to groundwater is generally greater than ten feet. Water infiltration and soil percolation is high. These are the drier soils of the ranch. The land use is primarily wildlife habitat and is usually vegetated with scattered creosote bush *(Larrea divaricata)*, more characteristic of the arid Mojave Desert.

b. Central Area Soils: Aridisols of southern Little Lake Ranch - (Typic Haplargids)

Soils formed in the central area of southern Little Lake Ranch are principally Aridisols derived from relict basalt flows of Red Hill. Aridisols are soils formed in desert regions and are high in pedogenic clay. This clay is found in the argillic subsoil horizon (Bt horizon below the A horizon). These soils also have an iron oxide content which imparts a reddish brown color (10YR 4/3) that contrasts with the other younger dark grayish brown-colored (2.5 Y 4/2) soils located to the east and west. Aridisols here are pedogenically well developed with a thick (>3 feet) Bt clay horizon (clay content >35%), and the soil's basalt parent minerals have weathered over time to clays. The slope on the soils ranges from 10 to 15%. This central raised-soil zone extends from one-half mile south of Little Lake Gap to beyond the southern boundary of southern Little Lake Ranch in the northwestern Indian Wells Valley. The surface of this terrace is covered with abundant boulders and cobbles of basalt, with very few granitic rocks (<1-2%).

The Little Lake Fault strikes southeast through this soil-mapping unit. Fault gouge clay- soil found on the Little Lake fault varies in composition from the other clay-textured soil formed as a result of chemical weathering of the Red Hill basalt flows. The former soil is light tan to gray in color, with a high plasticity, and is very sticky when wet, while the latter soil is red with a lower plasticity, and much less sticky when wet. Soils formed on the basalt occur on a slightly elevated abandoned stream terrace, whereas the fault-gouge soils formed primarily to the west, adjacent to the terrace deposit.

c. East Side Soils: Stream Deposits of southern Little Lake Ranch - (Typic Torrifluvents)

Soils on the east side of southern Little Lake Ranch are olive gray colored (5Y 4/2), sandy in texture, clay content < 5%, very deep, and occur on gentle slopes of 5 to 10%. They are highly stratified in profile view, indicating that they were deposited by stream action. These soils are very well-drained, loose, and are at the early stages of soil development. Their physical properties strongly resemble the Arizo soil series north of Little Lake in northeastern Little Lake Ranch (north of Little Lake). Their parent material consists of coarse sands from the Sierra Nevada, Coso Range, and possibly the Inyo Mountains. These soils are not as coarse as the Sierra Nevada-derived soils of the west side of southern Little Lake Ranch. Groundwater in this soil was never encountered from the surface to seven-foot depths. The sediments here are very loose and the soil auger was not able to penetrate any deeper than six feet. These soils are excessively well drained with a uniform texture of coarse sands throughout their profile. Field estimated porosities in this soil range from 45 to 55%. These soils are very dry and consequently, are sparsely vegetated. The surface is scattered with basaltic boulders which were dislodged from the overlying basalt flow that caps the Coso Range to the east. This soil-mapping unit is currently discontinuous with its northern portion north of Little Lake.

This soil that was formed in the abandoned stream channel seems to be discontinuous between the south shore of Little Lake and just south of Little Lake Gap. The missing stream channel section is probably buried by several feet of Sierra Nevada and Coso Range-derived alluvial fan deposits.

4.4 Hydrological Investigations at Little Lake Ranch

4.4.1 Overview

Little Lake Ranch can be divided into a northern shallow groundwater zone and a southern deeper groundwater zone. This change in the hydrogeology occurs rather abruptly at Little Lake Gap. In northern Little Lake Ranch, the water table occurs from the ground surface to depths of up to 75 feet below the ground surface. Hydrologic features located north of the gap are Little Lake, Little Lake outflow creek (a gaining stream), Coso Spring, a flowing artesian well, and two gaining ponds (P-1 and P-2) and their associated wetlands (Figure 31). Located south of the gap, in a desert landscape, is Little Lake outflow creek (a losing stream) and two small losing ponds (P-3 and P-4) (Figure 31). In order to quantify how much surface water was flowing south of the Rose Valley at Little Lake Gap, south-flowing Little Lake outflow creek was gaged at three sites, north of the gap. In addition, in order to quantify how much surface water was infiltrating into the alluvium of the Indian Wells Valley, two stream gaging sites on Little Lake outflow creek were monitored south of

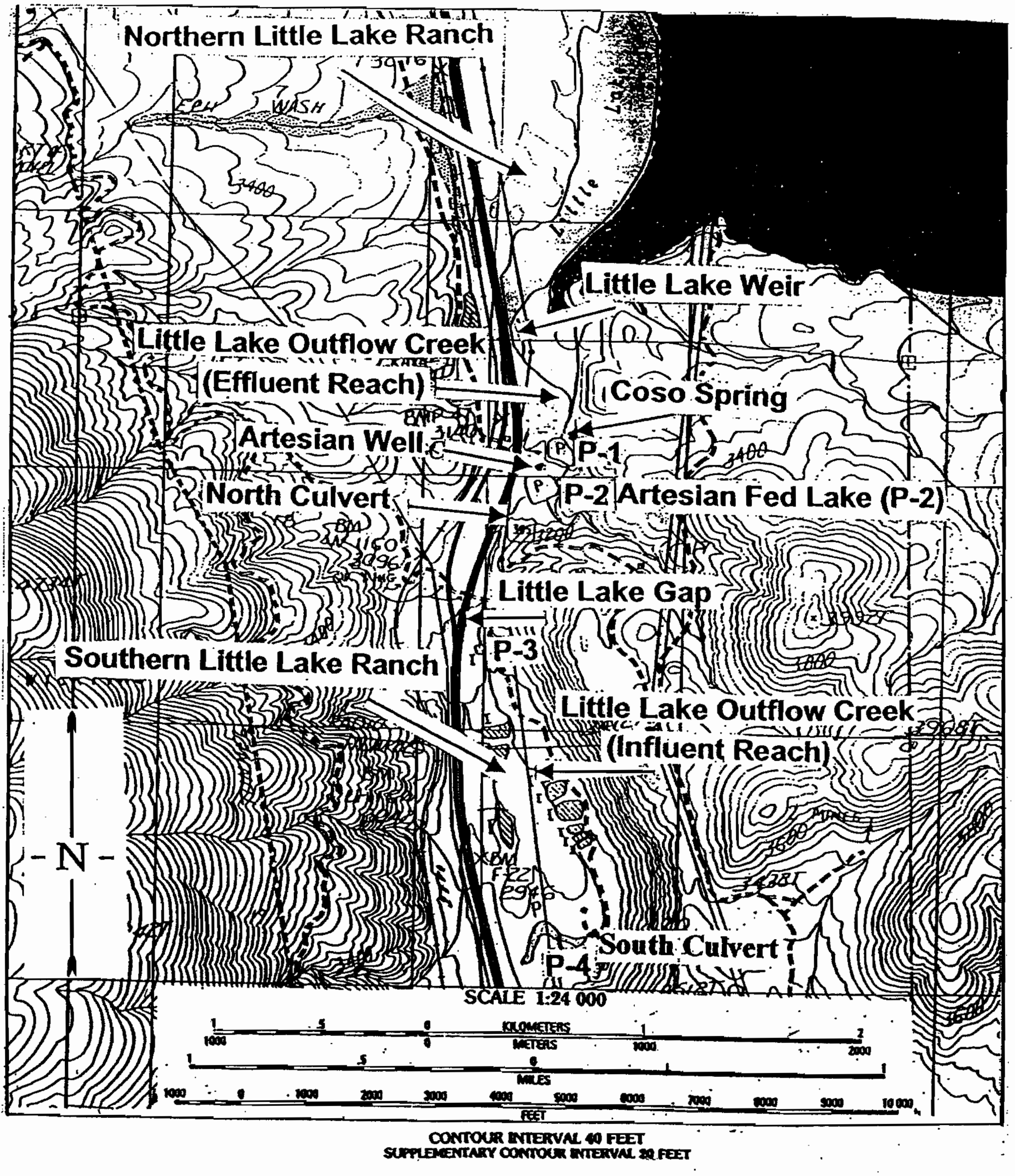


Figure 31. Location map of water bodies and stream gaging locations, mentioned in text, at Little Lake Ranch, Southern Rose Valley and Northwestern Indian Wells Valley, Inyo County, California. Little Lake, California, USGS 7.5 Minute Quadrangle Map.

Little Lake Gap. Perennial Coso Spring, discharging from fractures in Coso Range bedrock, adds water to the first pond (P-1) south of Little Lake. The second pond (P-2), which is fed by Little Lake outflow creek, a flowing artesian well, and overflow from P-1 stays at a constant height year round. The discharge of the flowing artesian well that supplies water to the artesian pond (P-2) was not gaged. The well flows year round through a one-foot diameter steel pipe completed at an unknown depth, located approximately 1,000 feet north of P-2. The total discharge from P-2, measured at the north culvert, contains the combined outflow from Little Lake, Coso Spring, P-1, and P-2. South of this point, Little Lake outflow creek discharges the combined flow to the northwestern Indian Wells Valley through Little Lake Gap. South of the gap, Little Lake outflow creek, becomes a losing creek, based on gaging results. In southern Little Lake Ranch, Little Lake outflow creek flows into P-3 then P-4 as it continues to infiltrate into the alluvium.

4.4.2 Stream Gaging at Little Lake Ranch

Little Lake's outflow creek (northern and southern Little Lake Ranch and Little Lake Gap), Coso Spring, and artesian pond discharge were measured at five locations on a quarterly basis over a one and one-half-year period (Figure 31). The first Little Lake gaging site was at Little Lake's spillway at the weir. The second gaging site was at the Coso Spring, a perennial spring located southeast of Little Lake located on the east boundary of northern Little Lake Ranch. Coso Spring discharges from Coso Range fractured bedrock and flows directly into the first pond (P-1, Figure 31). The third gaging site was at the north culvert in the Little Lake Gap area, downstream from P-2. The fourth stream gaging site was on Little Lake outflow creek located south of Little Lake Gap at the cottonwood tree. The fifth gaging site on Little Lake outflow creek was near the south culvert just up-stream from the south pond at the southern boundary of Little Lake Ranch. The last sites are located in the northwestern Indian Wells Valley (Figure 31).

After flowing out of Little Lake, over Little Lake weir, Little Lake outflow creek flows south into the two ponds north of the gap (P-1 and P-2). The flow rate measured at Little Lake weir ranged from 163 ac-ft/yr to 1,746 ac-ft/yr (Table 3). Coso Spring has discharges ranging from 874 ac-ft/yr to 1,976 ac-ft/yr (Table 3). The flow rates, measured at the north culvert, ranged from 2,043 ac-ft/yr to 5,357 ac-ft/yr (Table 3 and Figure 31). From here, Little Lake outflow creek discharges to the northwestern Indian Wells Valley through Little Lake Gap. The flow rates, measured at the south culvert (next to P-4), ranged from 318 ac-ft/yr to 1,866 ac-ft/yr (Table 3 and Figure 31).

4.4.3 Hydraulic Conductivity Determination of the Shallow Alluvium at Little Lake Ranch

In order to quantify the hydraulic conductivity of the shallow aquifer materials in northern Little Lake Ranch, Little Lake Gap, and southern Little Lake Ranch, a Guelph Constant Head Permeameter was utilized. The hydraulic conductivity testing locations are plotted on Figure 32, and the results of the Guelph Permeameter tests for Little Lake Ranch are summarized in Table 4.

Hydraulic conductivity of the shallow soils were measured from north to south and east to west within Little Lake Ranch, in order to characterize the hydraulic potential of these soils. Hydraulic conductivity measurements could only be performed in the top two to four feet of the soil due to equipment constraints. The soil's saturated hydraulic conductivity reflects how a three-dimensional soil column conducts groundwater. Due to a fairly uniform provenance and depositional environment, for purposes of this study, it is assumed that both

Table 3. Stream Gaging at Little Lake Outflow Creek and the Rose Valley

Location	Date	Cross Sectional Area square inches	Gage Rate ft/sec	Volume cfs ft^3/sec	Volume $ft^3/year$	Volume gpd	Volume ac-ft/yr
FALL 96							
Coso Spring	10/28/1996	110	2.37	1.81	57093300	1170022	**1311**
South Culvert	10/28/1998	78	0.81	0.44	13836420	283552	**318**
WINTER 96/97							
Coso Spring	2/2/1997	120	2.29	1.91	60181200	1233302	**1382**
South Culvert	2/2/1997	128	0.8	0.71	22425600	459571	**515**
North Culvert	2/2/1997	175	4.46	5.42	170929500	3502884	**3924**
Little Lake Weir	2/2/1997	275	0.94	1.79	56611500	1160148	**1299**
So Haiwee Toe Drain	12/4/1996	158	1.09	1.20	37716180	772923	**866**
So. Haiwee Toe Drain	2/2/1997	270	0.78	1.46	46121400	945173	**1059**
SPRING 97							
Coso Spring	5/14/1997	130	2.22	2.00	63203400	1295237	**1451**
South Culvert	5/14/1997	126	0.92	0.81	25386480	520249	**583**
North Culvert	5/14/1997	160	2.54	2.82	89001600	1823923	**2043**
Little Lake Weir	5/14/1997	168	0.37	0.43	13613040	278974	**312**
So. Haiwee Toe Drain	5/14/1997	72	0.31	0.16	4888080	100172	**112**
SUMMER 97							
Coso Spring	7/1197	124	3.17	2.73	86084520	1764143	**1976**
South Culvert	6/2/1997	120	1.12	0.93	29433600	603187	**676**
South Culvert	7/1197	66	1.29	0.59	18645660	382108	**428**
North Culvert	6/2/1997	176	2.99	3.65	115246560	2361765	**2646**
North Culvert	7/1197	50	3.52	1.22	38544000	789888.	**885**
Little Lake Weir	6/2/1997	108	0.30	0.23	7095600	145411	**166**
Little Lake Weir	7/1197	No Flow	0	0.00	0	0	**0**
Cottonwood Tree	7/1197	100	1.77	1.23	38763000	794376	**890**
So. Haiwee Toe Drain	7/11/1997	No Flow	0	0.00	0	0	**0**
FALL 97							
Coso Spring	10/1/1997	108	3.59	2.69	84910680	1740087	**1949**
South Culvert	10/1/1997	60	2.08	0.87	27331200	560102	**627**
North Culvert	10/1/1997	156	3.04	3.29	103858560	2128389	**2384**
Little Lake Weir	10/1/1997	120	0.36	0.30	9460800	193882	**217**
Cottonwood Tree	10/1/1997	76	1.73	0.91	28794120	590082	**661**
So. Haiwee Toe Drain	10/1/1997	No Flow	0	0.00	0	0	**0**
WINTER 98	**(El Nino Year)**						
Coso Spring	2/7/1998	108	2.25	1.69	53217000	1090584	**1222**
South Culvert	2/7/1998	160	2.32	2.58	81292800	1665946	**1866**
North Culvert	2/7/1998	240	4.44	7.40	233366400	4782413	**5357**
Little Lake Weir	2/7/1998	310	1.12	2.41	76036800	1558234	**1746**
Cottonwood Tree 1	2/7/1998	168	1.72	2.01	63282240	1296852	**1453**
Cottonwood Tree 2	2/7/1998	120	2.21	1.84	58078800	1190218	**1333**
Cottonwood Tree 3	2/7/1998	36	1.72	0.43	13560480	277897	**311**
Cottonwood Tree 4	2/7/1998	6	0.91	0.04	1195740	24504	**27**
SPRING 98							
Coso Spring	3/25/1998	95	1.83	1.21	38073150	780239	**874**
South Culvert	3/25/1998	96	1.9	1.27	39945600	818611	**917**
North Culvert	3/25/1998	150	4.56	4.75	149796000	3069792	**3439**
Little Lake Weir	3/25/1998	180	0.98	1.23	38631600	791683	**887**
Cottonwood Tree	3/25/1998	105	2.21	1.61	50818950	1041440	**1167**

Table 3. Results of stream gaging from Little Lake outflow creek, and other points within Little Lake Ranch and the Rose Valley, Inyo County, California. Note: Cottonwood Tree 1-4 are gaging sites where Little Lake outflow creek overtopped its banks and created 3 new channels.

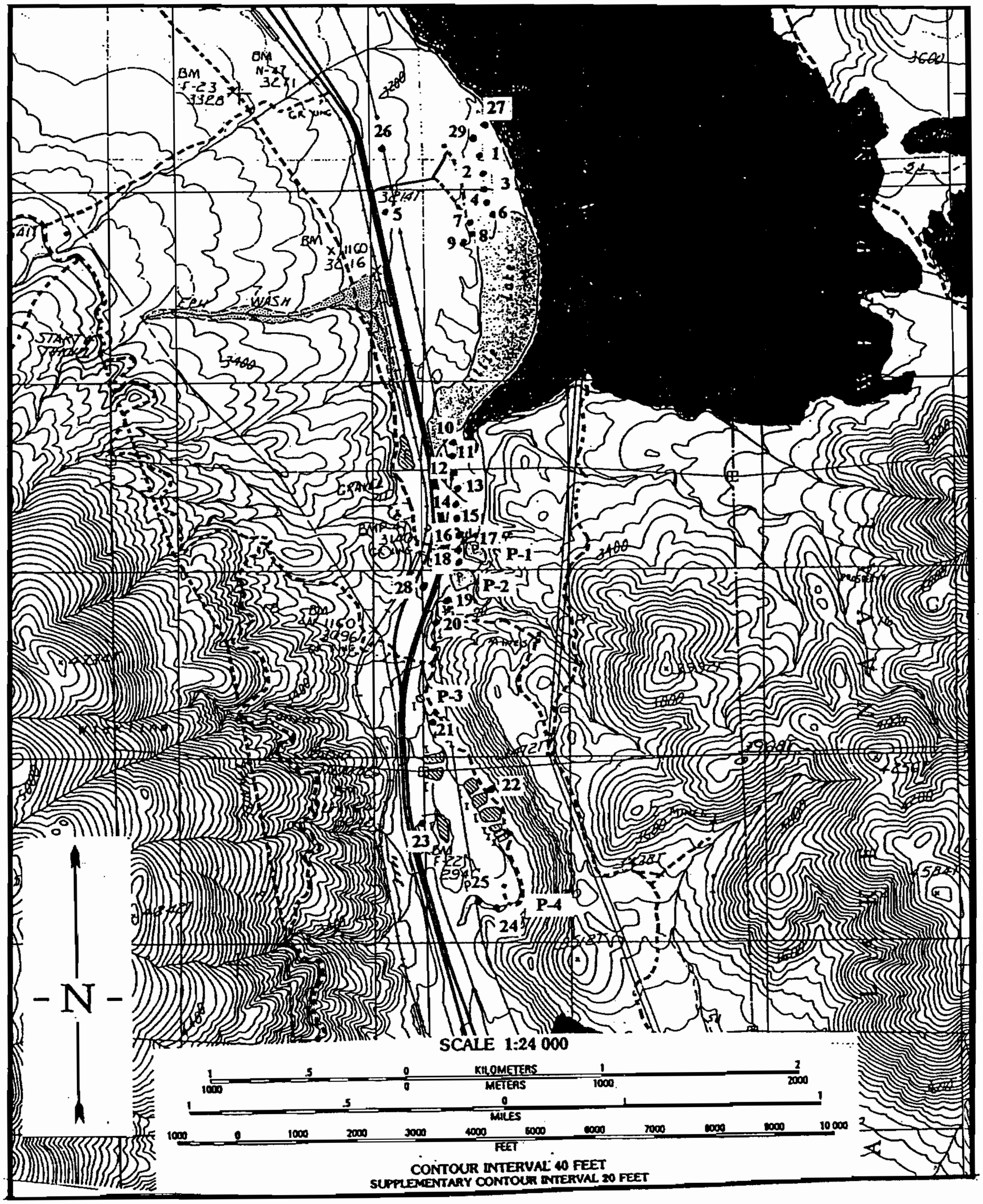


Figure 32. Guelph Permeameter sampling locations on Little Lake Ranch, southern Rose Valley, Inyo County, California.

Table 4. Guelph Permeameter - Field Determined Hydraulic Conductivity Data

WELL	Depth	Soil Type	Field	K	Method	Location
#	Inches	Texture	Saturated	FT/DAY	Used**	Rose Valley, Inyo County,
*		Bottom of Well	K (cm/sec)			California
1	32	Sandy Loam	4.16E-04	1.2	STD.	300' East of Ranch House
2	23	Sandy Loam	4.40E-04	1.3	STD.	300' South of Site 1
3	25	Loamy Sand	1.70E-03	4.8	STD.	300' South of Site 2
4	31	Coarse Sand	1.30E-03	3.7	STD.	300' South of Site 3
5	33	Coarse Sandy Loam	5.30E-04	1.4	STD.	50' South of Main Gate
6	24	Loamy Coarse Sand	2.60E-03	7.4	STD.	250' North of Little Lake
7	27	Sandy Loam	9.04E-04	2.6	STD.	200' North of Little Lake
8	23	Clay loam	NO DATA:	Saturated	None	150' North of Little Lake
9	9	Clay Loam	5.50E-06	0.016	STD.	150' North of Little Lake
10	10	Coarse Sandy Loam	9.40E-04	2.7	STD.	50' South of Little Lake
11	28	Fine Sandy Loam	8.40E-04	2.5	STD.	165' South of Little Lake
12	24	Coarse Sand	1.30E-03	3.8	GLOVER	350' South of Little Lake
13	25	Sandy Loam	2.80E-04	0.79	STD.	300' South of Site 11
14	16	Sandy Loam	5.60E-04	1.6	STD.	200' South of Site 12
15	16	Clay Loam	7.10E-06	0.02	STD.	150' South of Site 13
16	19	Loam	1.70E-04	0.48	STD.	300' South of Site 14
17	43	Gravelly Sandy Loam	1.00E-03	2.9	GLOVER	300' South of Site 15
18	26	Very Fine Sandy Loam	3.40E-03	9.6	STD.	400' South of Site 16
19	24	Loamy Sand	2.00E-03	5.7	GLOVER	150' South of Third Lake
20	32	Sandy Loam	7.10E-05	0.2	STD.	Little Lake Gap East of Hwy 395
21	38	Fine Loamy Sand	3.10E-03	8.8	STD.	100' South of Fourth Lake
22	24	Fine Sandy loam	2.90E-03	8.1	STD.	300' South of Fourth Lake
23	38	Very Fine Sandy Loam	3.40E-03	9.6	STD.	West Side Rd Lower LLR
24	22	Fine Sandy Loam	1.50E-04	0.43	STD.	Last Dry Lake Bed
25	32	Loamy Sand	4.20E-03	11.9	STD.	Dry Lake Bed 100' west of Last Lake
26*	26	Loamy Sand	1.20E-03	3.4	STD.	E-W Toposequence in ULLR
27*	40	Coarse Sandy Clay Loam	1.20E-05	0.03	STD.	E-W Toposequence in ULLR
28	60	Sandy Clay Loam	1.50E-03	4.2	STD.	Little Lake Gap West of Hwy 395
29*	32	Loamy Coarse Sand	1.90E-03	5.3	STD.	E-W Toposequence in ULLR

*West to east Toposequence performed on an alluvial fan in northern Little Lake Ranch.
**Method used to determine hydraulic conductivity value: (Std.) Standard Method and Glover Method.

Table 4. Guelph Permeameter results for Little Lake Ranch, Inyo County, California.
Note: Samples 1-16 & 26-29 are from northern Little Lake Ranch.
Samples 17-20 are from Little Lake Gap.
Samples 21-25 are from southern Little Lake Ranch.

the shallow saturated hydraulic conductivity and the shallow subsurface soil properties in this area are identical to or closely resemble the shallow aquifer properties found at Little Lake Ranch.

Hydraulic conductivity values range from > 4.0 ft/day in northern Little Lake Ranch, to > 8.0 ft/day in the Little Lake Gap area, to 9.6 ft/day south of Little Lake Gap. Hydraulic conductivity values near the north shore of Little Lake were not obtained, due to positive upward hydraulic pressure of groundwater from the shallow aquifer not allowing the permeameter to drain into the augered test well. Furthermore, the soils of the central terrace portion of southern Little Lake Ranch were also not tested for hydraulic conductivity, because the low permeability of the indurated, clay-textured subsoil horizon did not allow the permeameter to drain.

4.4.4 Little Lake's Water Budget

As the ultimate groundwater discharge area for Rose Valley, based on local topography at Little Lake Gap, Little Lake remains a significant hydrogeological entity worthy of study. Little Lake is a perennial emergent underflow lake located in the southern Rose Valley, despite an annual evaporative water deficit greater than 80 inches (California Department of Water Resources, 1975). The lake has a total surface area of approximately 75 acres and an average depth of 4.0 to 5.0 feet. Surface runoff from the surrounding mountains enters Little Lake only during, or shortly after, ephemeral, localized summer storm events and shortly after unusually heavy winter and spring rains. In spite of the lack of surface inflow, Little Lake stays at a fairly constant level despite surface water outflow via Little Lake outflow stream.

The annual average surface water discharge draining Little Lake measured at Little

Lake weir was 771 ac-ft/yr. This is outflow from Little Lake only and does not include outflow from the two northern ponds (P-1 and P-2), Coso Spring, and the artesian well. Stream gaging at the north culvert in the Little Lake Gap area indicates that as much as 5,300 ac-ft/yr is discharged into the Indian Wells Valley (Figure 31 and Table 3). In order to determine a water budget for Little Lake, recharge minus discharge of the lake should equal the change in storage. Sources of water, recharge and discharge as well as an analysis of water storage in the lake are discussed below.

An annual water budget for Little Lake was calculated in order to obtain an estimate of how much recharge is needed on an annual basis to maintain Little Lake at a fairly constant level. The annual discharge of the lake was also determined based upon the amount of surface water leaving the lake and the evaporation of water from the lake's surface. These parameters were determined by using the mass balance equation (Equation 4.1).

$$\text{Recharge - Discharge = Change in Storage} \qquad \textbf{(Eqn. 4.1)}$$

a. Inputs to Little Lake

There are three possible sources of water for Little Lake:

1) Direct precipitation over Little Lake (6" precip./year over a 75 acre lake surface). This is calculated to be 38 ac-ft/yr.

2) Eastern Sierra Nevada surface runoff occurring along the west side of Rose Valley from Dunmovin Hill (northern Rose Valley) south to Little Lake Canyon (southern Rose Valley). These streams are normally dry before they enter the Rose Valley and Little Lake, respectively. Therefore, surface water inputs into Little Lake on an annual basis are negligible.

3) Groundwater inflow from aquifers within the study area. This volume will be calculated from the mass balance equation (Eqn. 4.1).

b. Outputs from Little Lake

Discharge from Little Lake primarily occurs by the following three mechanisms:

1) Surface water outflow in Little Lake outflow creek. Stream gaging of Little Lake outflow creek was performed quarterly from the winter of 1996/97 to the spring of 1998 (Table 3 and Figure 31). The average annual discharge measured at Little Lake's weir was 771 ac-ft/yr.

2) Evaporation from the lake surface. Evaporation from Little Lake's surface is equal to approximately 500 ac-ft/yr. This is based on the lake's surface area (75 acres) multiplied by the annual evapotranspiration rate (80 inches/year, California Department of Water Resources, 1975).

3) Consumptive use. Consumptive use for Little Lake Ranch is negligible due to the lack of development, therefore it will be considered zero here.

c. Change in Storage: Daily Water Level Fluctuations at Little Lake and in a Well North of Little Lake

Daily water elevation fluctuations were measured for a 450-day period utilizing two pressure transducers in both Little Lake and a well located approximately 500 feet from the north shore of Little Lake (Figure 33). For the tested time period, Little Lake and groundwater table fluctuations were slightly greater than ± one foot (Figure 34). Due to the minor change in water level ($> \pm 1$ ft/yr) over the course of a year, the change in storage for the purpose of this study will be zero.

The lowest elevation for Little Lake and the groundwater table occurred in late fall of 1997. The highest water level point in both the lake and the groundwater table occurred in the early spring of 1998, an El Nino year of unusually high precipitation. As summer turned to fall, the water level in both the well and the lake simultaneously dropped (Figure 34). As winter and spring rains arrived, the groundwater in the well and Little Lake began to rise simultaneously (Figure 34).

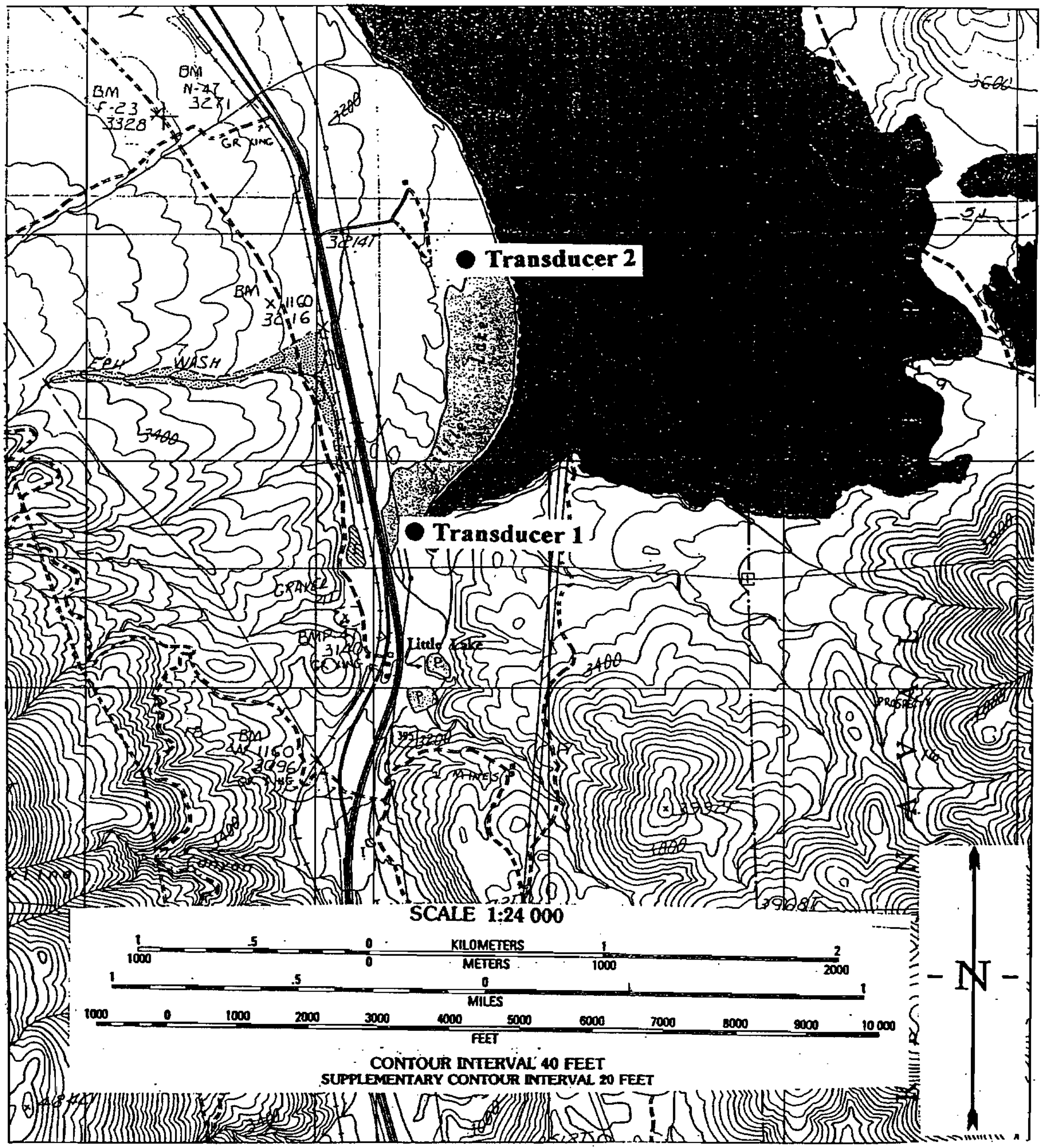
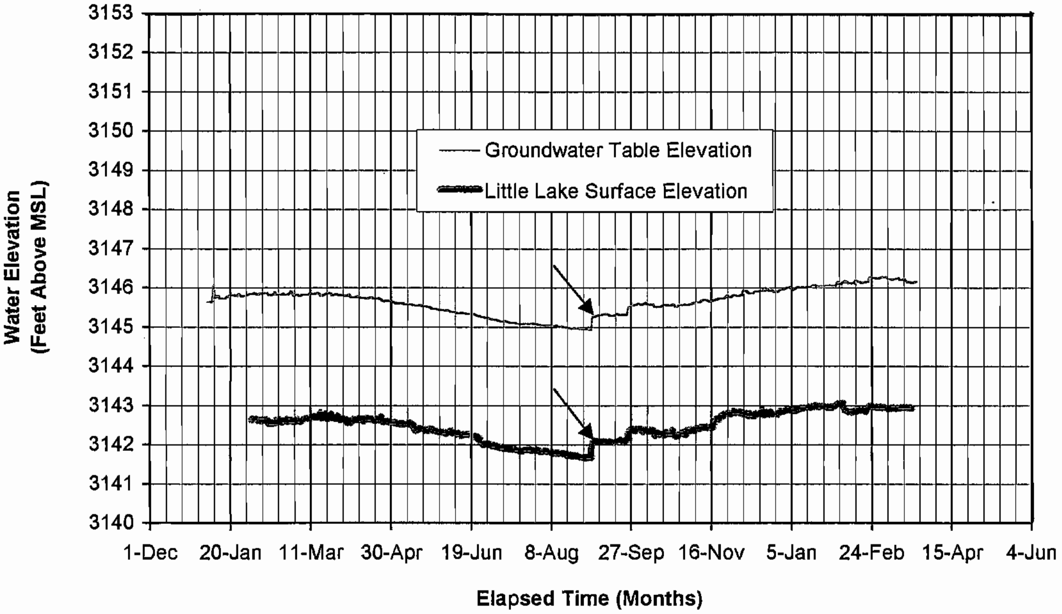


Figure 33. Transducer locations at Little Lake Ranch. Transducer one is on the south dock and transducer two is in a well located slightly north of Little Lake.



Combined Surface Water and Groundwater Elevations of Little Lake and the Well North of Little Lake, from January 6, 1997 to March 21, 1998. (September 5, 1997 (Arrow) date of Major Summer Precipitation Event. October 1, 1997 Beginning of El Nino Year.)

Elevation of Groundwater Table in well was measured from Top of Casing. Lake water elevation was measured from Lake Surface at end of South Dock, Little Lake. Increasing Groundwater Elevation Corresponds to Increasing Lake Levels.

Figure 34. Hydrograph of the combined Little Lake and shallow well, located north of Little Lake, water elevation as recorded by two pressure transducers from January 6, 1997 to March 21, 1998. (Arrow depicts a sudden rise in both lake and well groundwater levels as a result of an unusually heavy precipitation event that occurred on September 5, 1997). On this date 2 inches of precipitation fell in 45 minutes over the southern Rose Valley.

d. Calculation of Little Lake Water Budget

The mass balance equation is used in defining the water budget for Little Lake (Eqn. 4.1).

The following equations are used to calculate a water budget for Little Lake:

Recharge - Discharge = Change in Storage. **(Eqn. 4.1)**

Recharge = Precip. + Groundwater (inflow) + (Surface water inflow = 0). **(Eqn. 4.2)**

Discharge = ET + Groundwater (outflow) + Surface water (outflow) + (Consumption = negligible). **(Eqn. 4.3)**

Change in Storage = 0. **(Eqn. 4.4)**

The water budget Equation 4.1 for Little Lake then becomes (from the above equations):

(Precip. + Groundwater (inflow)) - (ET + Surface Water (outflow) + Groundwater (outflow)) = 0. **(Eqn. 4.5)**

The nonzero values for the terms in Equation 4.5 may be found in Table 5.

The only unknowns in Equation 4.5 are Groundwater (inflow) and Groundwater (outflow).

Groundwater (inflow) - Groundwater (outflow) = Groundwater (Net) **(Eqn. 4.6)**

The goal of these equations is to solve for the amount of groundwater that enters or leaves Little Lake (i.e., Net Groundwater). To accomplish this goal, substitute Eqn. 4.6 into Eqn. 4.5 and rearrange Eqn. 4.5 to solve for Net Groundwater Eqn. 4.7:

Groundwater (Net) = - Precip. + ET + Surface Water (Outflow) **(Eqn. 4.7)**

Equation 4.7 yields the minimal amount of water that enters Little Lake as groundwater on an annual basis. The net groundwater value obtained is 1,233 ac-ft/yr (Table 5).

Little Lake Parameters	**ac-ft/yr**
Precipitation Falling Directly on Little Lake, (6 inches/year) x (75 acres)	38.0
Evapotranspiration (ET) of Little Lake's Water, (80 inches/year x 75 acres)	500.0
Little Lake's Annual Average Surface Water Outflow Volume, (Measured at Little Lake Weir = 771 ac-ft/yr.)	771.0
Net Groundwater = - Precip. + ET + Surface Water (outflow) (Eqn. 4.7)	1,233.0

Table 5. Approximate Annual Water Budget for Little Lake.

II. Potential Deep and Shallow Aquifers

4.5 Potential Aquifers within the southern Owens and Rose Valleys

The purpose of characterizing the geology in the southern Owens and Rose Valleys is to determine probable aquifer units in this area, and to evaluate the possible existence of groundwater flowpaths between Owens and Rose Valleys. The results of the author's field, geologic, topographic map, water well, and aerial photographic studies will be presented in the following sections.

This discussion of the potential aquifers will begin in the southern Owens Valley with the Owens Lake Sand and Owens Lake Bed Members of the Coso Formation (Plate V). This will be followed by the potential shallow aquifers associated with the overlying Pleistocene Owens River channel deposit, and the Sierra Nevada derived alluvial fan deposits. In the Rose Valley, the Coso Sand and Coso Lake Beds Members of the Coso Formation will be evaluated as potential aquifers. Next, the overlying Rhyolite Tuff Member of the Coso Formation, followed by the Pleistocene Owens River channel deposit, and the Sierra Nevada- and Coso Range-derived alluvial fan deposits will be evaluated as potential aquifers.

4.5.1 Southern Owens Valley Potential Aquifers

The southern Owens Valley, for the purpose of this report, is the area south and west of Owens Lake, specifically along the west side of the southern Owens Valley from Cartago south to Olancha including the area north of Sageflat Road Divide and east to north Haiwee Reservoir. Underflow to the Rose Valley from deeper aquifer(s) in the southern Owens Valley through either (or both) the Coso Sand or Coso Lake Beds Member and then into the coarse alluvial deposits of the Rose Valley has been estimated at 10,860 acre-feet/ year (LADWP, 1976).

Based on well logs within the southern Owens Valley, there are shallow unconfined as well as deeper confined aquifers similar to those in the northern and central portions of the Owens Valley. For purposes of this section, the shallow alluvial aquifer in the southern Owens Valley is considered unconfined, while the deeper aquifer is considered either semi-confined or confined by clay layers of the Owens Lake Bed Member of the Coso Formation.

a. The Potential Deep Aquifer(s) - Owens Lake Bed and Owens Lake Sand Members in the southern Owens Valley

Porous and permeable beds occur within both the Owens Lake Bed and Owens Lake Sand Members of the Coso Formation. In the southern Owens Valley, near the south shore of Owens Lake, a 3,500 foot well (OV-D) was drilled for uranium exploration and the lithology was described by Schaer (1981) (Figure 11). In this area, the Owens Lake Bed Member and the Owens Lake Sand Member occur at depths from 20 to 220 feet and from 220 to 3,500 feet below ground surface, respectively. The Owens Lake Bed Member is functioning as an aquifer in this area, based on wells perforated in this unit. In addition, the underlying Owens Lake Sand Member contains permeable and porous zones which are functioning as an aquifer, based on perforations of a deep well located in the southern Owens Valley (Well Log #34, Appendix 8).

The Owens Lake Bed Member is composed of coarse sand to silt-size clastics in a 25 % matrix of gray-green montmorillonite and illite clay (Schaer, 1981). In J.H. well #34 below the shallow alluvium, there is a twenty-foot layer of clay, and below this is a 100 foot thick aquifer located from 140 to 240 feet (Well Log #34, Appendix 8). This porous and permeable aquifer unit consists of medium to coarse sand and gravel. This transition aquifer could be a coarse, near shore delta facies within the Owens Lake Bed Member, or a deeper and older river deposit of the pre-Pleistocene Owens River. A second deeper aquifer extends from 310 to 360 feet, and is composed of medium to coarse sand with some silt streaks. The third aquifer is overlain by 30 feet of clay and is lithologically similar to the second aquifer. Approximately 100 feet of silt and sand layers and a clay bed overlay the fourth aquifer, which consists of 30 feet of medium to coarse sand with scattered gravel lenses. This layer is assumed to be functioning as an aquifer, based on well perforations in the lower interval (Well Log #34, Appendix 8).

In Schaer's exploratory well OV-D, the Owens Lake Sand Member of the Coso Formation lies below 220 feet and consists of fine to very coarse-grained, brown arkosic sands and gravels with minor amounts of silt, tuffaceous clay, and clay (Schaer, 1981). Schaer (1981) described four water-bearing zones in well OV-D in the Owens Lake Sand Member of the Coso Formation. These four thin, gray, coarse sand beds, total 90 feet in combined thickness (Figure 11). They occur at the following four depths: 1) 1,330 to 1,350 feet; 2) 1,490 to 1,520 feet; 3) 1,990 to 2,010 feet; and 4) 2,500 to 2,520 feet (Figure 11). These four coarse sand beds are lacking in the hematite stains, clays, and silts encountered in the rest of the Owens Lake Sand Member (Schaer, 1981) (Figure 10 and Plate V). Schaer (1981) noted that, mineralogically, these thin beds were identical to the rest of the Owens Lake Sand Member. Schaer (1981) concluded that fluid migration through these four highly permeable and porous beds have removed the hematite stains.

In Schaer's drill-hole OV-E, located near the southern shore of Owens Lake, 4 miles east of OV-D, the Owens Lake Sand Member extends from 1,000 to 3,010 feet below the surface (Figure 12). In this well, the sand member is composed of fine to coarse-grained arkosic sand with silt, clay, and ash lenses (Figure 12). Well OV-E contains three of the more permeable and porous gray-sand zones found in well OV-D (Figures 11 and 12). These three gray-sand beds are found at depths of: 1) 2,000 to 2,130 feet; 2) 2,260 to 2,330 feet; and 3) 3,010 to 3,080 feet (Schaer, 1981). This suggests that the potential aquifer zone has tripled in size from 90 feet (well OV-D) to 270 feet four miles to the northeast at well OV-E. These findings suggest that favorable aquifer conditions may be found in the Owens Lake Sand Member from 220 feet to as deep as 3,080 feet below ground surface near the south end of Owens Lake (Figure 10 and Plate V).

b. Potential Shallow Aquifer(s) - Pleistocene Owens River Channel Aquifer in the Southern Owens Valley

The course of the Pleistocene Owens River (now essentially dry in the study area (Figure 17), except for a short section that ephemerally receives water from south Haiwee Reservoir dam's toe drain, and flows south for approximately three miles into the northern Rose Valley before infiltrating back into the fluvial deposits (Table 3) can be traced on aerial photographs. The areal extent of the Pleistocene Owens River channel sand and gravel deposit extends from south of Owens Lake to below Haiwee Reservoir, south into the Rose Valley. The width of the Pleistocene Owens River deposit in Haiwee Gorge ranges from 1,000 to 1,500 feet, based on field measurements. This information coupled with the probable depth of 150 to 200 feet of the river deposit is important for assessing the potential to transmit groundwater from the southern Owens Valley to the Rose Valley within the porous and permeable beds of this deposit. Favorable aquifer lithology is found in the coarse sands and gravels to depths of 175 feet both north and south of Haiwee Reservoir (L.A. Jackson, LADWP Geologist, personal communication, 1999). This fluvial deposit is saturated in the southern Owens Valley and beneath both north and south Haiwee Reservoirs.

J.H. agricultural well #34, located southeast of Olancha in the southern Owens Valley, will be used as a stratigraphic type log for the Pleistocene Owens River channel deposit aquifer (Well Log #34, Appendix 8). The Pleistocene Owens River channel aquifer extends from 15 to 120 feet below ground surface, and is composed of medium to coarse sand and gravel. This sand and gravel aquifer is separated from the underlying Owens Lake Bed aquifer by a white and light brown clay layer 20 feet thick (Well Log #34, Appendix 8). The water table in this well occurs at a depth of 29 feet below ground surface. This 600-foot well currently yields 1,500 gallons per minute (GPM) and is continuously perforated from 90 to 500 feet below ground surface.

Surface water from north Haiwee Reservoir infiltrates and flows north into the southern Owens Valley within the upper unconfined aquifer of the Pleistocene Owens River channel (Tim Thompson, personal communication, Western Water Co., 1998) (Plate II & Appendix 3). This is probably occurring because the surface elevation of the water in north Haiwee Reservoir is greater than the groundwater elevation in the Pleistocene Owens River channel aquifer located in the southern Owens Valley, thereby creating an anthropogenic hydraulic gradient favoring northward groundwater flow. This latter condition may be causing infiltrating north Haiwee Reservoir water to flow north within the Pleistocene Owens River channel deposits and then enter the shallow alluvial fan deposits of the southern Owens Valley.

c. Potential Shallow Aquifers - Quaternary Alluvial Fan Deposits in the Southern Owens Valley

The major source of groundwater in the southern Owens Valley is from the unconsolidated Quaternary alluvial sedimentary deposits that fill the valley (Hollett et al., 1991). Quaternary alluvial fan deposits are sourced from both the Sierra Nevada and Inyo Mountains and extend into the center of the southern Owens Valley. These deposits likely interfinger with the fluvial deposits of the Pleistocene Owens River and the lacustrine deposits of the Owens Lake Beds and Owens Lake Sand Members of the Coso Formation in the subsurface (Figure 9). Sierra Nevada surface water runoff infiltrates the eastern alluvial slope of the Sierra Nevada and flows as Owens Valley groundwater primarily toward the center of the alluvial valley fill and then southward to below Owens Lake (Danskin, 1988). In the central part of the Owens Valley, groundwater moves upward through the clay layers from the deep confined aquifers to the near surface unconfined alluvial aquifer (Rogers, 1987). Based on average depths where water wells are completed, it is assumed that, at a minimum, the upper 100 to 300 feet of alluvial deposits in the southern Owens Valley are functioning as a potable water aquifer (Well Logs #31, #25, and #41, Appendix 8).

In Olancha, the lithology of the uppermost (60 to 125 feet) alluvial aquifer units immediately adjacent to the Sierra Nevada front is sand and gravel alluvium (Well Log #22, Appendix 8). Closer to Owens Lake, the sand and gravel are probably interbedded and interfingered with clay layers and lenses. This is best illustrated in the well logs of Cabin Bar and Cartago's Mutual Water Companies north of Olancha and near the west shore of Owens Dry Lake, west of the Owens Valley fault (Well Logs #43 & #46, Appendix 8). Well logs and depth to water measurements in Olancha indicate that, in general, the water table for the shallow alluvial aquifer lies from 25 to 125 feet below ground surface. These wells are usually perforated from 90 to 150 feet below ground surface.

Along the western portion of the southern Owens Valley, south flowing groundwater in the alluvial aquifer may be partially blocked by the east-trending Sageflat Road Divide granitic bedrock mass (Figures 1 and 20). The result may be that south-flowing groundwater would be forced to flow around the eastern margin of the bedrock and then flow south into the Rose Valley through the alluvial aquifer located along the base of the Sierra Nevada mountain front.

4.5.2 Rose Valley Potential Aquifers

The Rose Valley, for the purpose of this report, is the area south and east of Sageflat Road Divide, specifically the area west of the Coso Range and east of the Sierra Nevada Mountains from northern Dunmovin Hill at Sageflat Road Divide south to Little Lake Gap. Within the Rose Valley, the groundwater table elevation decreases from north to south and appears to correspond with the drop in surface elevation and local topography. Potential aquifers in the Rose Valley may include permeable and porous layers within the Coso Sand and Coso Lake Beds Members of the Coso Formation. The Rhyolite Tuff Member of the Coso Formation and other volcanic deposits, such as basaltic cinders of Red Hill, are also included as potential aquifers. Furthermore, Pleistocene Owens River channel deposits, and Sierra Nevada and Coso Range-derived Quaternary alluvial deposits are functioning as aquifers within the Rose Valley.

a. The Potential Deep Aquifer(s)-Coso Lake Beds and Coso Sand Members in the Rose Valley

The Coso Lake Beds Member of the Coso Formation in the subsurface in the Meritt Divide area has been proposed to be acting as a barrier rather than a conduit for south-flowing Owens Valley groundwater (Lee, 1912, Knopf, 1918, Danskin, 1988). This section examines the geology of the Coso Lake Beds and Coso Sand Members of the Coso Formation in the Rose Valley to determine their lithology, depth, and potential to transmit groundwater.

The Owens Lake Bed and Coso Lake Bed Members of the Coso Formation are laterally continuous from the southern Owens Valley to the northern Rose Valley (Plate V). This suggests that these two members may be hydraulically connected. The potential to transmit groundwater in these beds, based on field observations of the Coso Lake Beds outcrop, appears to be primarily restricted to the more porous and permeable sands and volcanic tuff deposits within the lakebeds. The below-ground thickness of the Coso Lake Beds west of Haiwee Reservoir is approximately 1,000 feet (Figures 35 and 36).

The subsurface lithology of the Coso Lake Beds in the Rose Valley is composed of sand and clay with lesser amounts of tuff primarily in the upper portion (Figure 8). Sand and tuff layers within the Coso Lake Beds Member may have favorable aquifer properties in some parts of the Rose Valley to transmit groundwater. In order to investigate the probable western subsurface depth and extent of the Coso Lake Beds Member beneath the Haiwee Gorge, attitudes of shale beds within the Coso Lake Beds Member outcrop were measured and the results were projected west in the subsurface.

On the east side of south Haiwee Reservoir, limited exposures of the Coso Lake Beds dip 20^{O} NW into the subsurface (Figure 35). By projecting the 20^{O} NW dip of the Coso Lake Beds Member into the subsurface, an east-west cross section, below south Haiwee Reservoir and Dunmovin Hill, was constructed (Figure 35). From the cross section, it appears that, to the west the Coso Lake Beds Member occurs at a depths ranging from 500 to 1,000 feet, directly below the alluvial deposits of Dunmovin Hill (Figure 35). Further west along the base of the Sierra Nevada mountain front, the Sierra-sourced alluvial fill increases in thickness to 3,000 feet (Figure 36). Even if the Coso Lake Beds were acting as a groundwater barrier, they would be limited primarily to the area beneath and slightly west of south Haiwee

Cross Section of Coso Lake Beds Projected in the Subsurface Based on 20° NW Dip

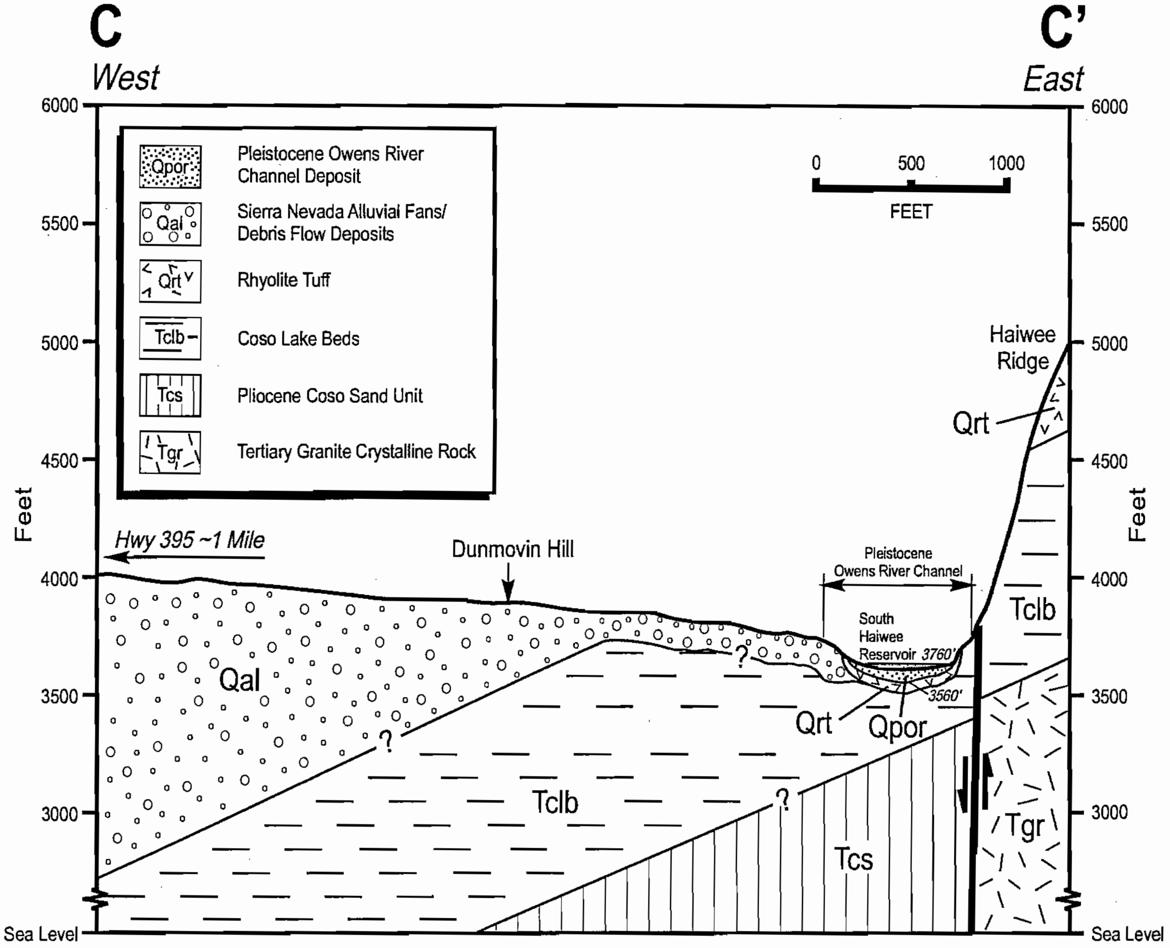


Figure 35. East-west cross section (C-C') depicting the depth of the Coso Lake Beds (Tclb) Member of the Coso Formation, utilizing a dip angle of N 20° W, west of Haiwee Ridge below south Haiwee Reservoir, and Dunmovin Hill approximately one mile west of south Haiwee Reservoir, Rose Valley, Inyo County, California. See Figure 19 for location of cross section.

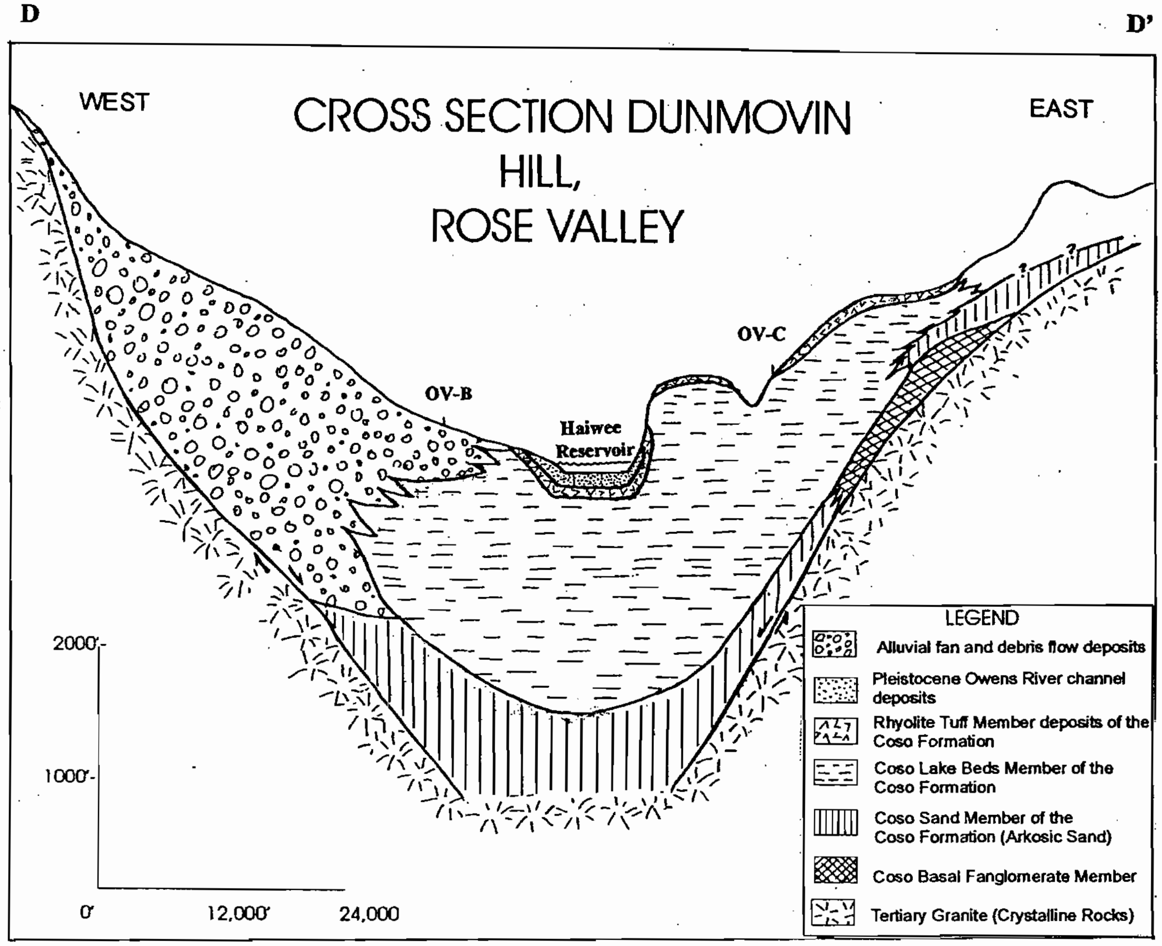


Figure 36. East-west cross section D-D' of Dunmovin Hill showing the probable subsurface lithology of Dunmovin Hill and the westward extent of Coso Lake Beds Member of the Coso Formation. This cross section is based on author's projected surface dip measurements and well logs in the area. (Modified from Schaer, 1981). See Figure 19 for location of cross section.

Reservoir (Figure 35). Providing support for this last conclusion is a well located west of south Haiwee Reservoir (well OV-B) which reveals that the subsurface lithology to a depth of 500 feet is composed of alluvial deposits (Dunmovin Hill), and underlying this deposit is the Coso Lake Beds Member (Figure 7).

In the central Rose Valley, the lower confined aquifer at Coso Junction most likely occurs within the Coso Lake Beds Member. This aquifer is at least 290 feet thick, and is separated from the upper, unconfined, alluvial aquifer by 55 feet of sticky blue clay that occurs from 395 to 450 feet below ground surface (Well # 7, Appendix 8). This clay is most likely part of the upper portion of the Coso Lake Beds Member of the Coso Formation. The top of the confined aquifer is at 445 feet below ground surface and extends to 740 feet below ground surface. Its lithology consists of sand and gravel layers that are separated by multiple clay lenses ranging from 5 to 30 feet thick. Based on well perforations, Well # 7 is completed in these sand and gravel layers. The depth to the groundwater table here is 180 feet.

A potential aquifer may occur in permeable and porous portions of the Pliocene Coso Sand Member of the Coso Formation, at a depth of 3,000 to 3,490 feet below ground surface in the northern Rose Valley. The lithology appears to be less favorable than the Owens Lake Sand Member due to increased concentrations of clay and increased iron staining. However, Schaer (1981) does mention that the Coso Sand in the Rose Valley is poorly consolidated. This potential aquifer may contain poorer quality water due to its depth and high iron content.

b. Potential Shallow Aquifers - Volcanic Deposits of the Rose Valley

Deposits of the Rhyolite Tuff Member of the Coso Formation occur primarily on the east side of south Haiwee Reservoir above the Coso Lake Beds Member (Figure 36). The

Rhyolite Tuff Member is friable, porous and permeable, and is not fused. Based on a large volume of discharge from a spring (approximately 1,000 gpm to 1,200 gpm) in the tuff, located below the east flank of south Haiwee dam, this member is capable of transmitting groundwater from beneath south Haiwee Reservoir south to the central Rose Valley. Furthermore, seepage in and through these tuffs also occurred when south Haiwee Reservoir was first filled (Lee, 1906). The exposed thickness of this member in the south Haiwee Reservoir area varies from one to four hundred feet (Power, 1958) (Figure 36).

In the southern Rose Valley, Red Hill and other cinder cones have extruded large amounts of both basaltic lava and porous cinders of various sizes. These volcanic deposits occur at the surface and most likely in the subsurface (at unknown depths and thicknesses). Buried cinders and lava flows from past eruptions of Red Hill could provide either potential aquifers or partial hydraulic barriers or shunts for south-flowing groundwater in the southern Rose Valley.

c. Potential Shallow Aquifer-Pleistocene Owens River Channel Aquifer in the Rose Valley

The Pleistocene Owens River meandered southward from the spillway of Pleistocene Owens Lake in the southern Owens Valley to the Rose Valley (Figure 17). The Pleistocene Owens River has completely eroded and truncated Dunmovin Hill's eastern extent. In the area of this ancient river channel, there is no continuous east-west topographic or surface bedrock divide between the Owens and Rose Valleys. The width of the river deposit in Haiwee Gorge (northern Rose Valley) ranges from 1,000 to 1,500 feet while in the central and southern Rose Valley it varies from approximately 500 to 1,000 feet. Favorable aquifer lithology is found in the coarse sands and gravels to depths of 175 feet immediately south of south Haiwee Reservoir (L.A. Jackson, LADWP Geologist, personal communication, 1999) (Figure 36). In Rose Valley, these channel deposits are coarse and composed predominately of sand and gravel. In the southern Rose Valley, in the Little Lake area, the river channel deposits are largely buried by recent, active alluvial fan and debris flow deposits of the Sierra Nevada and Coso Range.

This deposit is saturated in the northern Rose Valley beneath both north and south Haiwee Reservoirs. Whether this deposit is saturated farther south in the central Rose Valley is not known. However, the river deposit is saturated in the southern Rose Valley below northern Little Lake Ranch. The lateral extent of the Pleistocene Owens River's meander zone within the Rose Valley is not known. However, field observations and aerial photographs show the location where the river last flowed. This channel deposit aquifer has the potential to transmit groundwater within the Rose Valley to Little Lake. In addition, Duffield and Smith (1978) postulated that buried older river channels may exist farther east in the southern Rose Valley under younger basalt flows. These older channel deposits could transfer groundwater beneath the basalt flows.

d. Potential Shallow Aquifer(s)-Quaternary Alluvial Deposits in the Rose Valley

The Quaternary alluvial deposits (Qal) of the Rose Valley are composed of poorly sorted, subangular, granitic particles ranging from boulder to sand size near the mountain front to predominately subangular, moderately well sorted, gravel, sand, silt, and clay size clasts near the center of the basin. In the center of the Rose Valley, lacustrine deposits of the Coso Lake Beds and Coso Sand Members of the Coso Formation underlie and interfinger the alluvial deposits (Schaer, 1981). The alluvial deposits in the Rose Valley are the principal water-bearing units and consist predominately of Sierran-derived alluvial fan deposits occurring along the westside of the Rose Valley at subsurface thicknesses of up to 3,000 feet. Coso Range-derived alluvial deposits occur along the northeastern portion of the Rose Valley to depths of 5,600 feet (Rockwell Report, 1980).

Along the western side of the boundary between the southern Owens Valley and the Rose Valley, the recent Sierra-derived alluvial fans in the southern Owens Valley interfinger and grade southward into the alluvial fans of Sageflat Road Divide and the debris flow deposits of Dunmovin Hill forming a bajada. This lateral continuity of approximately 400 feet of subsurface alluvial fan deposits, east of Sageflat Road Divide, is providing a porous and permeable groundwater connection between the two valleys along the west side (Stinson, 1977) (Figure 20) (Plate II).

In the eastern Rose Valley, the shallow portions of the Coso Range-derived alluvial deposits are frequently dry due to a lack of recharge from the Coso Range (Rockwell Report, 1980). However, in the southern Rose Valley, south of Little Lake, Coso Range-derived alluvial deposits are functioning as an aquifer. It is assumed that, at a minimum, the upper 700 feet of alluvial deposits in the Rose Valley are functioning as a potable water aquifer, based on average depths of water well completions in the area (Well Logs #7, #8, and #14, Appendix 8).

Alluvial aquifers in the northern and central portions of the Rose Valley interfinger with the deposits of the Pleistocene Owens River, the Rhyolite Tuff Member, and the Coso Lake Beds and Sand Members of the Coso Formation (Figure 9). In addition, the 400+ foot thick debris flow deposit of Dunmovin Hill is functioning as an aquifer, as evidenced by five domestic wells completed within this deposit (Wells # 14-18, Appendix 8).

Dunmovin Hill is a topographic divide which extends from the base of the Sierra Nevada east to Haiwee Reservoir's west shore (Figure 14). Dunmovin Hill is made up of a series of alluvial and debris flow deposits that originated in the Sierra Nevada (Figure 36). The wells on the east side of Dunmovin Hill are completed in the lower portion of the alluvial aquifer (Wells # 15, 16, and 17, Appendix 8). Water is being extracted from a conglomerate facies of this formation from 240 to 300 feet below the ground surface (Well Log #15, Appendix 8).

A 300 foot well in Enchanted Lake Village, west of Haiwee Reservoir, is used here as a type log for the lithology of the alluvial aquifer units at Dunmovin Hill (Well Log #17, Appendix 8). Sand and boulders are found from 140 to 240 feet and sand and gravel are found from 240 to 300 feet below ground surface. It is plausible that the sand and gravel deposits that occur from 240 to 300 feet are remnants of the meandering Pleistocene Owens River channel or other river now buried by recent alluvial and debris flow deposits comprising Dunmovin Hill. Similar stratigraphic relationships are observed in wells 13 and 14 (Appendix 8) near the southern portion of Dunmovin Hill.

Currently, approximately 30 wells are producing groundwater from the alluvial aquifer beneath Dunmovin Hill. This suggests that the alluvium is sufficiently porous and permeable to provide groundwater for domestic use. Wells located on Dunmovin Hill have groundwater table elevations that vary from 3,570 feet in the north to 3,405 feet above mean sea level in the south. This suggests a southward hydraulic gradient towards the Rose Valley (Plate II). The aqueous geochemical evidence also suggests that the groundwater at Dunmovin Hill is genetically related to the shallow groundwater found in the southern Owens Valley (Figure 22).

Coso Junction is located in the central Rose Valley. In this area, the alluvial aquifer consists of 400 feet of boulders, coarse gravel, sand, and clay above the Coso Lake Beds Member (Well Log #7, Appendix 8). Based on wells completed in these deposits, the Quaternary alluvium provides suitable aquifer material within the central Rose Valley (Rockwell Report, 1980). Groundwater in the Rose Valley flows through these coarse alluvial sediments southward towards Little Lake Gap. Much of this groundwater ultimately emerges as surface water that passes through Little Lake Gap into the northwestern Indian Wells Valley (Rockwell, 1980). This alluvial aquifer constitutes the upper unconfined aquifer in this part of the Rose Valley.

A second Coso Junction pumping well #8, located approximately 0.75 mile east of well #7, has groundwater at 139 feet below ground surface (3,231 feet elevation, measured December, 1998), (Well Log #8, Appendix 8). Sand content in this well is less than the Coso #7 well. Well #8 is completed in four aquifers: an upper unconfined and three lower confined. Only the upper unconfined aquifer which occurs from approximately 140 to 200 feet is the alluvial aquifer.

There appears to be at least two aquifers in the southern Rose Valley at Little Lake Ranch: a shallow unconfined alluvial aquifer and a deeper artesian aquifer. The shallow unconfined aquifer extends from approximately 5 to 120 feet below ground surface in the central Little Lake Ranch area both north and south of Little Lake. This shallow aquifer consists of combined Sierra Nevada- and Coso Range-derived alluvium. Groundwater in the southern Rose Valley eventually emerges at the surface at Little Lake Ranch as Little Lake, ponds P-1 and P-2, and artesian springs.

The deeper, confined, artesian aquifer lies below 125 feet (personal communication Jim Pearson, Little Lake Ranch Officer, 1999). A flowing artesian well in central Little Lake Ranch taps this confined aquifer and is a perennial supply of water for the second pond (P-2) south of Little Lake. The well log is unavailable for the artesian well, but the estimated depth of this well is approximately 175 to 200 feet deep (Jim Pearson, Little Lake Ranch officer, personal communication, 1999). This artesian aquifer is separated from the shallow aquifer by a layer of clay of unknown thickness (Karl Kirschenmann, Kirschenmann Well Drillers, personal communication, 1999). Based on similar aqueous geochemistry, the artesian well, Little Lake, and Coso Spring are supplied with groundwater from this artesian aquifer.

In the Little Lake Gap area, the narrow strip of alluvium between Coso Range crystalline bedrock outcrops has, in effect, created a bottleneck for south-flowing Rose Valley groundwater. This causes groundwater to emerge at the surface north of the gap forming Little Lake, Coso Spring, the two other smaller water bodies (P-1 and P-2), and the associated wetlands south of Little Lake. South of Little Lake Gap, the alluvial fill thickens into the northwestern Indian Wells Valley. In this area, surface water from Little Lake outflow stream infiltrates to recharge the aquifer in the Indian Wells Valley. Chemically similar water to that of Little Lake is found in wells in the northwestern Indian Wells Valley suggesting that this recharge is occurring (Thyne et al., 1999).

5.0 Conclusions

- Groundwater enters the northern Rose Valley from below south Haiwee Reservoir, because the south Haiwee Reservoir dam is known to leak through the deposits of the Rhyolite Tuff Member of the Coso Formation (Tim Thompson, Western Water, personal communication, 1999). In addition, the sediments in the Pleistocene Owens

River Gorge, in which south Haiwee Reservoir is located, are composed of porous and permeable sands and gravels to a depth of 150 to 200 feet below ground surface (L.A. Jackson, personal communication, 1999). It is highly probable that leaking reservoir water is being transmitted to the Rose Valley through both of these permeable and porous deposits.

- Deep groundwater from the southern Owens Valley may enter the Rose Valley through sand and gravel lenses within the Coso Lake Beds Member, Coso Sand Member deposits of the Coso Formation, and/or Sierra Nevada alluvial fan deposits to combine in the subsurface with stream runoff from the Sierra Nevada and Coso Ranges. The water that supplies Little Lake appears to be geochemically similar to deep water found in the southern Owens Valley.
- Evidence for strong, upward hydraulic gradients north of Little Lake Gap are:

  1) Artesian well and springs,

  2) Water budget for Little Lake shows net groundwater inflow (springs around and below the lake),

  3) Upward hydraulic gradients along Little Lake's north shore prevented water to fill the augered test holes by percolation and infiltration during hydraulic conductivity measurements,

  4) The presence of a soil calcrete (calcium carbonate) horizon at shallow depths from south of Little Lake to Little Lake Gap suggests that groundwater in the south end of Rose Valley flows both upward and southward and evaporates near the surface.
- Water is leaving Rose Valley at an average rate of 3,300 ac-ft/yr via the Little Lake outflow stream into the northwestern Indian Wells Valley. This water infiltrates the

alluvium south of Little Lake Gap to become groundwater of northwestern Indian Wells Valley as evidenced by losing outflow stream and geochemistry.

- The Little Lake fault zone occurs south of Little Lake Gap. This fault has the potential to either conduct groundwater to deeper depths, where it may enter porous and permeable aquifers within the Indian Wells Valley, or it may act as a partial barrier to south-flowing groundwater flow causing the groundwater to have its surface expression in Little Lake.

6.0 Recommendations for Further Research

The focus of further research should be directed toward the areas of Little Lake Gap and east of Sageflat Road Divide. Additional studies focusing on geochemical and geophysical analyses and well logs in the area of Dunmovin Hill at Sageflat Road Divide are needed. These studies will help to determine bedrock continuity and extent as well as the physical properties, stratigraphic relationships (i.e., vertical and horizontal extent of the Owens Lake Bed, Owens Lake Sand Members, Coso Lake Beds, and Coso Sand Members of the Coso Formation), which in turn will bear on the potential groundwater source that supplies Rose Valley and ultimately Little Lake, and the probable aquifer(s) responsible for transmitting groundwater between the southern Owens and Rose Valleys.

Further research in the vicinity of Haiwee Reservoir could determine the amount of downcutting of the Pleistocene Owens River into the underlying Coso Lake Beds Member and Rhyolite Tuff Member of the Coso Formation, and subsequent deposition of river sands and gravels. Determinations of depth to groundwater along a north-south transect from north of Haiwee Reservoir to south of Haiwee Reservoir should also be performed. This will help in ascertaining the direction and the amount of groundwater flow through the abandoned

Pleistocene Owens River channel.

In addition, the vertical groundwater mound and the horizontal groundwater flow directional changes that occur as a result of leakage of north and south Haiwee Reservoir need to be investigated further. Depth to bedrock in the area east of Sageflat Road Divide and Little Lake Gap needs to be conclusively determined either geophysically or by exploratory wells. Furthermore, the lithology and the faults in the Little Lake Gap area need to be accurately mapped and characterized. Wells should be drilled both north and south of Little Lake Gap to determine the depth to bedrock within the gap and how much groundwater is actually flowing through the gap. Wells also need to be drilled in the Sageflat Road Divide area to determine more accurately the shallow and deep groundwater flow direction, as well as its subsurface effects on groundwater flow in the southern Owens Valley and northern Rose Valley.

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APPENDICES

APPENDIX ONE

Transducer Data for Hydrograph of Little Lake
and Well North of Little Lake
(see Figure 33 for transducer locations).

Water Level Fluctuations in Well Located
Near the North Shore of Little Lake(Elevation Top of Casing = 3150.69')

Jan	1997	Feb		March		April		May		June		July		Aug	
Day	Elev	Day	Elev	Day	Elev	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.
6	3145.64	1	3145.84	1	3145.79	1	3145.79	1	3145.65	1	3145.43	1	3145.20	1	3145.06
7	3145.64	2	3145.84	2	3145.83	2	3145.80	2	3145.63	2	3145.43	2	3145.21	2	3145.05
8	3145.64	3	3145.84	3	3145.83	3	3145.79	3	3145.61	3	3145.42	3	3145.19	3	3145.05
9	3145.69	4	3145.86	4	3145.79	4	3145.83	4	3145.60	4	3145.41	4	3145.19	4	3145.05
10	3146.09	5	3145.85	5	3145.79	5	3145.77	5	3145.61	5	3145.43	5	3145.19	5	3145.04
11	3145.76	6	3145.83	6	3145.83	6	3145.75	6	3145.60	6	3145.40	6	3145.17	6	3145.04
12	3145.79	7	3145.83	7	3145.83	7	3145.75	7	3145.61	7	3145.39	7	3145.16	7	3145.04
13	3145.79	8	3145.86	8	3145.83	8	3145.77	8	3145.60	8	3145.39	8	3145.15	8	3145.05
14	3145.72	9	3145.84	9	3145.81	9	3145.78	9	3145.58	9	3145.37	9	3145.15	9	3145.03
15	3145.72	10	3145.86	10	3145.83	10	3145.76	10	3145.58	10	3145.36	10	3145.16	10	3145.03
16	3145.73	11	3145.86	11	3145.86	11	3145.75	11	3145.58	11	3145.35	11	3145.15	11	3145.03
17	3145.73	12	3145.86	12	3145.85	12	3145.74	12	3145.58	12	3145.35	12	3145.13	12	3145.02
18	3145.76	13	3145.81	13	3145.84	13	3145.74	13	3145.57	13	3145.37	13	3145.12	13	3145.01
19	3145.79	14	3145.81	14	3145.85	14	3145.74	14	3145.56	14	3145.35	14	3145.11	14	3145.01
20	3145.81	15	3145.82	15	3145.86	15	3145.73	15	3145.55	15	3145.35	15	3145.11	15	3145.02
21	3145.80	16	3145.84	16	3145.86	16	3145.74	16	3145.55	16	3145.33	16	3145.11	16	3145.00
22	3145.81	17	3145.89	17	3145.81	17	3145.74	17	3145.55	17	3145.34	17	3145.11	17	3144.99
23	3145.81	18	3145.83	18	3145.79	18	3145.75	18	3145.56	18	3145.33	18	3145.09	18	3144.98
24	3145.79	19	3145.83	19	3145.81	19	3145.74	19	3145.56	19	3145.33	19	3145.08	19	3144.98
25	3145.83	20	3145.83	20	3145.84	20	3145.72	20	3145.54	20	3145.33	20	3145.07	20	3144.97
26	3145.84	21	3145.83	21	3145.85	21	3145.72	21	3145.53	21	3145.33	21	3145.07	21	3144.97
27	3145.78	22	3145.85	22	3145.85	22	3145.71	22	3145.52	22	3145.31	22	3145.08	22	3144.96
28	3145.79	23	3145.84	23	3145.86	23	3145.72	23	3145.51	23	3145.29	23	3145.08	23	3144.97
29	3145.79	24	3145.83	24	3145.83	24	3145.70	24	3145.51	24	3145.28	24	3145.08	24	3144.97
30	3145.80	25	3145.83	25	3145.80	25	3145.65	25	3145.49	25	3145.27	25	3145.09	25	3144.96
31	3145.83	26	3145.87	26	3145.83	26	3145.65	26	3145.46	26	3145.26	26	3145.09	26	3144.96
		27	3145.91	27	3145.84	27	3145.67	27	3145.46	27	3145.26	27	3145.08	27	3144.96
		28	3145.83	28	3145.83	28	3145.67	28	3145.46	28	3145.24	28	3145.10	28	3144.95
				29	3145.80	29	3145.65	29	3145.45	29	3145.25	29	3145.07	29	3144.95
				30	3145.81	30	3145.65	30	3145.44	30	3145.23	30	3145.07	30	3144.95
				31	3145.81			31	3145.44			31	3145.06	31	3144.96

Water Level Fluctuations in Well Located (Continued)
Near the North Shore of Little Lake Refernce Elevation, Top of Casing = 3150.69'

Sept		Oct		Nov		Dec		Jan	1998	Feb		March	
Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.
1	3144.94	1	3145.59	1	3145.56	1	3145.82	1	3145.99	1	3146.05	1	3146.26
2	3144.95	2	3145.60	2	3145.57	2	3145.80	2	3146.00	2	3146.09	2	3146.27
3	3145.25	3	3145.58	3	3145.59	3	3145.79	3	3146.00	3	3146.16	3	3146.28
4	3145.26	4	3145.58	4	3145.60	4	3145.81	4	3146.01	4	3146.12	4	3146.27
5	3145.29	5	3145.60	5	3145.61	5	3145.83	5	3145.96	5	3146.09	5	3146.28
6	3145.30	6	3145.63	6	3145.62	6	3145.93	6	3145.95	6	3146.14	6	3146.28
7	3145.31	7	3145.60	7	3145.64	7	3145.93	7	3145.97	7	3146.14	7	3146.23
8	3145.31	8	3145.58	8	3145.64	8	3145.93	8	3146.00	8	3146.18	8	3146.23
9	3145.32	9	3145.58	9	3145.64	9	3145.88	9	3146.02	9	3146.15	9	3146.21
10	3145.32	10	3145.59	10	3145.67	10	3145.86	10	3146.01	10	3146.11	10	3146.23
11	3145.33	11	3145.57	11	3145.69	11	3145.86	11	3146.00	11	3146.12	11	3146.23
12	3145.33	12	3145.53	12	3145.69	12	3145.86	12	3146.02	12	3146.12	12	3146.25
13	3145.32	13	3145.51	13	3145.69	13	3145.90	13	3146.00	13	3146.13	13	3146.25
14	3145.30	14	3145.53	14	3145.67	14	3145.92	14	3146.00	14	3146.19	14	3146.21
15	3145.30	15	3145.53	15	3145.65	15	3145.91	15	3146.03	15	3146.18	15	3146.21
16	3145.30	16	3145.54	16	3145.65	16	3145.91	16	3146.02	16	3146.15	16	3146.23
17	3145.32	17	3145.56	17	3145.67	17	3145.94	17	3146.01	17	3146.16	17	3146.23
18	3145.33	18	3145.56	18	3145.69	18	3145.97	18	3146.04	18	3146.11	18	3146.18
19	3145.33	19	3145.57	19	3145.70	19	3145.93	19	3146.07	19	3146.14	19	3146.14
20	3145.31	20	3145.57	20	3145.70	20	3145.94	20	3146.06	20	3146.14	20	3146.16
21	3145.31	21	3145.55	21	3145.72	21	3145.98	21	3146.04	21	3146.15	21	3146.14
22	3145.32	22	3145.56	22	3145.73	22	3145.94	22	3146.02	22	3146.16	22	3146.13
23	3145.32	23	3145.59	23	3145.73	23	3145.93	23	3146.04	23	3146.27	23	3146.16
24	3145.32	24	3145.57	24	3145.73	24	3145.95	24	3146.04	24	3146.28	24	3146.16
25	3145.47	25	3145.53	25	3145.75	25	3145.92	25	3146.02	25	3146.25		
26	3145.52	26	3145.54	26	3145.81	26	3145.89	26	3146.04	26	3146.26		
27	3145.54	27	3145.56	27	3145.77	27	3145.90	27	3146.05	27	3146.25		
28	3145.56	28	3145.56	28	3145.76	28	3145.92	28	3146.04	28	3146.24		
29	3145.57	29	3145.56	29	3145.78	29	3145.95	29	3146.07				
30	3145.57	30	3145.56	30	3145.81	30	3145.97	30	3146.04				
		31	3145.57			31	3145.96	31	3146.05				

Water Level Fluctuations in Little Lake. Transducer Located At The South Dock of Little Lake (Elevation = 3142.64')

Feb	1997	March		April		May		June		July		Aug	
Day	Elev	Day	Elev	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.
2	3142.64	1	3142.58	1	3142.63	1	3142.58	1	3142.31	1	3142.00	1	3141.85
3	3142.64	2	3142.61	2	3142.64	2	3142.56	2	3142.31	2	3141.98	2	3141.83
4	3142.66	3	3142.64	3	3142.57	3	3142.55	3	3142.30	3	3141.99	3	3141.83
5	3142.65	4	3142.62	4	3142.59	4	3142.55	4	3142.29	4	3141.97	4	3141.84
6	3142.64	5	3142.59	5	3142.57	5	3142.54	5	3142.31	5	3141.96	5	3141.84
7	3142.61	6	3142.63	6	3142.62	6	3142.53	6	3142.37	6	3141.96	6	3141.82
8	3142.63	7	3142.65	7	3142.65	7	3142.54	7	3142.30	7	3141.94	7	3141.82
9	3142.61	8	3142.68	8	3142.65	8	3142.53	8	3142.30	8	3141.92	8	3141.80
10	3142.61	9	3142.69	9	3142.64	9	3142.53	9	3142.29	9	3141.93	9	3141.80
11	3142.64	10	3142.68	10	3142.67	10	3142.53	10	3142.27	10	3141.91	10	3141.78
12	3142.63	11	3142.69	11	3142.64	11	3142.53	11	3142.29	11	3141.92	11	3141.79
13	3142.55	12	3142.69	12	3142.65	12	3142.55	12	3142.27	12	3141.90	12	3141.80
14	3142.54	13	3142.72	13	3142.61	13	3142.51	13	3142.24	13	3141.91	13	3141.79
15	3142.56	14	3142.70	14	3142.65	14	3142.49	14	3142.26	14	3141.90	14	3141.78
16	3142.54	15	3142.71	15	3142.67	15	3142.37	15	3142.26	15	3141.89	15	3141.78
17	3142.56	16	3142.71	16	3142.66	16	3142.37	16	3142.27	16	3141.88	16	3141.78
18	3142.64	17	3142.82	17	3142.65	17	3142.40	17	3142.27	17	3141.89	17	3141.76
19	3142.56	18	3142.68	18	3142.64	18	3142.40	18	3142.26	18	3141.87	18	3141.73
20	3142.64	19	3142.68	19	3142.64	19	3142.40	19	3142.24	19	3141.85	19	3141.75
21	3142.58	20	3142.80	20	3142.62	20	3142.42	20	3142.19	20	3141.85	20	3141.74
22	3142.61	21	3142.67	21	3142.64	21	3142.38	21	3142.22	21	3141.84	21	3141.73
23	3142.6	22	3142.67	22	3142.63	22	3142.37	22	3142.20	22	3141.87	22	3141.73
23	3142.65	23	3142.69	23	3142.66	23	3142.37	23	3142.19	23	3141.88	23	3141.72
24	3142.6	24	3142.78	24	3142.71	24	3142.39	24	3142.19	24	3141.89	24	3141.71
25	3142.59	25	3142.68	25	3142.58	25	3142.40	25	3142.06	25	3141.89	25	3141.72
26	3142.63	26	3142.68	26	3142.58	26	3142.38	26	3142.02	26	3141.87	26	3141.70
27	3142.62	27	3142.66	27	3142.60	27	3142.36	27	3142.00	27	3141.87	27	3141.69
28	3145.83	28	3142.74	28	3142.60	28	3142.35	28	3142.02	28	3141.86	28	3141.67
		29	3142.67	29	3142.56	29	3142.34	29	3142.02	29	3141.88	29	3141.69
		30	3142.63	30	3142.59	30	3142.33	30	3142.03	30	3141.87	30	3141.69
		31	3142.65			31	3142.34			31	3141.85	31	3141.67

Water Level Fluctuations in Little Lake. Transducer Located At The South Dock of Little Lake (Elevation = 3142.64')

Sept		Oct		Nov		Dec		Jan	1998	Feb		March	
Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.	Day	Elev.
1	3141.69	1	3142.40	1	3142.36	1	3142.83	1	3142.88	1	3143.00	1	3142.96
2	3141.69	2	3142.40	2	3142.36	2	3142.82	2	3142.89	2	3143.04	2	3142.96
3	3142.09	3	3142.40	3	3142.38	3	3142.82	3	3142.88	3	3143.07	3	3142.96
4	3142.11	4	3142.38	4	3142.39	4	3142.83	4	3142.91	4	3143.05	4	3142.95
5	3142.10	5	3142.34	5	3142.38	5	3142.80	5	3142.89	5	3143.06	5	3142.96
6	3142.09	6	3142.39	6	3142.38	6	3142.79	6	3142.87	6	3143.07	6	3142.93
7	3142.10	7	3142.37	7	3142.40	7	3142.80	7	3142.88	7	3142.92	7	3142.91
8	3142.09	8	3142.35	8	3142.44	8	3142.79	8	3142.88	8	3142.90	8	3142.93
9	3142.09	9	3142.38	9	3142.42	9	3142.74	9	3142.91	9	3142.87	9	3142.93
10	3142.09	10	3142.37	10	3142.45	10	3142.80	10	3142.92	10	3142.85	10	3142.94
11	3142.09	11	3142.36	11	3142.45	11	3142.78	11	3142.93	11	3142.83	11	3142.93
12	3142.08	12	3142.25	12	3142.45	12	3142.74	12	3142.93	12	3142.83	12	3142.93
13	3142.08	13	3142.25	13	3142.45	13	3142.74	13	3142.93	13	3142.85	13	3142.94
14	3142.08	14	3142.29	14	3142.44	14	3142.80	14	3142.95	14	3142.90	14	3142.94
15	3142.09	15	3142.27	15	3142.44	15	3142.77	15	3142.96	15	3142.85	15	3142.96
16	3142.07	16	3142.27	16	3142.44	16	3142.77	16	3142.97	16	3142.89	16	3142.96
17	3142.07	17	3142.29	17	3142.45	17	3142.81	17	3142.96	17	3142.88	17	3142.96
18	3142.08	18	3142.27	18	3142.62	18	3142.90	18	3142.98	18	3142.87	18	3142.94
19	3142.10	19	3142.32	19	3142.65	19	3142.76	19	3142.98	19	3142.90	19	3142.94
20	3142.14	20	3142.29	20	3142.65	20	3142.82	20	3142.99	20	3142.85	20	3142.94
21	3142.11	21	3142.30	21	3142.65	21	3142.83	21	3142.98	21	3142.87	21	3142.94
22	3142.10	22	3142.29	22	3142.74	22	3142.77	22	3142.97	22	3142.97	22	3142.96
23	3142.11	23	3142.38	23	3142.74	23	3142.85	23	3142.98	23	3143.00	23	3142.96
24	3142.10	24	3142.26	24	3142.76	24	3142.80	24	3142.98	24	3142.98	24	3146.16
25	3142.27	25	3142.23	25	3142.80	25	3142.77	25	3142.98	25	3142.98		
26	3142.37	26	3142.24	26	3142.81	26	3142.78	26	3142.97	26	3142.96		
27	3142.40	27	3142.25	27	3142.80	27	3142.78	27	3142.97	27	3142.96		
28	3142.40	28	3142.29	28	3142.80	28	3142.83	28	3142.96	28	3142.96		
29	3142.38	29	3142.30	29	3142.82	29	3142.85	29	3142.97				
30	3142.37	30	3142.31	30	3142.87	30	3142.86	30	3142.97				
	3142.4	31	3142.26			31	3142.86	31	3142.96				

APPENDIX TWO

Groundwater Elevations in southern Owens
and Rose Valleys
(see Map Plate II for well locations).

Plate II Potentiometric Surface Map for Rose and Southern Owens Valleys

Well No.	Well or Surface Water Location	Date of Measurement	Well Refernce Elevation (Feet)	Depth to Water (Feet)	Water Level Elevation (Feet)	Condition of Well
1	Little Lake	Mar-98	N/A	3145	3145	N/A
2	Upper Little Lake Ranch	Sep-97	3244	30	3214	Pumping
3	Well at N. Dock Little Lake	Mar-98	3151	6	3145	Static
4	Little Lake Ranch Well	Mar-98	3158.6	7.6	3151	Pumping
5	Well in Wetland	Mar-98	3140.4	2.25	3138.15	Static
6	Little Lake Hotel	Dec-98	3140	25	3115	Pumping
7	Cinder Road Red Hill	May-98	3344	200	3144	Pumping
8	Coso JX. W. Well	Jun-97	3395	180	3215	Pumping
9	Coso JX. Strore	Dec-98	3370	139	3231	Pumping
10	Portugese Bench	May-98	3820	0	3820	Spring
11	Coso JX. Caltrans	Oct-80	3370	140	3230	Pumping
12	Coso JX. W. Ag.Well	Dec-98	3398	270	3128	Pumping
13	Coso JX. E. Ag.Well	Dec-98	3420	185	3235	Pumping
14	Coso JX. E. Mobile HomeWell	Dec-98	3427	199	3228	Pumping
15	Cal-Pumice	Dec-98	3480	242	3238	Pumping
16	Dunmovin Miriam's Well	Dec-98	3485	303	3182	Pumping
17	T21S,R37E,Sec2,NW1/4,SW1/4	Dec-74	3700	10.6	3689.4	Pumping
18	T21S,R37E,Sec11,NE1/4,NW1/4	Nov-75	3833	39.3	3793.7	Pumping
19	Rose Spring	Mar-98	3580	0	3580	Spring
20	Enchanted Lake Village Buckland	Oct-86	3960	75	3885	Pumping
21	Enchanted Lake Village McNalley	Jun-86	3980	105	3875	Pumping
22	Enchanted Lake Village Toone	Jan-96	3800	195	3605	Pumping
23	Enchanted Lake Village Dews	May-98	3960	230	3730	Pumping
24	So. Haiwee Reservoir	Mar-86	N/A	3745.8	N/A	Surface
25	No. Haiwee Reservoir	Mar-86	N/A	3751.9	N/A	Surface
26	Sageflat Rd. Lien's Well	May-98	4220	53	4167	Flowing artesian
27	Sageflat Rd. V. Price	May-98	4520	0	4520	Fracture Flow
28	Sageflat Rd. Krick's Well	May-98	4000	25	3975	Pumping
29	Sageflat Rd. Hwy 395 Fault Scarp	Dec-98	3980	11.5	3968.5	Spring
30	Olancha V. Moore	Jul-77	3704	65	3639	Pumping
31	Olancha Trent	Feb-79	3670	37	3633	Pumping
32	Olancha Kivler	Nov-87	3656	25	3631	Pumping
33	Olancha Evan	May-88	3760	65	3695	Pumping
34	Olancha Woods	Jul-86	3695	19	3676	Pumping
35	Olancha Ronnie Bill	May-98	3760	30	3730	Pumping
36	Olancha Sheffield	Jul-87	3704	70	3634	Pumping
37	Crystal Geyser	Apr-90	3640	5	3635	Pumping
38	Olancha Fritcher	May-98	3900	140	3760	Pumping
39	Olancha-Gordon	May-98	3760	76	3684	Pumping
40	John Hunter Ranch	May-98	3680	28	3652	Pumping
41	John Hunter Ranch Ag	May-98	3680	29	3651	Pumping
42	Olancha Butterworth	May-98	3697	31	3666	Monitoring
43	Olancha Oyster	Aug-92	3670	18	3652	Pumping
44	Olancha Mini-Mart	May-94	3670	39	3631	Pumping
45	Cabin Bar Ranch	Sep-82	3640	18	3622	Artesian

Well No.	Well or Surface Water Location	Date of Measurement	Well Reference Elevation (Feet)	Depth to Water (Feet)	Water Level Elevation (Feet)	Condition of Well
46	Cartago-Holt	May-98	3680	48	3632	Pumping
47	Cartago Mutual Water Co.	Nov-85	3600	10	3590	Pumping
48	Cartago-Rogers	Jan-90	3640	36	3604	Pumping
49	Olancha-Owen	Nov-79	3635	2	3633	Pumping
	Western Water Data					
50	Hunter #1	Oct-98	3695.2	90.72	3604.48	Pumping
51	MW-2	Oct-98	3659.43	11.43	3648	Monitoring
52	MW-3	Oct-98	3712.23	63.59	3648.64	Monitoring
53	MW-4	Oct-98	3691.71	40.01	3651.7	Monitoring
54	MW-5	Oct-98	3731.79	79.35	3652.44	Monitoring
55	MW-6	Oct-98	3745.02	78.22	3666.8	Monitoring
56	MW-7	Oct-98	3693.5	39.75	3653.75	Monitoring
57	MW-8A	Oct-98	3644	3.02	3640.98	Monitoring
58	MW-8B	Oct-98	3645.2	4.55	3640.65	Monitoring
59	MW-9	Oct-98	3680.3	37.71	3642.59	Monitoring
60	MW-10	Oct-98	3657.2	15.23	3641.97	Monitoring
61	Butterworth #1	Oct-98	3702.96	29.32	3673.64	Static
62	Butterworth #2	Oct-98	3700.4	N/A	N/A	Static
63	Butterworth #3	Oct-98	3701.21	16.61	3684.6	Pumping
64	Butterworth #4	May-98	N/A	N/A	N/A	Static
65	Butterworth #5	Oct-98	3708.38	26.75	3681.63	Pumping
66	Butterworth #6	Oct-98	3698.53	33.73	3664.8	Pumping
67	86-4	Oct-98	3750.29	13.35	3736.94	Monitoring
68	86-6	Oct-98	3757.87	24.67	3733.2	Pumping
69	GR-2	Oct-98	3775	91.57	3683.43	Pumping

APPENDIX THREE

Southern Owens Valley Aquifer Tests and Long Term Well
Monitoring Levels in the southern Owens Valley
Provided by Western Water Company

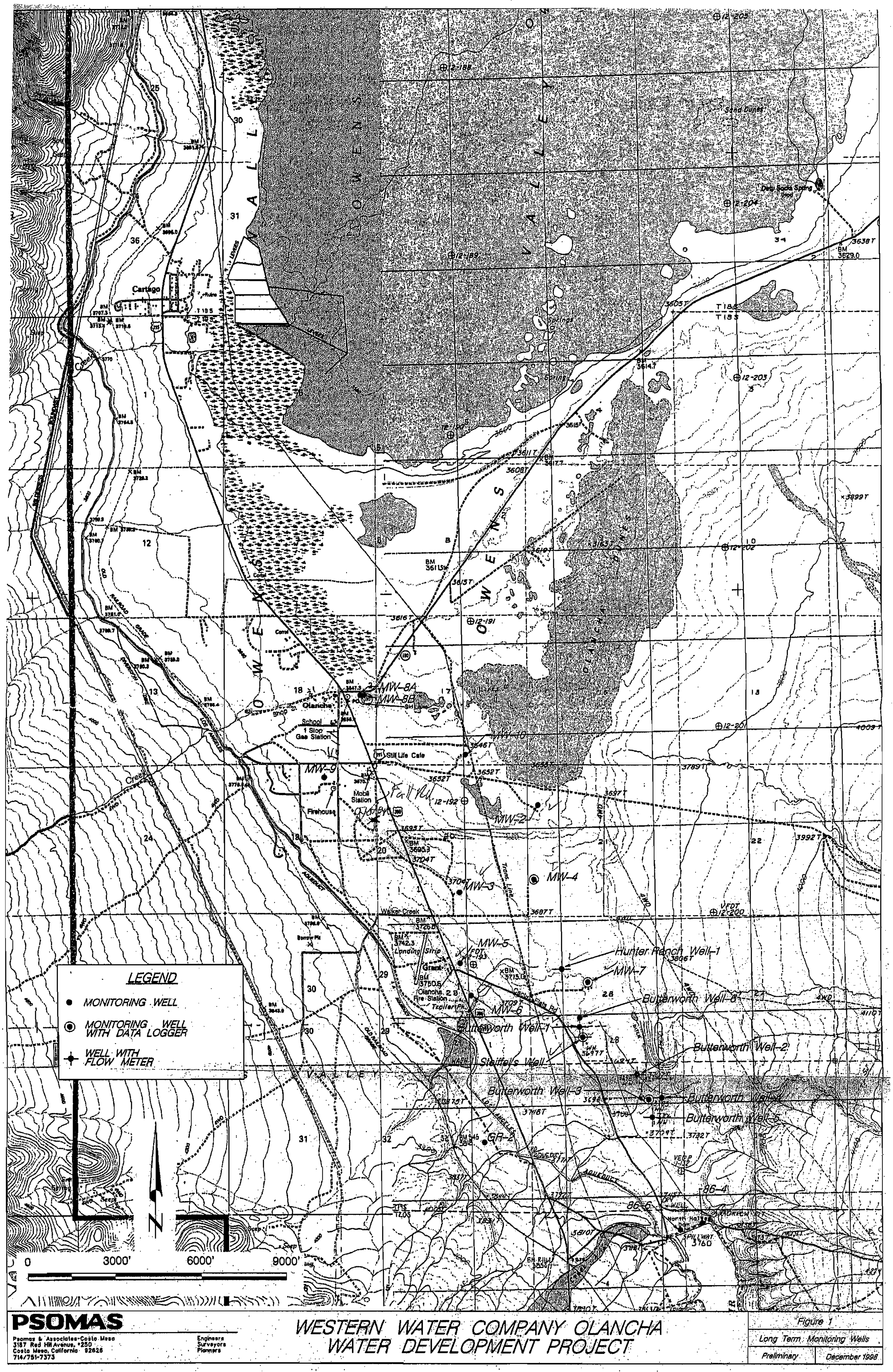
LEGEND
● MONITORING WELL
◉ MONITORING WELL WITH DATA LOGGER
WELL WITH FLOW METER
0
3000'
6000'
9000'
O W E N S
V A L L E Y
Cartago
Olancha
School
1 Stop Gas Station
Still Life Cafe
Mobil Station
Firehouse
Walker Creek
Landing Strip
Grant
Olancha Fire Station
Trailer Pk.
Cactus Flats Rd
Trans. Line
AQUEDUCT
Sand Dunes
Dirty Socks Spring
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8A
MW-8B
MW-9
MW-10
GR-2
Hunter Ranch Well-1
Butterworth Well-1
Butterworth Well-2
Butterworth Well-3
Butterworth Well-4
Butterworth Well-5
Butterworth Well-6
Steiffel's Well
86-4
86-6
12-188
12-189
12-190
12-191
12-192
12-193
12-200
12-201
12-202
12-203
12-204
12-205
North Haiwee Dam
SPILLWAY 3760
PSOMAS
Psomas & Associates-Costa Mesa
3187 Red Hill Avenue, #250
Costa Mesa, California 92626
714/751-7373
Engineers
Surveyors
Planners
WESTERN WATER COMPANY OLANCHA
WATER DEVELOPMENT PROJECT
Figure 1
Long Term Monitoring Wells
Preliminary
December 1998

Figure A-3-1

TABLE B-4
WESTERN WATER COMPANY
OLANCHA AQUIFER TESTS
COMPARISON OF AQUIFER TESTS CONDUCTED IN SOUTHERN OWENS VALLEY

Location	Screened (ft)	Hydraulic Conductivity (ft/day)	Transmissivity ft^2/min	ft^2/day	gpd/ft	Storativity (unitless)
Western Water						
Hunter #1						
low value	90-500	7.5	2.14	3,075	23,000	0.0001
higher value	90-500	12.4	3.53	5,080	38,000	0.001
Butterworth #4						
low value	30-145	111.0	9.28	13,369	100,000	0.001
higher value	30-145	167.0	13.93	20,053	150,000	0.15
Anheuser Busch/ Montgomery Watson(1)						
MW-1	150-600	8.3	2.60	3,743	28,000	0.00071
MW-2	165-615	7.8	2.45	3,529	26,400	0.0014
MW-3	200-420	15.3	2.34	3,369	25,200	0.0013
Grant Ranch/Dames & Moore(2)						
GR-2	120-510	9.8	2.65	3,810	28,500	
Flood Irrigation Project/DRI(3)						
South FIP	615-700	14.7	0.87	1,247	9,328	0.00058

References:

(1) Montgomery Watson, 1993. Revised Environmental Impact Report for the Anheuser-Busch Companies Los Angeles Brewery Water Supply Study

(2) Dames & Moore, 1993. Letter Report: Installation of Test Well GR-2, Grant Ranch Property, Olancha, California: For Crystal Geyser-Roxane

(3) Desert Research Institute, 1996. South Flood Irrigation Wells, Owens Dry Lake: Completion Report and Aquifer Test Analyses, Pub. No. 41150

TABLE 3
WESTERN WATER COMPANY
LONG TERM MONITORING
WATER LEVEL RECORD SHEET

Well Name	Date	Reference Point Elevation (ft)	Time of Day (24 hr.)	Depth - Ref. Pt. to Water (ft)	Water Level Elev (ft)	Comments
Butterworth #1	8/18/98	3702.96	14:22	29.14	3673.82	Pump off.
	9/15/98		11:25	29.20	3673.76	Pump off.
	10/14/98		12:31	29.32	3673.64	Pump off.
Butterworth #2	5/7/98	3700.40	15:30	–		Well not accessible–pump installed
Butterworth #3	8/18/98	3701.21	13:10	26.50	3674.71	
	9/15/98		11:35	26.80	3674.41	
	10/14/98		11:15	16.61	3684.60	
Butterworth #4	5/7/98		16:00	–		Well not accessible–pump installed
Butterworth #5	8/18/98	3708.38	14:07	25.40	3682.98	Pump off.
	9/15/98		11:45	25.92	3682.46	Pump off.
	10/14/98		12:17	26.75	3681.63	Pump off.
Butterworth #6	8/18/98	3698.53	14:18	38.60	3659.93	
	9/15/98		12:00	35.55	3662.98	Water heard cascading in well.
	10/15/98		12:35	33.73	3664.80	Water heard cascading in well.
86-4	8/18/98	3750.29	12:34	14.10	3736.19	
	9/15/98		11:00	13.80	3736.49	
	10/14/98		10:25	13.35	3736.94	
86-6	8/18/98	3757.87	12:41	25.30	3732.57	
	9/15/98		11:05	24.90	3732.97	
	10/15/98		10:35	24.67	3733.20	
GR-2	8/18/98	3775	18:15	92.80	3682.20	
	9/15/98		13:00	91.40	3683.60	Accompanied by Dustin Hardwick of Crystal Geyser.
	10/14/98		9:55	91.57	3683.43	

TABLE 3
WESTERN WATER COMPANY
LONG TERM MONITORING
WATER LEVEL RECORD SHEET

Well Name	Date	Reference Point Elevation (ft)	Time of Day (24 hr.)	Depth - Ref. Pt. to Water (ft)	Water Level Elev (ft)	Comments
Hunter #1	8/18/98	3695.20	18:09	92.74	3602.46	Pumped well.
	9/15/98		15:45	99.80	3595.40	Pumped well.
	10/14/98		14:37	90.72	3604.48	Pumped well.
MW-2 PVC	8/18/98	3659.43	15:35	11.35	3648.08	
	9/15/98		15:05	11.60	3647.83	
	10/14/98		15:40	11.43	3648.00	
MW-3	8/18/98	3712.23	15:45	63.50	3648.73	
	9/15/98		14:29	63.50	3648.73	
	10/14/98		15:10	63.59	3648.64	
MW-4	8/18/98	3691.71	15:53	40.00	3651.71	
	9/15/98		16:07	40.20	3651.51	
	10/14/98		15:20	40.01	3651.70	
MW-5	8/18/98	3731.79	15:40	79.50	3652.29	
	9/15/98		19:12	79.50	3652.29	
	10/14/98		14:45	79.35	3652.44	
MW-6	8/18/98	3745.02	12:10	78.20	3666.82	
	9/15/98		14:00	78.30	3666.72	
	10/14/98		10:00	78.22	3666.80	
MW-7	8/18/98	3693.50	17:58	43.20	3650.30	
	9/15/98		14:26	42.80	3650.70	
	10/14/98		14:01	39.75	3653.75	
MW-8A	8/18/98	3644.00	11:40	2.90	3641.10	Top of plastic casing
	9/15/98		15:03	3.00	3641.00	
	10/14/98		16:45	3.02	3640.98	
MW-8B	8/18/98	3645.20	17:40	3.46	3641.74	top of plastic casing
	9/15/98		15:05	4.80	3640.40	
	10/14/98		16:45	4.55	3640.65	
MW-9	8/18/98	3680.30	14:52	37.20	3643.10	
	9/15/98		15:30	38.30	3642.00	
	10/14/98		16:20	37.71	3642.59	
MW-10	8/18/98	3657.20	15:00	15.00	3642.20	top of metal lid
	9/15/98		16:00	15.80	3641.40	
	10/14/98		16:00	15.23	3641.97	

APPENDIX FOUR

Water Chemistry Data
for Rose and Southern Owens Valleys
(See Figure 21 for Chemical Water Sampling Locations)

Chemical Water Concentrations of Major Cations and Anions Used to Construct Fingerprint Plots of Water Samples from the Indian Wells, Rose, and Southern Owens Valleys, Inyo County, California.

(Water Samples Collected in 1997 & 1998)

Location of Water Samples	K	Na	Ca	Mg	HCO3	SO4	Cl
(See Figure 21 for sample locations)				(All values in meq/l)			
1. Fritcher's Well, Sageflat Road, Owens Valley	0.70	1.19	1.49	0.98	3.53	0.31	0.78
2. Pruce's Well, Olancha, Owens Valley	1.00	1.70	2.65	1.17	5.11	0.26	1.65
3. Hunter Ranch Well, Olancha, Owens Valley	1.10	1.88	4.12	1.66	7.15	0.34	1.87
4. Lien's Well, Sageflat Road, Owens Valley	1.60	2.72	4.60	1.71	7.10	0.24	3.80
5. Price Spring, Sageflat Road, Owens Valley	0.62	1.06	1.93	0.83	3.62	0.27	0.99
6. Red Hill Well, Rose Valley	1.13	1.92	2.31	1.24	5.68	0.17	1.69
7. Dews' Well, Lakeview Drive, Rose Valley	0.81	1.38	2.98	1.58	4.75	0.24	2.18
8. Gordon's Well, Olancha, Owens Valley	0.28	0.49	0.78	0.43	1.67	0.27	0.28
9. Bills' Well, Olancha, Owens Valley	0.34	0.58	0.74	0.33	1.87	0.19	0.27
10. Krick's Well, Sageflat Road, Owens Valley	0.40	0.68	1.26	0.53	2.28	0.33	0.51
11. Haiwee Creek, Sierra Nevada/Rose Valley	0.97	1.65	2.64	1.23	6.05	0.17	1.01
12. Pierre's Well, Olancha, Owens Valley	0.68	1.16	2.73	1.05	4.18	0.26	1.54
13. Holt's Well, Cartago, Owens Valley	0.22	0.37	0.52	0.12	1.06	0.32	0.10
14. Cartago Creek, Sierra Nevada/Owens Valley	0.09	0.15	0.25	0.05	0.47	0.12	0.03
15. Coso Junction Store, Rose Valley	0.23	2.38	4.47	2.81	4.98	2.48	1.29
16. Protugese Bench Spring; Rose Valley	0.09	0.78	3.07	0.86	3.12	0.56	0.14
17. Coso Junction, West Well, Rose Valley	0.14	2.29	3.04	1.13	2.96	1.50	1.14
18. Tunawee Canyon Spring, Sierra Nevada/Rose Valley	0.12	1.18	3.85	1.48	5.11	0.75	0.24
19. Little Lake Canyon Spring, Sierra Nevada/Rose Valley	0.14	2.12	4.40	1.71	4.14	1.70	0.89
20. Northern Little Lake Ranch Well, Rose Valley	0.01	0.70	4.52	2.77	8.47	1.50	1.31
21. Hunter Agricultural Well, Olancha, Owens Valley	1.22	2.09	1.87	1.11	5.00	0.41	1.47
22. Haiwee Ridge Spring, Rose Valley	1.14	1.94	1.27	0.47	4.16	0.34	1.15
23. Haiwee Pump Station, Toe Drain, Rose Valley	0.15	2.01	1.38	0.49	2.78	0.71	0.49
24. Haiwee Reservior, Rose Valley	0.10	1.54	1.04	0.37	1.83	0.72	0.49
25. Little Lake Ranch House Well, Rose Valley	0.43	6.45	3.15	2.47	5.14	2.02	4.28
26. Little Lake Fault Spring, Sierra Nevada/ Indian Wells Valley	0.17	6.95	3.68	1.58	2.34	7.98	1.08
27. Dunmovin Well, Rose Valley	0.16	6.58	3.94	2.20	3.77	6.88	1.47
28. Coso Spring, Coso Range/Rose Valley	0.46	9.31	4.13	4.10	15.64	2.21	5.09
29. Little Lake Outflow Stream, South Culvert, Indian Wells Valley	0.54	11.51	1.98	4.88	15.02	2.94	5.79
30. Artesian Well-Fed Lake, Little Lake Ranch, Rose Valley	0.48	9.48	3.87	4.04	8.95	2.18	5.11
31. Little Lake (North Dock), Rose Valley	7.43	12.68	1.55	4.45	22.76	0.41	6.58
32. Little Lake (South Dock), Rose Valley	7.10	12.10	0.31	4.35	18.18	0.27	5.80

Water Chemistry Results for Water Samples from Rose and Southern Owens Valleys, Inyo County, California

Sample Locations Numbers keyed to locations on Figure 21	Na (All values in ppm)	K	Li	Ca	Mg	Sr	HCO_3 Calculated by charge	Cl	SO_4	SiO_2	NO_3	PO_4	B	Br	F	Ba	Fe	Mn
1) Fritcher well, Sageflat Rd.	27.25	1.88	0.01	29.95	11.93	0.25	215.54	15.20	27.80	14.89	0.89	0.18	0.25	0.03	0.43	0.06	0.26	0.01
2) Pruce well, Olancha	39.03	3.41	0.03	53.10	14.24	0.54	311.64	63.30	58.60	12.43	3.15	0.06	0.41	0.12	0.16	0.03	0.01	0.00
3) Hunter ranch, Olancha	42.99	4.16	0.02	82.57	20.14	0.60	436.01	37.90	66.20	16.25	2.73	0.03	0.57	0.08	0.38	0.12	0.02	0.00
4) Lien well, Sageflat Rd.	62.41	3.55	0.03	92.25	20.75	0.49	433.24	48.50	134.60	11.61	1.99	0.18	0.71	0.12	0.37	0.10	0.06	0.00
5) Price Spring, Sageflat Rd..	24.20	3.10	0.01	38.75	10.06	0.20	220.74	11.20	35.20	12.98	0.92	0.07	0.16	0.03	0.27	0.03	0.01	0.00
6) Red Hill well, Rose Valley	44.04	6.51	0.02	46.33	15.08	0.43	346.33	25.30	60.00	8.17	0.00	0.06	0.07	0.11	0.51	0.03	0.23	0.06
7) Dews well, Lakeview Dr.	31.64	2.90	0.01	59.70	19.16	0.54	289.55	51.40	77.30	11.49	4.28	0.09	0.27	0.27	0.2	0.08	0.05	0.00
8) Gordon well, Olancha.	11.12	1.59	0.00	15.72	5.25	0.14	101.64	2.50	9.80	12.84	0.66	0.21	0.06	0.01	0.2	0.04	0.04	0.00
9) Bills well, Olancha.	13.22	2.43	0.00	14.88	3.99	0.11	113.83	1.60	9.70	9.23	0.40	0.10	0.14	0.02	0.22	0.03	0.04	0.00
10) Krick well, Sageflat. Rd.	15.61	1.68	0.01	25.32	6.48	0.22	138.84	4.50	18.00	15.99	0.27	0.10	0.05	0.03	0.29	0.04	0.05	0.00
11) Haiwee Creek	37.81	5.08	0.18	52.99	14.91	0.41	368.83	31.60	35.70	8.28	0.01	0.02	1.05	0.08	0.21	0.02	0.02	0.00
12) Pierre's well, Olancha	26.60	2.45	0.01	54.72	12.79	0.36	254.98	17.60	54.60	12.26	0.61	0.14	0.09	0.04	0.41	0.04	0.02	0.00
13) Holt's well, Cartago	8.57	1.78	0.02	10.33	1.48	0.13	64.86	1.30	3.40	15.28	0.49	0.31	0.06	0.01	0.54	0.01	0.02	0.00
14) Cartago Creek	3.37	0.70	0.00	4.93	0.60	0.06	28.86	0.60	1.10	5.92	0.01	0.00	0.02	0.01	0.2	0.01	0.13	0.00
15) Coso Junc. Store, Rose Vly.	54.50	9.10	0.06	89.60	34.10	0.78	369.50	45.60	119.20	61.70	3.78	0.00	0.33	0.19	0.48	0.08	0.01	0.01
16) Protugese Bench Spring	17.81	3.37	0.00	61.49	10.47	0.36	248.73	5.10	26.90	25.00	0.21	0.05	0.05	0.03	0.31	0.06	0.01	0.00
17) Coso Junction W. well	52.46	5.33	0.00	60.98	13.67	0.40	233.84	40.50	71.90	24.71	6.14	0.03	0.06	0.17	0.55	0.08	0.05	0.00
18) Tunawee Cyn sprg	26.99	4.50	0.00	77.11	18.00	0.44	342.89	8.60	35.90	26.18	0.33	0.06	0.08	0.05	0.28	0.08	0.05	0.00
19) Little Lake Cyn. sprg.	48.64	5.57	0.01	88.12	20.79	0.49	343.47	31.70	81.70	27.49	0.16	0.05	0.16	0.12	2.92	0.06	0.01	0.03
20) Northern LL Ranch	15.97	0.43	0.02	90.58	33.64	0.99	315.20	46.50	71.90	55.00	0.66	0.05	1.94	0.13	0.62	0.06	0.14	0.15
21) Hunter Ag. well, Olancha	47.86	4.06	0.03	37.54	13.50	0.41	305.15	25.50	52.10	19.56	1.10	0.01	0.36	0.07	0.5	0.09	0.01	0.01
22) Haiwee Ridge Sprg.	44.57	5.83	0.09	25.43	5.76	0.20	253.79	19.10	40.90	16.49	0.61	0.35	0.42	0.05	0.68	0.00	0.02	0.00
23) Haiwee pump station	45.97	5.73	0.08	27.64	5.94	0.22	169.62	17.50	34.10	40.60	0.32	0.26	0.52	0.04	0.89	0.00	0.01	0.00
24) Haiwee Reservior	35.30	3.90	0.11	20.90	4.53	0.13	111.46	17.30	34.60	15.84	0.04	0.05	0.54	0.03	0.71	0.01	0.05	0.00
25) LL Ranch House well	147.80	16.96	0.34	63.14	29.99	0.89	377.59	151.90	96.80	54.52	2.72	0.00	3.66	0.33	0.60	0.04	0.01	0.00
26) Little Lake fault	159.30	6.60	0.01	73.80	19.20	0.88	194.20	38.20	382.90	26.40	1.97	0.06	0.38	0.14	2.52	0.03	1.86	0.06
27) Dunmovin well	150.70	6.40	0.16	78.96	26.78	0.66	274.61	52.00	330.00	29.59	2.81	0.06	1.75	0.14	0.59	0.02	0.04	0.00
28) Coso Spring	213.30	17.90	0.50	82.70	49.76	0.97	653.40	180.60	106.10	60.80	1.27	0.05	5.18	0.38	0.74	0.04	0.01	0.00
29) LL So. culvert stream	263.70	21.30	0.55	39.60	59.30	0.65	623.16	205.20	141.10	46.76	0.39	0.00	5.85	0.43	0.87	0.01	0.01	0.00
30) Artesian lake	217.30	18.60	0.49	77.50	49.10	0.94	646.96	181.30	104.60	59.10	0.87	0.03	5.10	0.35	0.75	0.04	0.01	0.07
31) Little Lake (n. dock)	290.55	25.31	0.05	30.99	54.13	0.36	1388.15	205.70	233.20	19.72	0.02	0.16	4.18	0.87	1.05	0.03	0.38	0.02
32) Little Lake (s. dock)	277.42	21.73	0.40	6.29	52.89	0.06	1108.87	182.70	205.70	13.06	0.02	0.01	3.93	0.46	1.09	0.00	0.04	0.00

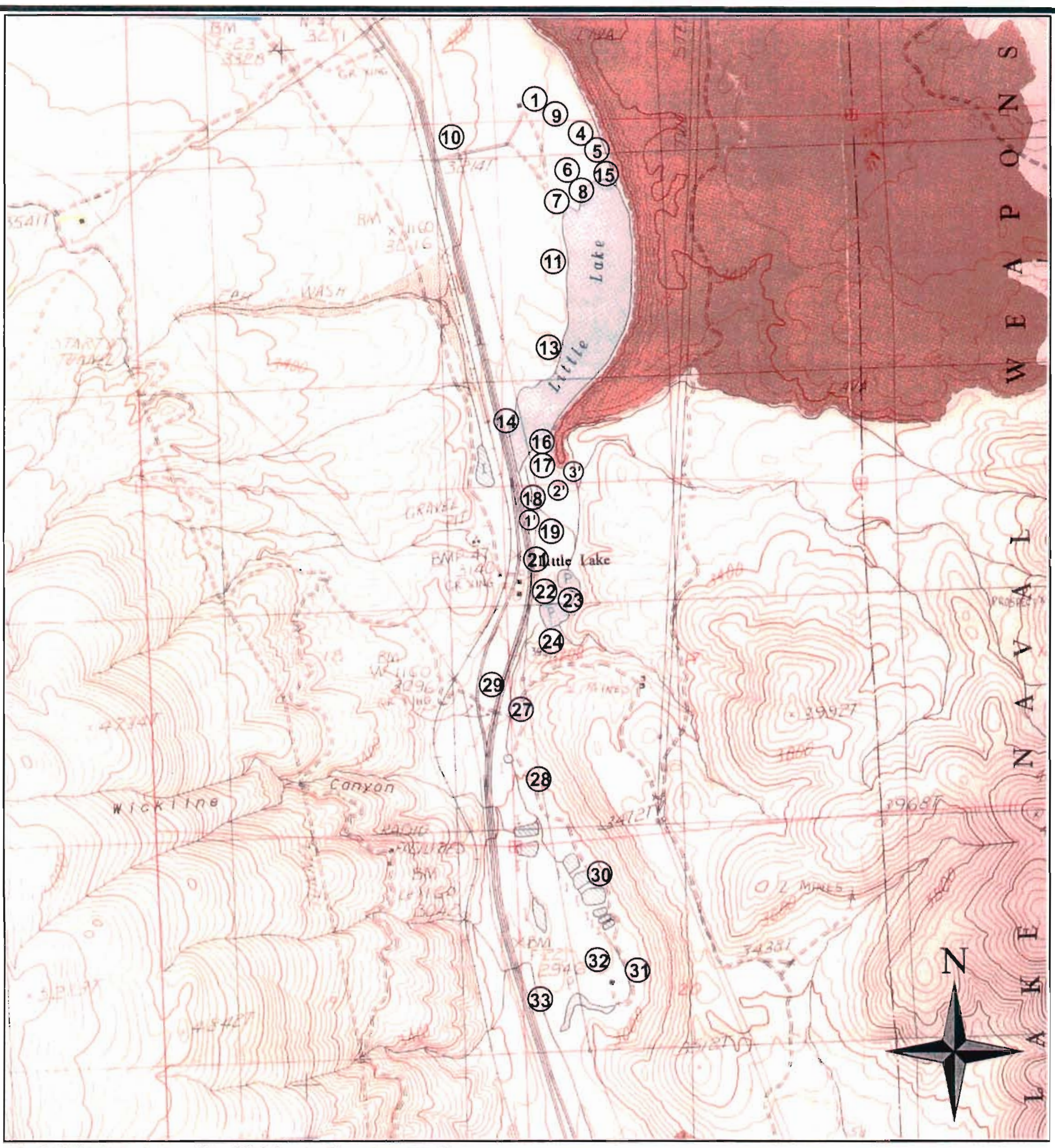
Coso Geothermal Area (CGA) Water Chemistry (1988 Samples) - Coso Range, Inyo County, California
Courtesy of China Lake Naval Weapons Center, (Coso Monitoring Program, 1989)

Water Samples	K mg/L	Na mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	SO4 mg/L	Cl mg/L	pH	EC umohs/cm	TDS mg/L
4K1	21.00	178.00	55.00	0.69	9.50	138.00	306.00	5.80	1,525.00	840.00
Coso #1	10,760.00	87,500.00	170.00	0.56	2,826.00	3,620.00	139,122.00	6.60	130,800.00	301,100.00
Red Mud Pots	12.00	36.00	29.00	9.60	0.00	680.00	1.80	2.40	3,100.00	1,107.00
South Pool, West Edge	9.00	64.00	88.00	31.00	0.00	1,580.00	1.80	2.20	5,500.00	2,580.00
Devils Kitchen Array	35.00	51.00	71.00	28.00	0.00	1,500.00	1.80	2.00	6,100.00	2,450.00

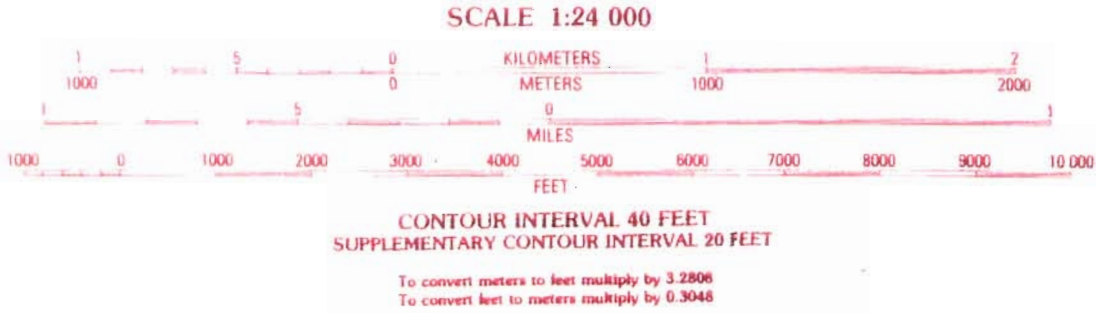
Water Samples	meq/L						
	K	Na	Ca	Mg	HCO3	SO4	Cl
4K1	0.54	7.74	2.74	0.06	0.16	2.88	8.63
Coso #1	275.19	3,804.35	8.48	0.01	46.33	75.42	######
Red Mud Pots	0.31	1.57	1.45	0.79	0.01	14.17	0.05
South Pool, West Edge	0.23	2.78	4.39	2.55	0.01	32.92	0.05
Devils Kitchen Array	0.90	2.22	3.54	2.30	0.01	31.25	0.05

APPENDIX FIVE

Soil Taxonomic Classifications
for Little Lake Ranch
(See Figure A-5-1 for Soil Pit Locations)



Ref. USGS Little Lake, CA 7.5 Minute Quadrangle Map



Soil Pit Locations
For
Little Lake Ranch, Rose Valley, Inyo County, California

LEGEND

①	Site of Soil Pit Descriptions Used for Soil Taxonomic Classification
① to ③	Toposequence Soil Transect

Figure A-5-1

Soil Taxonomic Classification of Little Lake Ranch to the Family Level

Soil Mapping Units for Map Plate IV	**Northern Little Lake Ranch**	**Soil Pit Location***
101	mixed, thermic, Typic Torripsamment	(**1,** 2, 3, 7)
102	Loamy, mixed, superactive, thermic, Typic Torrifluvent	**(4)**
103	Loamy-skeletal, mixed, superactive, thermic, Typic Torrifluvent	**(5)**
104	Loamy, mixed, superactive thermic, Typic Torripsamment	**(6)**
105	Coarse-loamy, mixed, superactive, thermic, Aquic Torrifluvent	**(8, 15)**
106	Loamy-skeletal, mixed, superactive, thermic, Typic Torriorthent	**(9)**
107	Coarse-loamy, mixed, superactive, thermic, Typic Torriorthent	**(10)**
108	Coarse-loamy, mixed, superactive, thermic, Typic Haplargid	(**11**, 12)
109	Fine-loamy, mixed, superactive, thermic Typic Haplargid	**(13, 32)**

Central Little Lake Ranch

110	Loamy, mixed, superactive, thermic, Typic Torriorthent	**(14)**
111	Fine-loamy, mixed, superactive, thermic, Aquic Torrifluvent	**(16)**
114	Coarse-loamy, mixed, superactive, thermic, Typic Torriorthent	(**17**, 25)
102	Loamy, mixed, superactive, thermic, Typic Torrifluvent	(**18**, 26)
112	Fine-loamy, mixed, superactive, thermic, Typic Torrifluvent	**(19)**
113	Fine-loamy, mixed, superactive, calcareous, thermic, Typic Torrifluvent	(20,**21,5'**)**
114	Fine-loamy, mixed, calcareous, superactive, thermic, Typic Torriorthent	**(3')**
115	Fine-loamy, mixed, superactive, thermic, Typic Petrocalcid	**(1')**
116	Sandy-skeletal, mixed, superactive, thermic, Calcic Petrocalcid	**(22)**
117	Fine-loamy, mixed, superactive, thermic, Aquic, Petrocalcid	**(23)**
101	mixed, thermic, Typic Torripsamment	**(24)**

Southern Little Lake Ranch

101	mixed, thermic, Typic Torripsamment	(**27**, 34)
118	Loamy-skeletal, mixed, thermic, Typic Torripsamment	**(28)**
119	Fine-loamy, mixed, superactive, thermic, Calcic Petrocalcid	**(29)**
120	Sandy, mixed, superactive, thermic, Typic Torriorthent	**(30)**
121	Loamy, mixed, superactive, thermic, calcareous, Typic Torriorthent	**(31)**
109	Fine-loamy, mixed, superactive, thermic, Typic Haplargid	**(32)**
122	Loamy-skeletal, mixed, superactive, thermic, calcareous, Typic Torrifluvent	**(33)**

* Numbers in bold are shown on the Soil Pit Location Figure A-5-1.

**Numbers with single quote marks (1', 2', 3') designate the location of a soil transect as shown on Figure A-5-1.

APPENDIX SEVEN

Soil Pit Profile Descriptions
for Little Lake Ranch
(Refer to Figure A-5-1 for Location of Soil Pits and Map Plate IV for Location of Soil Mapping Units).

General Soils Map Legend Descriptions found on Map Plate IV
Little Lake Ranch Study Area
Inyo County, California

Map Unit Symbol	**Soils on Alluvial Fans, Debris Flows, Stream Terraces, and Floodplains**
101	Mixed, thermic, Typic Torripsamment Very deep, nearly level to moderately sloping, excessively drained sandy soils; formed in alluvium from the Sierra Nevada Mountains. Soil pit location is 1 on Figure A-5-1.
102	Loamy, mixed, superactive, thermic, Typic Torrifluvent Deep, nearly level, well drained sandy loam soils, formed in alluvium from the Sierra Nevada Mountains. Groundwater occurs at 6.5 feet below the surface. Soil pit location is 4 on Figure A-5-1.
103	Loamy-skeletal, mixed, superactive, thermic Typic Torrifluvent Very deep, nearly level to slightly sloping, very well drained coarse sandy soils, formed in alluvium from Little Lake Canyon Creek and sediment laden waters from Fossil Falls along the east side of Northern Little Lake Ranch. Soil pit location is 5 on Figure A-5-1.
104	Loamy, mixed, thermic, Typic Torripsamment Very deep, nearly level, well drained sandy soils, formed in alluvium and debris flows from the Sierra Nevada Mountains. Groundwater occurs at 5 feet below ground surface. Soil pit location is 6 on Figure A-5-1.
105	Coarse-loamy, mixed, superactive, thermic, Aquic Torrifluvent Shallow, level, somewhat poorly drained, formed in alluvium and floodplain deposits of Pleistocene Owens River. Groundwater occurs at 20 to 24 inches from the surface. Soil pit locations are 8 and 15 on Figure A-5-1.
106	Loamy-skeletal, mixed, superactive, thermic, Typic Torriorthent Very deep, nearly level, very well drained coarse sandy soils over loamy soils, formed in alluvial/fluvial stream terraces from Little Lake Canyon Creek and sediment laden waters from Fossil Falls along the east side of Northern Little Lake Ranch. Soil pit location is 9 on Figure A-5-1.

107 Coarse-loamy, mixed, superactive, thermic, Typic Torriorthent

Very deep, moderately sloping, well drained, coarse sandy soils, formed in alluvium and debris flows from the Sierra Nevada Mountains. Soil pit location is 10 on Figure A-5-1.

108 Coarse-loamy, mixed, superactive, thermic, Typic Haplargid

Moderately deep, gently sloping, well drained sandy soils with an argillic horizon, formed on older relict alluvial fans from the Sierra Nevada Mountains. Soil pit location is 11 on Figure A-5-1.

109 Fine-loamy, mixed, superactive, thermic Typic Haplargid

Deep, nearly level, well drained sandy soils with an argillic horizon; formed on older relict alluvial fans from the Sierra Nevada Mountains. Soil pit locations are 13 and 32 on Figure A-5-1.

110 Loamy, mixed, superactive, thermic, Typic Torriorthent

Deep, nearly level, well drained sandy soils, formed on relict stream channels draining the Sierra Nevada west of Little Lake. Soil pit location is 14 on Figure A-5-1.

111 Fine-loamy, mixed, superactive, thermic, Aquic Torrifluvent

Deep, nearly level, poorly drained, loamy and clayey very stratified soils, formed on relict river deposits of Pleistocene Owens River encircling Little Lake. Groundwater occurs at three feet below ground surface. Soil pit location is 16 on Figure A-5-1.

112 Fine-loamy, mixed, superactive, thermic, Typic Torrifluvent

Very deep, slightly sloping, well drained, sandy soils formed on a combination of Coso alluvial fan toe slope deposits and Pleistocene Owens River deposits. Groundwater occurs at a depth of 6 feet four inches below the land surface. Soil pit location is 19 on Figure A-5-1.

113 Fine-loamy, mixed, superactive, calcareous, thermic, Typic Torrifluvent

Moderately deep, slightly sloping, somewhat poorly drained, loamy soils formed on alluvial fans from the Coso Mountains. These soils are moist year-round and have an indurated petrocalcic horizon at depths of 41 to 48 inches below the ground surface. Soil pit locations are 21 and 5' on Figure A-5-1.

114 Fine-loamy, mixed, calcareous, superactive, thermic, Typic Torriorthent

Very deep, slightly sloping, well drained sand clay loam soils; formed in alluvium from Coso Mountains Alluvial fans on toe slopes. Groundwater occurs at a depth of 6 feet below the ground surface. Soil pit location is 3' on Figure A-5-1.

115 Fine-loamy, mixed, superactive, thermic, Typic Petrocalcid

Moderately deep, nearly level, poorly drained loamy soils; formed on alluvial fan deposits of the Coso Mountains. These soils remain moist throughout the year and have an indurated petrocalcic horizon at 32 inches below the ground surface. Soil pit location is 1' on Figure A-5-1.

116 Sandy-skeletal, mixed, superactive, thermic, Calcic Petrocalcid

Moderately deep, complex sloped, undulating, well drained sandy soils formed on alluvial fan deposits of the Coso Mountains and relict stream deposits. These soils are moist at a depth of 48 inches below the ground surface and have a fractured petrocalcic horizon from 24 to 60 inches below the ground surface. Soil pit location is 22 on Figure A-5-1.

117 Fine-loamy, mixed, superactive, thermic, Aquic, Petrocalcid

Shallow, gently sloping, poorly drained sandy clay loam soils formed on alluvial fans of the Coso Range and relict stream deposits. Soil is moist at the surface and a petrocalcic horizon occurs at a depth of 18 inches. This horizon has pores and is wet down to 38 inches below the ground surface. Soil pit location is 23 on Figure A-5-1.

118 Loamy-skeletal, mixed, thermic, Typic Torripsamment

Shallow, level, very well drained gravelly sands formed from alluvial fans and debris avalanches from the Coso Mountains and the Sierra Nevada Mountains. Soil pit location is 28 on Figure A-5-1.

119 Fine-loamy, mixed, superactive, thermic, Calcic Petrocalcid

Very shallow, slightly sloping, poorly drained sandy soils resting directly upon an indurated petrocalcic horizon. This unit also has areas where the petrocalcic horizon is directly on the surface. These soils formed from debris lows of the Sierra Nevada Mountains and stream deposits from Pleistocene Owens River. These soils are situated directly north and south of Little Lake Gap. Soil pit location is 29 on Figure A-5-1.

120 Sandy, mixed, superactive, thermic, Typic Torriorthent

Very deep, slightly sloping, excessively drained sandy soils formed in alluvial fans of the Coso Mountains and Sierra Nevada Mountains and stream deposits of Pleistocene Owens River. Soil pit location is 30 on Figure A-5-1.

121 Loamy, mixed, superactive, thermic, calcareous, Typic Torriorthent

Very deep, level, excessively drained sandy soils, formed in alluvium of the Coso Mountains and possibly from materials deposited by the Pleistocene Owens River. Soil pit location is 31 on Figure A-5-1.

122 Loamy-skeletal, mixed, superactive, thermic, calcareous, Typic Torrifluvent

Very deep, level, moderately well drained, sandy stratified soils, formed in alluvium predominately from the Sierra Nevada and from fluvial deposits of the Pleistocene Owens River. Soil pit location is 33 on Figure A-5-1.

APPENDIX SEVEN

Soil Pit Profile Descriptions
for Little Lake Ranch
(Refer to Figure A-5-1 for Location of Soil Pits and Map
Plate IV for Location of Soil Mapping Units).

Soil Profile Descriptions

(101) **TAXONOMIC CLASS:** Mixed, thermic, Typic Torripsamment

Typical pedon of Mixed, thermic, Typic Torripsamment is very deep, nearly level to moderately sloping, excessively drained sandy soils; formed in alluvium from the Sierra Nevada Mountains. This soil occurs in Northern Little Lake Ranch, approximately 10 feet west of ranch house well. Soil pit location is 1 on Figure A-5-1.

A--0 to 4 inches; very dark grayish brown (2.5Y 3/2) moist; loamy sand; 10% clay; slightly subangular blocky structure, soft very friable nonsticky and nonplastic, few fine roots, 40% gravel, gravel is subangular to subrounded and is granitic, moderate effervescence; mildly alkaline (pH 7.5), gradual smooth boundary.
C1--4 to 102 inches; dark grayish brown (10YR 4/2) moist; sandy, 8 to 10% clay; massive: slightly hard, very friable, nonsticky and nonplastic, very few fine roots, 35% gravel, gravel increases vertically, strongly effervescent, alkaline (pH 8.0).
C2--102 to 114 inches; dark grayish brown (10YR 4/2) moist; sandy loam, 10 to 12% clay, massive, well sorted sands, gravel at depth is subrounded to rounded and are granitic and basaltic in composition, continuous cobble layer from approximately 9 to 10 feet; strongly effervescent; strongly alkaline (pH 8.5).

(102) **TAXONOMIC CLASS**: Loamy, mixed, superactive, thermic, Typic Torrifluvent

Typical pedon of Loamy, mixed, superactive, thermic, Typic Torrifluvent is deep, nearly level, moderately well drained sandy loam soils, formed in alluvium from the Sierra Nevada Mountains. This soil occurs approximately one-half mile north of Little Lake. Groundwater occurs at 6.5 feet below ground surface. Vegetation associated with this soil is saltgrass and pickleweed. Sodic surface crusts up to 1 inch thick may occur with these soils. Soil pit location is 4 on Figure A-5-1.

A--0 to 3 inches; brown (7.5YR 4/2) moist; sandy clay loam; sands are rounded to subrounded, 30% clay, massive, hard, very friable, slightly sticky, 2% gravel of a granitic source, gravel is subrounded to subangular, no to few roots; calcium carbonate cemented surface that is strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary.
C1--3 to 45 inches; black (10YR 2/1) moist; sandy, 18 to 20% clay; massive, slightly hard, very friable, slightly sticky and nonplastic, very few fine roots,

15% gravel, gravel increases vertically, strongly effervescent, moderately alkaline (pH 8.3).
C2--45 to 78 inches; dark grayish brown (2.5 Y 4/2) moist; sand; 5% clay; massive loose, nonsticky and nonplastic, well sorted sands, 30% gravel, granitic gravel at depth is subrounded, minerals are feldspars and quartz, groundwater occurs at lower boundary, strongly effervescent, strongly alkaline (pH 8.5).

(103) **TAXONOMIC CLASS**: Loamy-skeletal, mixed, superactive, thermic Typic Torrifluvent

A typical pedon of Loamy-skeletal, mixed, superactive, thermic Typic Torrifluvent on a 2% slope under rabbitbrush is very deep, nearly level to slightly sloping, well stratified, very well drained, coarse sandy soils, formed in alluvium from Little Lake Canyon Creek and sediment laden waters. This soil occurs from Fossil Falls along the east side of Northern Little Lake Ranch. Vegetation consists of rabbitbrush and saltgrass. Soil pit location is 5 on Figure A-5-1.

A--0 to 5 inches; very dark grayish brown (2.5Y 3/2) moist; silt loam; 15% clay; weak platy structure; hard, very friable, nonsticky; few fine and medium roots; 2% gravel; gravel is well rounded; moderately alkaline (pH 8.0); abrupt boundary.
C1--5 to 15 inches; dark grayish brown (10YR 4/2) moist; fine sandy loam; 8% clay; single grain; sand grains are rounded; roots are medium to coarse; gravel is absent; moderately alkaline (pH 8.0); abrupt boundary.
C2--15 to 27 inches; dark grayish brown (2.5Y 4/2) moist; very coarse sand; single grain; loose; >50% gravel; gravel is predominately granitic with some basltic; mildly alkaline (pH 7.5); abrupt boundary.
C3--27 to 36 inches; dark grayish brown (2.5Y 4/2) moist; fine sand; single grain; loose; mildly alkaline (pH 7.5); roots absent; abrupt boundary.
C4--36 to 96 inches; reddish brown (2.5YR 5/3) moist; silt loam; very friable; massive; roots absent; moderately alkaline (pH 8.0); abrupt boundary; groundwater occurs at lower boundary.
C5--96 to 120 inches; saturated aquifer material; weak red (2.5YR 4/2) moist; sand; very friable; single grain; sands are subrounded to rounded; 15% gravel; strongly alkaline (pH 8.5); abrupt boundary.
C6--122 to 144 inches; saturated aquifer material; weak red (2.5YR 4/2) moist; coarse sand; 8 to 10 % clay; single grain; sand is subrounded to subangular; 15% gravel; strongly alkaline (pH 8.5); abrupt boundary.
C7-->144 to ? Inches; saturated aquifer material; brown (10YR 4/3) moist; sandy clay loam; 20 to 22% clay; massive; slightly sticky; 5% gravel; strongly alkaline (pH 8.5).

(104) **TAXONOMIC CLASS:** Loamy, mixed, thermic, Typic Torripsamment

A typical pedon of Loamy, mixed, thermic, Typic Torripsamment is very deep, nearly level, well drained sandy soils, formed in alluvium and debris flows from the Sierra Nevada Mountains. Groundwater occurs at 5 feet below ground surface. Vegetation consists of saltgrass and saltbush. Soil pit location is 6 on Figure A-5-1.

A--0 to 5 inches; dark grayish brown (10YR 4/2) moist; loamy coarse sandy; <5% clay; massive; hard, very friable, nonsticky; common fine and medium roots; 10% gravel; surface is crusted with salts of sodium; mildly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.
C1--5 to 36 inches; weak red (2.5 YR 4/2) moist; medium sandy loam; 10% clay; massive; very friable; 10 to 15% gravel; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.
C2--36 to 55 inches; reddish brown (2.5YR 4/3) moist; loamy sand; 8% clay; single grain; very friable; 5% gravel; strongly effervescent; strongly alkaline (pH 8.5); moist throughout this horizon; abrupt clear boundary.
C3--55 to 60 inches; weak red (2.5YR 4/2) moist; loamy coarse sand; 10 to 13% clay; single grain; 5% gravel; sand is subrounded to subangular granitic in composition; strongly effervescent; moderately alkaline (pH 8.0); wet throughout this sub-horizon.
C4-- > 60 inches; saturated aquifer material; weak red (2.5YR 4/2) moist; loamy coarse sand; 10 to 13% clay; single grain; 5% gravel; sand is subrounded to subangular and is granitic in composition; strongly effervescent; pH of water is 8.0.

(105) **TAXONOMIC CLASS**: Coarse-loamy, mixed, superactive, thermic, Aquic Torrifluvent

A typical pedon of Coarse-loamy, mixed, superactive, thermic, Aquic Torrifluvent is shallow, level, and somewhat poorly drained. This soil formed in alluvium and floodplain deposits of the Pleistocene Owens River. Groundwater occurs at 20 to 24 inches below ground surface. This soil occurs approximately 1000 feet north of Little Lake's north shore. Vegetation associated with this soil is saltgrass, pickleweed, and *Yerba mansa*. Soil pit locations are 8 and 15 on Figure A-5-1.

A--0 to 6 inches; light olive brown (2.5Y 5/4) moist; sandy clay loam; 18% clay; weak subangular blocky; 10% gravel; roots common fine; firm; slightly sticky; moderately alkaline (pH 8.0); gradual boundary. Surface is moist.
C1--6 to 21 inches; light olive brown (2.5Y 5/4) moist; fine sandy clay loam; 18 to 22% clay; massive; 10% gravel; roots common fine; slightly sticky; moderately alkaline (pH 8.0); abrupt boundary. This sub-horizon is wet.
C2--21 to 63 inches; **saturated aquifer material**; dark gray (5Y 4/1) moist; very coarse sand; 8 to 9% clay; single grain; 20% gravel; nonsticky; moderately alkaline (pH 8.0); abrupt boundary.

C3--63 to 80 inches; **saturated aquifer material**; olive gray (5Y 4/2) moist; fine sandy clay loam; 20 to 22% clay; massive; 5% gravel; slightly sticky; moderately alkaline (pH 8.0); abrupt color change boundary.
C4--80 to 92 inches; **saturated aquifer material**; light olive brown (2.5Y 5/4) moist; very coarse sand; 8 to 9% clay; single grain; 20% gravel nonsticky; moderately alkaline (pH 8.0).

(106) **TAXONOMIC CLASS:** Loamy-skeletal, mixed, superactive, thermic, Typic Torriorthent

A typical pedon of Loamy-skeletal, mixed, superactive, thermic, Typic Torriorthent is very deep, nearly level, very well drained coarse sandy soils over loamy soils. This soil was formed in alluvial/fluvial stream terrace deposits from Little Lake Canyon Creek and sediment laden waters from Fossil Falls located along the east side of Northern Little Lake Ranch. Soil pit location is 9 on Figure A-5-1.

A--0 to 5 inches; very dark grayish brown (10YR 3/2) moist; sandy loam; 18 % clay; massive; soft, very friable, nonsticky; common fine roots; 15 % gravel; mildly alkaline (pH 7.5); diffuse boundary.
C1--5 to 56 inches; dark grayish brown (10YR 4/2) moist; sandy loam; 10 to 13% clay; massive; slightly hard; very friable, nonsticky; 35% gravel; nonsticky; roots medium common; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C2--56 to 72 inches; dark grayish brown (10YR 4/2) moist; loam; 18 to 20% clay; massive; friable; slightly sticky; 10% gravel; medium roots common; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary.
C3--72 to 78 inches; brown (10YR 4/3) moist; gravelly sandy loam; 10 to 12% clay; massive; friable; nonsticky; 50% gravel; subrounded stones; fine roots present; strongly effervescent; strongly alkaline (pH 8.5).
C4--78 to 84 inches; brown (10YR 4/3) moist very gravelly sandy loam; 10% clay; massive; >65% gravel and cobbles; soil is wet at bottom of horizon; strongly effervescent; strongly alkaline (pH 8.5).

(107) **TAXONOMIC CLASS**: Coarse-loamy, mixed, superactive, thermic, Typic Torriorthent

Typical pedon of Coarse-loamy, mixed, superactive, thermic, Typic Torriorthent is very deep, moderately sloping, well drained, coarse sandy soils. This soil occurs in alluvium and debris flows from the Sierra Nevada. Soil pit location is 10 on Figure A-5-1.

A--0 to 3 inches; olive brown (2.5Y 4/4) moist; coarse sand; <5% clay; moderate platy; soft, loose, nonsticky; 15% gravel; deflation surface; few very fine roots; no effervescence; neutral (pH 7.0); clear boundary.

C1--3 to 48 inches; olive brown (2.5Y 4/3) moist; coarse loamy sand; 8 to 10% clay; weak platy; 25% gravel of a granitic composition; minerals are rich in orthoclase feldspar; roots fine common; poorly sorted; porosity is 25 to 30%; weak effervescence; mildly alkaline (pH 7.5) gradual boundary.
C2-- 48 to 72 inches; olive brown (2.5Y 4/4) moist; loamy coarse sand; <5% clay; single grain; 30% gravel; few fine roots; weakly effervescent; mildly alkaline (pH 7.5); gradual boundary.
C3-- 72 to 96 inches; dark grayish brown (2.5Y 4/2) moist; coarse sand; <5% clay; clay films; single grain; 20% gravel; strongly effervescent; moderately alkaline (pH 8.0).

(108) **TAXONOMIC CLASS:** Coarse-loamy, mixed, superactive, thermic, Typic Haplargid

A typical pedon of Coarse-loamy, mixed, superactive, thermic, Typic Haplargid is moderately deep, gently sloping, well drained sandy soils with an argillic horizon, formed on older relict alluvial fans from the Sierra Nevada Mountains. Soil pit location is 11 on Figure A-5-1.

A--0 to 5 inches; brown (10YR 4/3) moist; coarse sand; 8% clay; weak platy structure; soft, loose, nonsticky; few fine roots; 10% gravel; no effervescence; mildly alkaline (pH 7.5); abrupt boundary.
AB--5 to 13 inches; brown (10YR 4/3) moist; medium sandy loam; 10% clay; platy to subangular blocky structure; soft, very friable; few fine roots; 10% gravel; well sorted; gravel is subrounded to rounded; no effervescence; moderately alkaline (pH 8.0); gradual boundary.
Bt--13 to 24 inches; brown (10YR 4/3) moist; medium sandy loam; 15% clay; clay films on ped faces; medium subangular blocky structure; slightly hard, very friable; 1% gravel; gravel is subrounded to subangular; very few fine roots; no effervescence; moderately alkaline (pH 8.0) abrupt boundary.
C1--24 to 30 inches; brown (10YR 4/3) moist; loamy medium sand; 8 to 10% clay; massive structure; loose, nonsticky; 10% gravel; gravel is poorly sorted and is subrounded to subangular; no effervescence; moderately alkaline (pH 8.0).
C2--30 to 54 inches; brown (10YR 4/3) moist; medium sand; 5% clay; single grain; loose, nonsticky; 15% gravel; gravel is subrounded to subangular; no effervescence; moderately alkaline (pH 8.0).

(109) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic Typic Haplargid

A typical pedon of Fine-loamy, mixed, superactive, thermic Typic Haplargid is deep, nearly level, well drained sandy soils with an argillic horizon. This soil occurs on older alluvial fans from the Sierra Nevada Mountains. (See 13 and 32 on Figure A-5-1).

A1--0 to 4 inches; brown (10YR 4/3) moist; loamy sand; 8% clay; massive to single grain structure; loose, loose, nonsticky; few fine roots; 3% gravel; gravel is subangular; no effervescence; mildly alkaline (pH 7.5); diffuse boundary.
A2--4 to 8 inches; brown (10YR 4/3) moist; sand; <5% clay; weak platy structure; soft, loose, nonsticky; common fine roots; 5% gravel; no effervescence; moderately alkaline (pH 8.0); abrupt boundary.
Bt--8 to 20 inches; brown (10YR 4/3) moist; medium sandy clay loam; 21% clay; medium subangular blocky structure; hard, firm, slightly sticky; 15% gravel; gravel is angular to subangular; very few fine roots; no effervescence; moderately alkaline (pH 8.0); gradual boundary.
C--20 to 24 inches; brown (10YR 4/3) moist; loamy medium sand; 27% clay; medium subangular blocky structure; loose, nonsticky; 25% gravel; no effervescence; moderately alkaline (pH 8.0).

(110) **TAXONOMIC CLASS**: Loamy, mixed, superactive, thermic, Typic Torriorthent

A typical pedon of Loamy, mixed, superactive, thermic, Typic Torriorthent is deep, nearly level, well drained sandy soils, formed on relict stream channels draining the Sierra Nevada west of Little Lake. Vegetation is primarily saltbush (Atriplex spp.). Soil pit location is 14 on Figure A-5-1.

A--0 to 3 inches; dark grayish brown (10YR 4/2) moist; loamy sand; 12% clay; deflation surface; sand is rounded to subrounded; platy to weak subangular blocky structure; soft, loose, nonsticky; 5% gravel; few fine roots; no effervescence; mildly alkaline (pH 7.5); diffuse boundary.
C1--3 to 26 inches; dark grayish brown (10YR 3/2) moist; loamy sand; medium to coarse sand; 10% clay; platy to weak subangular blocky structure; soft, very friable, nonsticky, 10% gravel; common fine roots; slightly effervescent; moderately alkaline (pH 8.0); gradual boundary.
C2--26 to 36 inches; dark grayish brown (10YR 3/2) moist; loamy sand; 10% clay; massive structure; soft, very friable, nonsticky; 5% gravel; gravels are subrounded; few medium roots; slight effervescence; mildly alkaline (pH 7.5); abrupt boundary.
C3--36 to 44 inches; dark grayish brown (10YR 3/2) moist; sandy loam; 13% clay; massive structure; slightly hard, very friable; slightly sticky; 25% gravel; gravel is subrounded and basaltic in composition; fine roots present; slightly effervescent; medium acid (pH 6.0); gradual boundary.

C4--44 to 50 inches; dark brown (10YR 3/3) moist; loam; 15% clay; subangular blocky structure; slightly hard, very friable, nonsticky; 25% gravel; cobbles at bottom of horizon; slightly effervescent; moderately alkaline (pH 8.0).

(111) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic, Aquic Torrifluvent

A typical pedon of Fine-loamy, mixed, superactive, thermic, Aquic Torrifluvent is deep, nearly level, poorly drained, loamy and clayey very stratified soils, formed on relict river deposits of Pleistocene Owens River encircling Little Lake. Groundwater occurs at three feet or less below ground surface. This pedon is located approximately fifty feet south of Little Lake. Surface soil is moist. Soil pit location is 16 on Figure A-5-1.

A-- 0 to 6 inches; grayish brown (2.5Y 5/2) moist; loam; 20% clay; massive structure; slightly hard, very friable; nonsticky; common fine and medium roots; 5% gravel; strong effervescence; strongly alkaline (pH 9.0); gradual boundary; soil is moist.

C1--6 to 12 inches; dark grayish brown (10 YR 4/2) moist; loam; 18% clay; massive; slightly hard, very friable, nonsticky; common medium and fine roots; 15% gravel; strong effervescence; strongly alkaline (pH 8.5); gradual boundary; soil is moist.

C2--12 to 25 inches; light olive brown (2.5Y 5/3) moist; silty clay; 28 to 32% clay; massive structure; very friable, slightly sticky; common fine roots; <5% gravel; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary; soil is increasing in degree of water saturation with increasing depth.

C3--25 to 34 inches; light olive brown (2.5Y 5/3) moist; clay loam; 28% clay; massive structure; slightly sticky; 10% gravel; moderately effervescent; moderately alkaline (pH 8.0); abrupt boundary; groundwater at 34 inches.

C4--34 to 36 inches; saturated aquifer material; greenish gray (10Y 5/1) wet; sandy clay loam; 34% clay massive structure; slightly sticky; 25% gravel; moderately alkaline (pH 8.0); roots absent; abrupt boundary.

C5--36 to 40 inches; saturated aquifer material; greenish black (5BG 2.5/1) wet; coarse sandy clay loam; 20% clay; massive structure; sands are subrounded to rounded; roots absent; 20% gravel; non effervescent; moderately alkaline (pH 8.0); abrupt boundary.

C6--40 to 48 inches; saturated aquifer material; dark greenish gray (10G 3/1) wet; coarse sandy loam; 15% clay; massive structure; sands are subrounded to rounded; 30% gravel; non effervescent; moderately alkaline (pH 8.0); abrupt boundary.

C7--48 to 65 inches; saturated aquifer material; dark greenish gray (5GY 3/1) wet; silty clay loam; 30% clay; massive structure; sand is subrounded to subangular; non effervescent; moderately alkaline (pH 8.0); abrupt boundary.

C 8 -->65 to 72 inches; saturated aquifer material; greenish black (10G 3/1) wet; clay loam; 35% clay; massive structure; slightly sticky; moderately alkaline (pH 8.5).

(112) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic, Typic Torrifluvent

A typical pedon of Fine-loamy, mixed, superactive, thermic, Typic Torrifluvent is very deep, slightly sloping, well drained, sandy soils formed on a combination of Coso Range alluvial fan toe slope deposits and Pleistocene Owens River deposits. Groundwater occurs at a depth of 6 feet four inches below ground surface. Soil pit location is 19 on Figure A-5-1.

A1--0 to 5 inches; very dark grayish brown (10 YR 3/2) moist; fine sandy loam; 10% clay; weak platy structure; slightly hard, very friable, nonsticky; common medium roots; 2% gravel; no effervescence; moderately alkaline (pH 8.0); abrupt boundary.
C1--5 to 26 inches; olive brown (2.5Y 4/3) moist; loamy coarse sand; 8% clay; moderate platy; loose, loose, nonsticky; 15% gravel; granitic subrounded to subangular; no effervescence; moderately alkaline (pH 8.0); gradual boundary.
C2--26 to 32 inches; dark grayish brown (2.5Y 4/2) moist; loam; 10% clay; massive; soft, very friable, nonsticky; 25% gravel; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.
C3--32 to 40 inches; dark grayish brown (2.5Y 4/2) moist; silt loam; 25% clay; massive; strongly effervescent; strongly alkaline (pH 8.5); roots absent; abrupt boundary.
C4--40 to 58 inches; reddish brown (2.5YR 4/3) moist; coarse sandy loam; 18% clay; massive; soft, very friable, nonsticky; 25% gravel; roots absent; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.
C5--58 to 72 inches; weak red (2.5YR 4/2) moist; sandy loam; 18% clay; massiveloose, loose, nonsticky; 20% gravel; sand and gravels are subrounded to rounded; gravel is extremely weathered and crumbles easily under mild pressure; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary; <u>groundwater occurs at lower boundary</u>.
C6--72 to 76 inches; <u>saturated aquifer material</u>; weak red (2.5YR 4/2) moist; very coarse sand; 8 to 10 % clay; single grain; loose, loose, nonsticky; sand I subrounded to 20% gravel; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.

(113) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, calcareous, thermic, Typic Torrifluvent

A typical pedon of Fine-loamy, mixed, superactive, calcareous, thermic, Typic Torrifluvent is moderately deep, slightly sloping, somewhat poorly drained, loamy soils formed on alluvial fans from the Coso Mountains. These soils are moist year-round and have an indurated petrocalcic horizon at depths of 41 to 48 inches below the ground surface. Vegetation is saltgrass, Yerba mansa, willows, sedges, and rushes. Soil pit locations include 21 and 5' on Figure A-5-1.

A--0 to 3 inches; olive gray (5Y 4/2) moist; clay loam; 30% clay; massive structure; very friable, slightly sticky; common fine roots; 0% gravel; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary; soil is moist at the surface.
C1--3 to 21 inches; grayish brown (2.5Y 5/2) moist; fine sandy loam; 12% clay; massive structure; very friable, slightly sticky; common fine roots; gravel is absent; sand is fine and well sorted; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary; soil is moist to wet.
C2--21 to 29 inches; grayish brown (2.5Y 5/2) moist; loam; 18% clay; massive structure; very friable, slightly sticky; few fine roots; 5% gravel; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.
Ck1--29 to 41 inches; grayish brown (2.5Y 5/2) moist; sandy clay loam; 20% clay; massive structure; friable, slightly sticky; strongly effervescent; strongly alkaline (pH 8.5); roots absent; abrupt boundary.
R-- 41 to ? inches; pale brown (10YR 6/3) moist; very hard; massive structure; roots absent; porous; strongly effervescent; strongly alkaline (pH 9.0); this layer is wet. Petrocalcic horizon.

(114) **TAXONOMIC CLASS**: Fine-loamy, mixed, calcareous, superactive, thermic, Typic Torriorthent

A typical pedon of Fine-loamy, mixed, calcareous, superactive, thermic, Typic Torriorthent is very deep, slightly sloping, well drained sand clay loam soils; formed on alluvial fan toe slopes in alluvium derived from Coso Mountains. Groundwater occurs at a depth of 6 feet below the ground surface. Soil pit location is 3' on Figure A-5-1.

A--0 to 6 inches; dark grayish brown (2.5Y 4/2) moist; sandy clay loam; 25% clay; massive structure; friable, slightly sticky; common fine roots; no gravel; strongly effervescent; strongly alkaline (pH 9.0); gradual boundary. Moist at surface.
C1--6 to 18 inches; dark grayish brown (2.5Y 4/2) moist; sandy clay loam; 25% clay; massive structure; very friable, slightly sticky; 10% gravel; common fine roots; strongly effervescent; moderately alkaline (pH 8.0); gradual boundary.

C2--18 to 48 inches; dark grayish brown (2.5Y 4/2) moist; sandy clay loam; 25% clay; massive structure; friable; slightly sticky; 25% gravel; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C3--48 to 58 inches; greenish gray (10Y 5/1) moist; sandy clay loam; 30% clay; massive structure; friable; slightly sticky; 15% gravel; gravel is granitic and crumbles under mild pressure; strongly effervescent; moderately alkaline (pH 8.0); gradual boundary.
C4--58 to 68 inches; greenish gray (10Y 5/1) moist; sandy clay loam; 27% clay; massive structure; friable, slightly sticky; no gravel; soil is wet throughout the horizon; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C5--68 to 76 inches; greenish black (10Y 2.5/1) wet; coarse sand; 6% clay; massive structure; sand is coarse to medium; no gravel; soil is saturated at bottom of horizon; strongly effervescent; moderately alkaline (pH 8.0); gradual boundary.
C6--76 to 90 inches; greenish black (10Y 5/1) wet; saturated aquifer material; coarse sand; <5% clay; massive structure; 10% gravel; strongly effervescent; moderately alkaline (pH 8.0).

(115) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic, Typic Petrocalcid

A typical pedon of Fine-loamy, mixed, superactive, thermic, Typic Petrocalcid is moderately shallow, nearly level, poorly drained loamy soils. This soil occurs on alluvial fan deposits of the Coso Mountains and Sierra Nevada. These soils remain moist throughout the year and have an indurated petrocalcic horizon at 32 inches below ground surface. Soil pit location is 1' on Figure A-5-1.

A--0 to 3 inches; dark gray (2.5Y 4/1); clay loam; 30% clay; massive structure; soft, very friable, few fine roots; strongly effervescent; strongly alkaline (pH 9.0); gradual boundary.
C1--3 to 9 inches; grayish brown (2.5Y 5/2); clay loam; 30% clay; massive structure; soft, very friable; few fine roots; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary.
C2--9 to 32 inches; grayish brown (2.5Y 5/2); clay loam; 34% clay; massive structure; soft, very friable; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.
R--32 to ? inches; pale brown (10YR 6/3) moist; very hard; massive structure; roots absent; porous; strongly effervescent; strongly alkaline (pH 9.0); this layer is wet, petrocalcic.

(116) **TAXONOMIC CLASS**: Sandy-skeletal, mixed, superactive, thermic, Calcic Petrocalcid

A typical pedon of Sandy-skeletal, mixed, superactive, thermic, Calcic Petrocalcid consists of somewhat shallow, complex sloped, undulating, well drained sandy soils formed on alluvial fan deposits of the Coso Mountains and relict stream deposits. These soils are moist at a depth of 48 inches below the ground surface and have a fractured porous petrocalcic horizon from 24 to 60 inches below the ground surface. Moisture conditions encountered at a depth of 48 inches. Soil pit location is 22 on Figure A-5-1.

A--0 to 6 inches; dark grayish brown (2.5Y 4/2) moist; coarse sand; < 5% clay; weak platy structure; hard, loose, nonsticky; few fine roots; 10% gravel; moderately effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C1--6 to 14 inches; dark grayish brown (2.5Y 4/2); loamy sand; 5% clay; platy structure; extremely hard, extremely firm, nonsticky; 20% gravel; strongly effervescent; strongly alkaline (pH 8.0); abrupt boundary. Beginning to show petrocalcic effects, i.e. pieces of cemented soil material in profile.
C2--14 to 24 inches; olive brown (2.5Y 4/3); fine sand; 5% clay; massive structure; soft, very friable, nonsticky; 5% gravel; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary. Petrocalcic effects are increasing.
R--24 to 60+ inches; gray (2.5Y 5/1) moist; very hard; massive structure; roots absent; porous; strongly effervescent; strongly alkaline (pH 9.0). Petrocalcic horizon.

(117) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic, Aquic, Petrocalcid

A typical pedon of Fine-loamy, mixed, superactive, thermic, Aquic, Petrocalcid is shallow, gently sloping, poorly drained sandy clay loam soils formed on alluvial fans of the Coso Range and relict stream deposits. Soil is moist at the surface and a petrocalcic horizon occurs at a depth of 18 inches. This horizon has pores and is wet down to 38 inches below the ground surface. Vegetation consists of saltgrass, saltbush, pickleweed, and *Yerba mansa*. Soil pit location is 23 on Figure A-5-1.

A--0 to 6 inches; very dark grayish brown (10YR 3/2) moist; loam; 15% clay; massive; very friable, nonsticky; common medium roots; 0% gravel; strongly effervescent; strongly alkaline (pH 9.0); gradual boundary: soil is moist at the surface.
C--6 to 18 inches; black (7.5YR 2.5/1) moist; coarse sandy clay loam; 25% clay; massive structure; extremely firm, slightly sticky; 75% gravel; strongly effervescent; strongly alkalinity (pH 9.0); soil is wet throughout this horizon; abrupt boundary. This horizon is showing strong petrocalcic characteristics, i.e. gravel is broken pieces of calcium carbonate.

R--18 to 38 inches; dark gray (10YR 4/1) moist; indurated; massive structure; roots absent; porous; strongly effervescent; strongly alkaline (pH 8.5); horizon is wet.

(118) **TAXONOMIC CLASS**: Loamy-skeletal, mixed, thermic, Typic Torripsamment

A typical pedon of Loamy-skeletal, mixed, thermic, Typic Torripsamment is shallow, level, very well drained gravelly sands formed from alluvial fans and debris avalanches from the Coso Mountains and the Sierra Nevada Mountains. Vegetation is saltbush and creosote bush. Soil pit location is 28 on Figure A-5-1.

A--0 to 2 inches; dark grayish brown (2.5Y 4/2) moist; medium sandy loam; 15% clay; platy structure; loose, loose, nonsticky; few fine roots; 15% cobbles to boulder size of basltic composition; 25% gravel; gravel is angular to subangular, moderately well sorted and is granitic; slightly effervescent; moderately alkaline (pH 8.0); gradual boundary.
C1--2 to 36 inches; dark grayish brown (2.5Y 4/2) moist; very gravelly loamy sand; 10% clay; single grain; loose, loose, nonsticky; few fine roots; 75% gravel; gravel is angular to subangular, poorly sorted and is granitic in composition; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C2-- 36+ inches; mostly gravel and coarse sand of granitic composition.

(119) **TAXONOMIC CLASS**: Fine-loamy, mixed, superactive, thermic, Calcic Petrocalcid

Typical pedon of Fine-loamy, mixed, superactive, thermic, Calcic Petrocalcid is very shallow, nearly level, poorly drained sandy soils resting upon an indurated petrocalcic layer. This unit also has minor areas where the petrocalcic horizon occurs on the surface. These soils formed from debris flows originating from the Sierra Nevada. These soils are situated directly north and south of Little Lake Gap. See 29 on Figure A-5-1 for soil pit.

A--0 to 3 inches; dark grayish brown (2.5Y 4/2) moist; loam; 20% clay; massive structure; extremely hard, extremely firm, slightly sticky; few fine and medium roots; 20% gravel; strongly effervescent; strongly alkaline (pH 8.5); abrupt boundary.
CR--3 to 10 inches; dark grayish brown (2.5Y 4/2) moist; sandy loam; 15% clay; platy to weak subangular blocky structure; extremely hard, extremely firm; strongly effervescent; strongly alkaline (pH 8.5); gradual boundary.
R--10+ inches; gray (2.5Y 5/1) moist; very hard; massive structure; roots absent; porous; strongly effervescent; strongly alkaline (pH 9.0).

(120) **TAXONOMIC CLASS**: Sandy, mixed, superactive, thermic, Typic Torriorthent

A typical pedon of Sandy, mixed, superactive, thermic, Typic Torriorthent is very deep, slightly sloping, excessively drained sandy soils formed in alluvial fans of the Coso Mountains and Sierra Nevada Mountains and stream deposits of the Pleistocene Owens River. Soil pit location is 30 on Figure A-5-1.

A--0 to 4 inches; brown (10YR 4/3) moist; coarse loamy sand; 10 %clay; platy structure; loose; loose, nonsticky; 20 % gravel; gravel is angular, poorly sorted and is granitic in composition; moderately effervescent; moderately alkaline (pH 8.0); gradual boundary.
C1--4 to 22 inches; dark grayish brown (2.5Y 4/2) moist; loamy coarse sand; 8% clay; massive structure; loose, loose, nonsticky; 40% gravel; gravel is coated with calcium carbonate deposits on the underside; moderately effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C2--22 to 54+ inches; grayish brown (2.5Y 5/2) moist; coarse sand; 8% clay; single grain, loose, nonsticky; 10% gravel; strongly effervescent; strongly alkaline (pH 8.5). This horizon is deeper, but the sand is too loose to remain in the auger.

(121) **TAXONOMIC CLASS**: Loamy, mixed, superactive, thermic, calcareous, Typic Torriorthent

A typical pedon of Loamy, mixed, superactive, thermic, calcareous, Typic Torriorthent is very deep, level, excessively drained sandy soils, formed in alluvium of the Coso Mountains and possibly from materials deposited by the Pleistocene Owens River. Gravel is granitic in composition and angular in geometry. Soil pit location is 31 on Figure A-5-1.

A--0 to 4 inches; dark grayish brown (2.5Y 4/2) moist; loam; 22% clay; weak subangular blocky to blocky structure; soft, very friable, nonsticky; common fine roots; 15% gravel; moderately effervescent; moderately alkaline (pH 8.0); gradual boundary.
C1--4 to 38 inches; light dark grayish brown (2.5Y 4/2) moist; fine sandy loam; 15% clay; weak subangular blocky structure; soft, very friable, slightly sticky; 2% gravel; gravel is rounded and granitic in composition; few medium roots; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C2--38 to 63 inches; dark grayish brown (2.5Y 4/2) moist; very coarse sand; <5% clay; massive structure; hard, very friable; slightly sticky; 10% gravel; gravel is rounded to subrounded and well sorted; strongly effervescent; strongly alkaline (pH 8.0).

(122) **TAXONOMIC CLASS**: Loamy-skeletal, mixed, superactive, thermic, calcareous, Typic Torrifluvent

A typical pedon of Loamy-skeletal, mixed, superactive, thermic, calcareous, Typic Torrifluvent is very deep, level, moderately well drained, sandy stratified soils, formed in alluvium predominately from the Sierra Nevada and from fluvial deposits of the Pleistocene Owens River. Soil pit location is 33 on Figure A-5-1.

A--0 to 5 inches; dark grayish brown (2.5Y 4/2) moist; loam; 20 % clay; platy structure; loose, very friable, slightly sticky; common fine roots; 15 % gravel; moderately effervescent; moderately alkaline (pH 8.0); gradual boundary.
C1--5 to 16 inches; light olive brown (2.5Y 5/3) moist; gravelly sandy loam; 18% clay; massive structure; hard, very friable, slightly sticky; 35% gravel; nonsticky; few medium roots; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C2--16 to 34 inches; light olive brown (2.5Y 5/3) moist; loamy sand; 12% clay; massive structure; hard, very friable; slightly sticky; 45% gravel; moderately effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C3--34 to 48 inches; light olive brown (2.5Y 5/3) moist; sandy loam; 15% clay; massive structure; slightly hard, very friable; slightly sticky; 15% gravel; moderately effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C4--48 to 66 inches; light olive brown (2.5Y 5/3) moist; very gravelly loamy sand; 12% clay; massive structure; slightly hard, loose, nonsticky; 55% gravel; no roots; moderately effervescent; strongly alkaline (pH 8.0); abrupt boundary.
C5--48 to 78 inches; light olive brown (2.5Y 5/3) moist; sandy loam; 15% clay; massive structure; loose, very friable, nonsticky; 10% gravel; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary.
C6-- 78+ inches;.light olive brown (2.5Y 5/3) moist; gravely sandy loam; 15% clay; massive structure; loose, very friable, slightly sticky; 35% gravel; strongly effervescent; moderately alkaline (pH 8.0).

APPENDIX EIGHT

Well Logs for Southern Owens and Rose Valleys
(See Figure A-8-1 for well log locations)

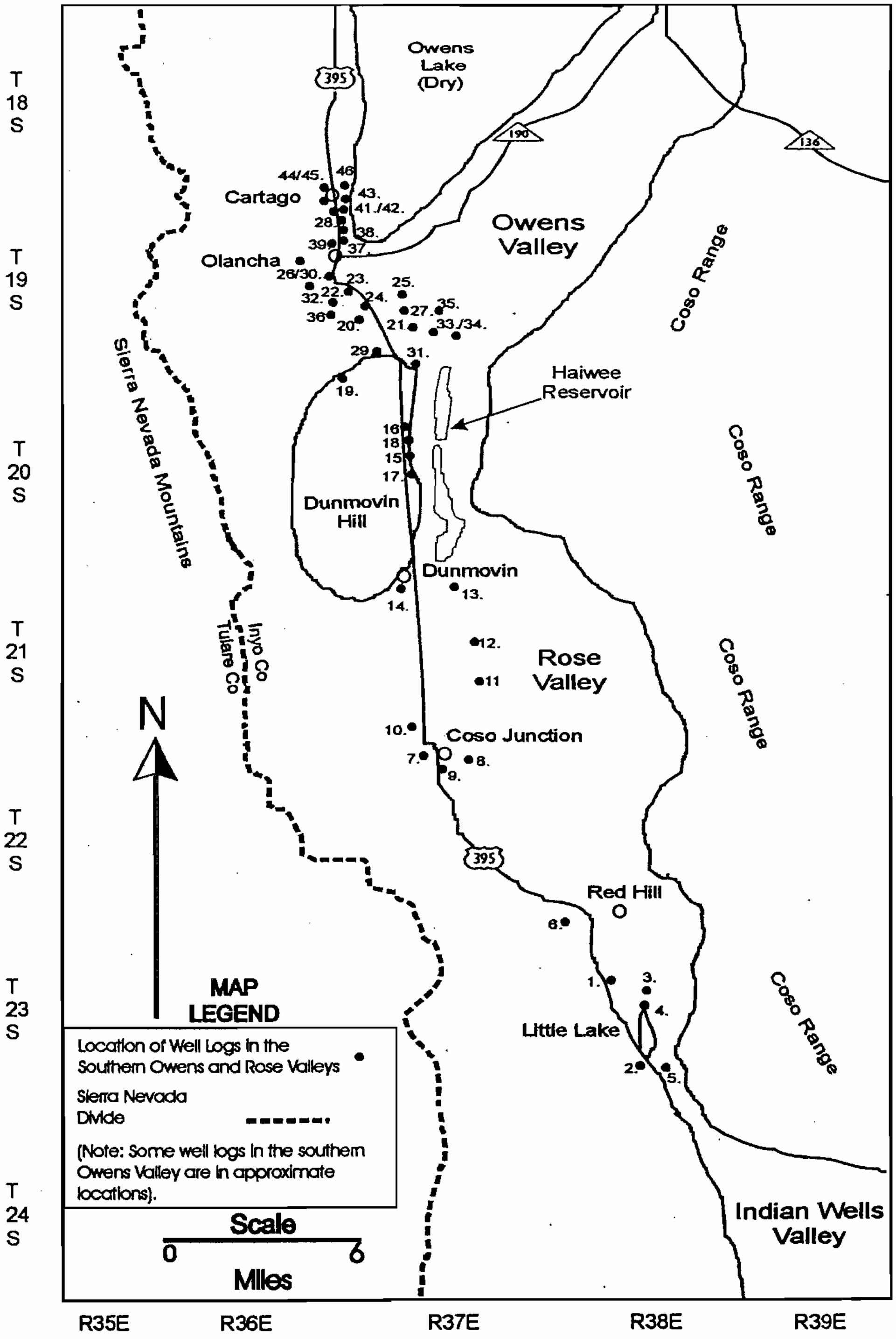


Figure A-8-1. Map location of well logs in the southern Owens Valley and Rose Valley, Inyo County, California.

Well Logs - Southern Rose Valley

Location	**Depth Feet**	**Lithology**
1. Little Lake		
Upper Little Lake Ranch Well		
T.23 S. R. 38 E. Sec. 6	0 to 20'	Sand, Gravel, Brown Clay, Boulders
Wellhead @ 3244'.	20 to 40'	Sand, Brown Clay, Black Lava
Water @ 58.5 feet	40 to 60'	Sand, Black Lava, Orange Clay
Dec. 83.	60 to 80'	Sand, Orange Clay, Lava
	80 to 97'	Sand, Lava, Brown Clay
Groundwater Contour at 3185 feet.		
2. Little Lake Hotel	0 to 20'	Brown Clay, Gravel
Perforation from	20-120'	Sand, Green Clay, Small Rocks
79-119(40')	120-125	Gray Clay
T.23 S. R. 38 E. Sec. 17		
Wellhead @ 3140'.		
Water @ 25 feet.		
Dec. 98.		
Groundwater Contour at 3115 feet.		
3. Little Lake Ranch House Well	0 to 8'	Loamy Sand and Gravel
T.23 S. R. 38 E. Sec. 5	8 to 11'	Sandy Loam, Gravel and Cobbles
Wellhead @ 3162'.		
Water @ 11 feet.		
Groundwater Contour at 3151 feet.		
Aug. 98.		
4. Little Lake North Dock Well	0 to 2'	Sandy Clay Loam
T.23 S. R. 38 E. Sec. 8	2 to 5'	Coarse Sand
Wellhead @ 3150'.	5 to 7'	Sandy Clay Loam
Water @ 5 feet.	7 to 8'	Very Coarse Sand
March 98.		
Groundwater Contour at 3145 feet.		

Well Logs - Southern Rose Valley

Location	Depth Feet	Lithology
5. Little Lake Ranch Well in Wetland South of Little Lake	0 to 2'	Clay Loam, and Loam
T.23 S. R. 38 E. Sec. 17	2 to 4'	Sandy Clay Loam and Gravel
Wellhead @ 3140'. *Water @ 2'3".* March 98. Groundwater Contour at 3137.75 feet.		
6. Red Hill Well		
Faye Ray	200+?	Sand and Cinders?
T.23 S. R. 38 E. Sec. 37 West of Highway 395 *Wellhead @ 3344'.* *Water @ 200 feet.* May 98. Groundwater Contour at 3144 feet.		

Well Logs - Central Rose Valley

Location	Depth Feet	Lithology
7. Coso Junction West Well		
T.22 S., R. 37 E., Sec 2	0 to 20'	Sand and Clay
Perforations from:	20 to 45'	Gravel and Clay
160 to 375'	45 to 50'	Large Gravel
445 to 565'	50 to 55'	Small Gravel
565 to 635'	55 to 70'	Coarse Sand
635 to 735'	70 to 110'	Coarse Gravel
Water @ 180 feet.	110 to 120'	Gravel
Wellhead @ 3395'	120 to 125'	Granitic Boulders
Groundwater @ 3215 feet.	125 to 150'	Coarse Sand and Gravel
June 97.	150 to 166'	Coarse Gravel and Clay
	166 to 180'	Large Gravel and Clay
	180 to 202'	Boulders
	202 to 230'	Sand and Clay
	230 to 290'	Coarse Sand
	290 to 310'	Small Gravel
	310 to 319'	Gravel and Clay
	319 to 325'	Sand and Gravel
	325 to 326'	Gravel and Clay
	325 to 350'	Gravel and Some Clay
	350 to 385'	Sand and Clay
	385 to 395'	Sand
	395 to 450'	Sticky Blue Clay
	450 to 475'	Sand and Clay
	475 to 501'	Blue Clay
	501 to 525'	Sand and Gravel
	525 to 540'	Brown Clay
	540 to 545'	Sand
	545 to 595'	Brown Clay
	595 to 601'	Sand
	601 to 614'	Brown Sticky Clay
	614 to 645'	Coarse Sand
	645 to 663'	Clay
	663 to 682'	Sand
	682 to 690'	Clay
	690 to 702'	Sand
	702 to 725'	Clay
	725 to 730'	Sand
	730 to 740'	Clay

Well Logs - Central Rose Valley

Location	**Depth Feet**	**Lithology**
8. Coso Junction Ranch Store		
T.22 S., R. 37 E., Sec. 2	0 to 20'	Fine Silty Sand
Perforations from 273 to 293';	20 to 25'	Boulders
343 to 363'; 383 to 403';	25 to 50'	Fine Silty Sand
421 to 445'	50 to 100'	Coarse Sand and Gravel
Wellhead Elevation @ 3370'.	100 to 120'	Coarse Sand and Gravel and Rock
Water @ 139 feet.	120 to 130'	Medium Sand and Brown Clay
Groundwater @ 3231 feet.	130 to 140'	Medium Sand
Dec. 98.	140 to 150'	Sand and Brown Clay
	150 to 160'	Brown Clay
	160 to 190'	Coarse Sand and Gravel
	190 to 200'	Medium Sand and Brown Clay
	200 to 230'	Gray Clay
	230 to 240'	Sandy Gray Clay
	240 to 250'	Coarse Sand and Brown Clay
	250 to 260'	Brown Clay
	260 to 270'	Gravel, Coarse Sand, and Clay
	270 to 280'	White Clay
	280 to 290'	Coarse Sand
	290 to 370'	Blue Clay
	370 to 380'	Coarse Sand and Blue Clay
	380 to 390'	Blue Clay
	390 to 410'	Medium Sand and Blue Clay
	410 to 420'	Brown Clay
	420 to 430'	Medium Sand and Brown Clay
	430 to 440'	Gravel and Medium Sand
	440 to 450'	Brown Clay
	450 to 460'	Blue Clay
	460 to 470'	Brown Clay

Well Logs - Central Rose Valley

Location	Depth Feet	Lithology
9. Coso Junction Caltrans Rest Stop T. 22 S., R. 37 E., Sec 2. Well Drilled in 1941, Well log not available. Distance to Highest Perforations is 160 feet. ***Wellhead Elevation @ 3370'.*** ***Water @ 140 feet.*** Groundwater @ 3230 feet. Oct. 80.	0 to 400'	*???*
10. Coso Junction West Side of Hwy 395 Ag Well, North of Coso Junction. T. 22 S., R. 37 E., Sec 2. ***Wellhead Elevation 3398'*** ***Water @ 270 feet.*** Groundwater @ 3128 feet. Dec. 98.	300?	?
11. Coso Junction East Side of Hwy 395 Ag Well, North of Coso Junction. T. 21 S., R. 37 E., Sec 23 S. ***Wellhead Elevation @ 3420'.*** ***Water @ 185 feet.*** Groundwater @ 3235 feet. Dec. 98	300?	?
12. Coso Junction East Side of Hwy 395- Abandoned Mobile Home Well, North of Coso Junction. T. 21 S., R. 37 E., Sec 23 S. ***Wellhead Elevation @ 3427'.*** ***Water @ 199 feet.*** Groundwater @ 3228 feet. Dec. 98	300?	?

Well Logs - Northern Rose Valley

Location	**Depth Feet**	**Lithology**
DUNMOVIN		
13. Cal-Pumice Inc.		
T. 21 S., R. 37 E., Sec 23 S.	0 to 317'	Red Clay, Granite Boulders
East of Dunmovin	317 to 322'	Gravel
Perforations from 300 to 397 feet	322 to 368'	Red Clay and Boulders
Water @ 242 feet.	368 to 370'	Gravel
Wellhead Elevation at 3480'	370 to 397'	Red Clay and Boulders
Groundwater @ 3238'		
Dec. 98		
14. Dunmovin		
T. 21 S., R. 37 E., Sec. 22	0 to 20'	Sand Boulders
Perforations from 340 to 400 feet	20 to 40'	Sand and Boulders
Water @ 303 feet.	40 to 60'	Sand and Boulders
Wellhead Elevation at 3480'	60 to 140'	Sand and Boulders
Groundwater at 3177'	140 to 160'	Sand, Boulders, Brown Clay
Dec. 98	160 to 200'	Sand and Boulder
	200 to 220'	Sand, Boulders, Brown Clay
	220 to 300'	Sand and Boulders
	300 to 405'	Sand and Boulders

Well Logs - Dunmovin Hill

Location	Depth Feet	Lithology
15. Enchanted Lake Village	0 to 3'	Overburden
Buckland West of Haiwee Reservoir	3 to 89'	Boulders and Brown Clay
Perforations from 240 to 300 feet.	89 to 154'	Brown Clay
T.20, R.37 E., Sec. 15	154 to 173'	Granite
Water @ 260 feet.	173 to 260'	Conglomerate, Brown Clay
Standing Water @ 75 feet.	260 to 300'	Water-Bearing Conglomerate
Wellhead Elevation at 3600'		
Oct. 86.		
16.Enchanted Lake Village	0 to 14'	Conglomerate, Boulders
West of Haiwee Reservoir	14 to 174'	Conglomerate, Brown Clay
McNalley	174 to 178'	Granite
Perforations from 212 to 275 feet.	178 to 275'	Blue Clay
T. 20, R.37 E., Sec. 15		
First Water @ 230 feet.		
Standing Water @ 105 feet.		
Wellhead Elevation at 3800'		
17. Enchanted Lake Village	0 to 60'	Sand and Gravel
Toone-West of Haiwee Reservoir	60 to 70'	Boulders
T. 20, R.37 E., Sec. 15	70 to 75'	Sand and Gravel
Perforations from 200 to 300 feet	75 to 90'	Boulders
Water @ 195 feet.	90 to 125'	Sand and Gravel
Wellhead Elevation at 3800'	125 to 130'	Boulders
	130 to 140'	Sand and Gravel
	140 to 240'	Sand and Boulders
	240 to 300'	Sand and Gravel
18. Enchanted Lake Village		
Tom and Betty Dews Well	T.D. = 299'	?
Lakeview Dr. and Highway 395		
West of Haiwee Reservoir		
T. 20, R.37 E., Sec. 21		
Water @ 230 feet.		
Wellhead Elevation at 3800'		

Well Logs - Dunmovin Hill

Location	**Depth Feet**	**Lithology**
19. Lien's Well Sageflat Rd. ***Water @ Surface, Free-Flowing Artesian*** Wellhead Elevation at 30'	T.D. = 53'	?
20. West Side of Summer Road Lot # 5 Olancha Perforations from 100 to 160 feet. ***Water @ 104 feet.*** Wellhead Elevation at 3480'	0 to 30'	Boulders and some Sand
	30 to 31'	Boulder
	31 to 42'	Sand and Gravel
	42 to 62'	Clay and small Gravel
	62 to 80'	Clay and Boulders
	80 to 81'	Very hard Boulders
	81 to 87'	Clay and small Gravel
	87 to 88'	Boulder
	88 to 110'	Clay and Gravel
	110 to 116'	Small Boulders
	116 to 119'	Loose Gravel
	119 to 130'	Boulders
	130 to 142'	Loose Gravel Water @ 20 G.P.M.
	142 to 150'	Boulder
	150 to 152'	Boulder
	152 to 165'	Gravel

Well Logs - Olancha

Location	**Depth Feet**	**Lithology**
21. 2.5 miles northwest of North Haiwee Reservoir, Olancha	0 to 10'	Sand
Venda Moore	10 to 30'	Sand and Gravel
T. 19 S., R. 37 E., Sec. 20.,	30 to 43'	Hard Sand
W ½ of SE 1/4.	43 to 49'	Sand
Perforations from 65 to 125 feet.	49 to 53'	Shale
Water @ 65'.	53 to 59'	Sand and Rock
Wellhead Elevation at 3704'	59 to 79'	Sand
	79 to 81'	Sand and Rock
	81 to 125'	Sand and Clay
22. 1200 feet West of Highway 395, Trent's well.	0 to 20'	Sand and Gravel
T. 19 S., R. 37 E., Sec 19	20 to 40'	Sand and Gravel
Perforations from 80 to 120 feet.	40 to 60'	Sand
Water @ 37 feet.	60 to 80'	Sand
Wellhead Elevation at 3670'	80 to 100'	Sand and Gravel
	100 to 125'	Sand and Gravel
23. Kivler's Well, Corner of Fall Rd. and Shop St.	0 to 20'	Sand, Gravel, Brown Clay
Perforations from 100 to 140 feet.	20 to 40'	Sand, Gravel, Brown Clay
Water @ 25 feet.	40 to 60'	Sand, Gravel, Brown Clay
Wellhead Elevation at 3656'	60 to 80'	Sand, Gravel, Brown Clay
	80 to 120'	Sand, Gravel, Brown Clay
	120 to 145'	Sand, Gravel, Brown Clay

Well Logs - Olancha

Location	Depth Feet	Lithology
24. Evan's Well, Summer Rd.		
T. 19 S., R. 37 E., Sec. 19, NW1/4.	0 to 3'	Brown Soil
Perforations from 80 to 120 feet.	3 to 64'	Brown Conglomerate, Clay
First Water @ 98 feet.	64 to 71'	Gray Granite
Standing Water @ 65 feet.	71 to 77'	Brown Decomposed Granite
Wellhead Elevation at 3760'	77 to 83'	Gray Granite
	83 to 120'	Gray Decomposed Granite
25. Wood's Well, 540 E. Fall Rd.		
Perforations from 200 to 140 feet.	0 to 12'	Overburden
First Water @ 135 feet.	12 to 73'	Brown Sand
Standing Water @ 19 feet.	73 to 89'	Blue Clay
Wellhead Elevation at 3695'	89 to 135'	Brown Sand
	135 to 200'	Sand and Conglomerate
26. Bill's Well		
Standing Water @ 51 feet.	0 to 20'	Sand, Gravel, Brown Clay
Wellhead Elevation at 3760'	20 to 40'	Sand, Gravel, Brown Clay
	40 to 60'	Sand, Gravel, Brown Clay
	60 to 80'	Sand, Gravel, Brown Clay
	80 to 100'	Sand, Gravel, Brown Clay
	100 to 140'	Sand, Gravel, Brown Clay

Well Logs - Olancha

Location	**Depth Feet**	**Lithology**
27. Sheffield's Well. 1525' North of Walker Creek Rd. East of Hwy. 395.		
T. 19 S., R. 37 E., Sec. 20.	0 to 3'	Overburden
Perforations from 140 to 60 feet.	3 to 100'	Small Brown Conglomerate
First Water @ 101 feet.	100 to 140'	Med. Brown Conglomerate
Standing Water @ 70 feet. Wellhead Elevation at 3704'		
28. Crystal Geyser's Well		
T. 19 S., R. 36 E., Sec. 12		
Perorations from 57 to 87 feet. Standing water @ 5 feet Wellhead Elevation @ 3640'.	0 to 10'	White to Light Brown, to Black. Coarse to very Coarse Sand and Gravel
	10 to 20'	Dark Brown Medium to Coarse Sand W/ some Fine Sand, Trace Very Coarse Sand
	20 to 28'	As Above
	28 to 30'	Lite Brown Medium to Coarse Sand
	30 to 35'	As Above, Pale Yellowish
	35 to 40'	As Above Brown Trace Very Coarse Sand
	40 to 50'	Blue to Gray Medium Sand W/ some Coarse Sand and Some Fine Sand
	50 to 58'	As Above, Light Brown
	58 to 70'	As Above
	70 to 75'	As Above Dark Brown to Gray
	75 to 80'	As Above
	80 to 83'	Slight Sulfur Odor
	83 to 88'	Blue-Gray Med.To Coarse Sand
	88 to 90'	Slight Sulfur Odor
	90 to 93'	As Above, W/ Shell Fragments
	93 to 94'	Small Blue-Gray Clay

Well Logs - Olancha

Location	**Depth Feet**	**Lithology**
29. Pierre’s Well, Olancha 0.25 miles West of Highway 395 *Water @ 100 feet.* Wellhead Elevation at 3480'	?	?
30. Ronnie Bill’s Well **Olancha**. 1 mile west of Highway 395. ***Water @ 30 feet.*** Wellhead Elevation at 3760'	T.D.= 130'	?
31. Francis Fritcher’s Well **Olancha.** 0.5 mile East of Highway 395 opposite Sageflat Rd. ***Water @ 140 feet.*** Wellhead Elevation at 3900'	T.D. = 200'	?
32. Neal Gordon’s Well **Olancha** Shop St., 1 mile west of Highway 395 ***Water @ 76 feet.*** Wellhead Elevation at 3760'	T.D. = 200'	?
33. John Hunter’s Ranch Well **Olancha.** In Pleistocene Owens River Channel. ***Water @ 28 feet.*** Wellhead Elevation at 3680'	T.D. = 600'?	?

Well Logs - Olancha

Location	**Depth Feet**	**Lithology**
34. John Hunter's Ag Well Olancha. In Pleistocene Owens River Channel. T. 19 S., R. 37 E., Sec. 28, NW 1/4 Cased to 507 feet. 1500 GPM, (4 Aquifers) Perforations from 90 to 500 feet. Wellhead Elevation at 3680' *Water @ 29 feet.*	0 to 15'	Fine Sand
	15 to 120'	Med. to Coarse Sand and Gravel
	120 to 140'	White & Lite Brown Clay
	140 to 240'	Med. To Coarse Sand and Gravel
	240 to 310'	Multi-Colored Silt & Clay Layer (Brown, White, Black)
	310 to 360'	Med. To Coarse Sand-Small Gravel, Silt Streaks
	360 to 420'	Clay
	420 to 450'	Med. to Coarse Sand W/ Small Gravel Lenses
	450 to 500'	Silt and Clay Layers
	500 to 600'	Silt and Sand Layer Lenses W/ Clay
35. Butterworth Monitoring Well Olancha. In Pleistocene Owens River Channel. Four Wells Oriented from South to North in a Straight Line. *MW 1 Water @ 31 feet.* *MW 2 Water @ 23 feet.* *MW 3 Water @ 20 feet* *MW 4 Water @ 23 feet.* Wellhead Elevations Approximately at 3700'	?	?
36. Oyster's Well T. 19 S., R. 37 E., Sec. 19. Perforations from 108 to 118 feet. *Water @ 18 feet.* Wellhead Elevation at 3670'	0 to 100'	Sand and Brown Clay
	100 to 155'	Coarse Sand, Streaks of Brown Clay

Well Logs - Olancha

Location	**Depth Feet**	**Lithology**
37. Olancha Mini-Mart's Well		
T. 19 S., R. 37 E., Sec. 19.	0 to 80'	Sand and Brown Clay
Water @ 39 feet.	80 to 105'	Sand and Gravel, Brown Clay
Wellhead Elevation at 3670'		
38. Rancho Olancha Water Company		
T. 19 S., R. 37 E., NW 1/4, Sec. 18	0 to 5'	Top Soil
Screened from 52 to 92 feet.	5 to 95'	Coarse Sand and Brown Clay
Water @ 31 feet.		
Wellhead Elevation at 3680'	95 to 98'	Sand and Gray Clay
39. Big Red Cafe	?	?
Water @ 27 feet.		
Wellhead Elevation at 3680'		
Unable to locate on map		
40. High Sierra Springs		
Perforations from 50 to 100 feet.	0 to 20'	Sand and Black Clay
Water @ 2 feet.	20 to 60'	Sand and Black Clay
Wellhead Elevation at 3690'	60 to 105'	Sand and Black Clay
Unable to locate on map		

Well Logs - Cartago

Location	Depth Feet	Lithology
41. Cabin Bar Ranch		
Artesian - Well 1	0 to 65'	Sand
T. 19 S., R. 36 E., Sec. 1	65 to 70'	Boulder
No Perforations	70 to 85'	Sand
Water @ 18 feet.	85 to 87'	Boulder
Wellhead Elevation at 3640'	87 to 110'	Sand
	110 to 111'	Boulder
	111 to 140'	Sand
	140 to 145'	Gray Clay
	145 to 160'	Boulder
	160 to 165'	Sand & Gravel
	165 to 185'	Boulder
	185 to 200'	Gravel
	200 to 230'	Sand & Gravel
	230 to 240'	Blue Clay
	240 to 255'	Sand
	255 to 260'	Blue Clay
	260 to 265'	Gravel
	265 to 285'	Boulders and Gravel
	285 to 295'	Blue Clay
	295 to 300'	Boulder
42. Cabin Bar Ranch		
50 GPM Artesian - Well 2	0 to 22'	Rocks
T. 19 S., R. 36 E., Sec. 1	22 to 25'	Sand
Perforations from 62 to 1123 feet and	55 to 80'	Gray Clay
from 143 to 186 feet.	80 to 100'	Gravel and Clay
Water @ 24 feet.	100 to 115'	Gray Clay
Wellhead Elevation at 3640'	115 to 130'	Clay and Gravel
	130 to 135'	Rocks
	135 to 150'	Sand
	150 to 186'	Sand and Gravel

Well Logs - Cartago

Location	Depth Feet	Lithology
43. Cabin Bar Mutual Water Co.		
T. 19 S., R. 36 E., Sec. 1	0 to 2'	Sand
Perforations from 60 to 120 feet.	2 to 10'	Sand & Clay
Water @ 15 feet.	10 to 20'	Sand and Gravel
Wellhead Elevation at 3480'	20 to 25'	Green Clay
	25 to 30'	Large Gravel
	30 to 40'	Gravel and Clay
	40 to 45'	Gravel
	45 to 65'	Green Clay
	65 to 75'	Gravel
	75 to 90'	Green Clay
	90 to 105'	Gravel
	105 to 120'	Black Clay
	120 to 130'	Green Clay
	130 to 165'	Sand
	165 to 175'	Gravel
	175 to 180'	Sand
	180 to 190'	Gravel
	190 to 198'	Clay
44. Roger's Well, Cartago		
T. 18 S., R. 36 E., Sec 36		
Perforations from 60 to 100 feet. ***Water @ 36 feet.***	0 to 20'	Sand, Boulders, Brown Clay
Wellhead Elevation at 3640'	20 to 105'	Sand, Boulders, Brown Clay
45. Zona Holt's Well Cartago.	T.D. = 145'	Sand and Gravel
0.25 miles West of Highway 395		
Well Completed to 90 feet.		
75 GPM.		
Water @ 48 feet.		
Wellhead Elevation at 3680'		

Well Logs - Cartago

Location	**Depth Feet**	**Lithology**
46. Cartago Mutual Water Co.		
T. 18 S., R. 36 E., Sec. 36 *Static Water @ 10 feet.* *First Water @ 44 feet.*	0 to 5'	Poorly Sorted Med. to Fine Sand
Wellhead @ 3600'.	5 to 10'	Very Poorly Sorted Pebbles and Med. to Wellhead Fine Grained Sand
	10 to 15'	Very Well Sorted Fine to Very Fine Sand
	15 to 30'	Very Poorly Sorted & Angular Cobbles, Gravels, Very Coarse to Fine Grained Sand
	30 to 35'	Dark Gray Silty Clay H_2S Odor
	35 to 40'	Gray Silt W/ Mica and Some Gravel H_2S Odor
	40 to 45'	Moderately Sorted Very Coarse to Medium Grained Sand
	45 to 50'	Well Sorted Very Coarse to Med. Sand
	50 to 55'	Very Poorly Sorted Angular Pebbles & Very Coarse to Fine Sand
	55 to 60'	Moderately Sorted Med. To Fine Sand W/ Gravel
	60 to 65'	Poorly Sorted Coarse to Fine Sand W/ Gravel
	65 to 70'	Very Well Sorted Very Fine Sand and Silt
	70 to 72'	Dark Organic Rich Silty Clay W/ Wood Chips H_2S Odor
	72 to 75'	Very Well Sorted Medium to Fine Sand
	75 to 87'	Very Well Sorted Medium to Fine Sand & Silt
	87 to 95'	Dark Organic-Rich Silty Clay H_2S Odor

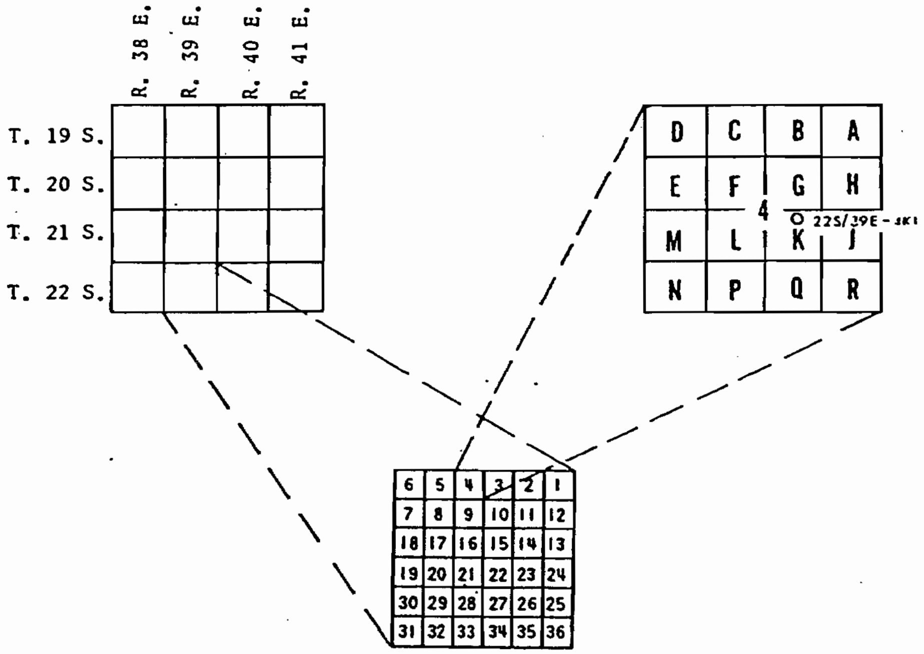
Well Logs - Cartago

Location	Depth Feet	Lithology
46. Cartago Mutual Water Co. **(Continued)**	95 to 100'	Gravel, Coarse to Fine Sand and Silty Clay
	100 to 105'	Very Poorly Sorted Gravels & Coarse to Medium Clean Sand-No Odor.
	105 to 110'	Very Well Sorted Very fine Sand & Silt - H_2S Odor
	110 to 115'	Very Poorly Sorted Coarse to Very Fine Sand
	115 to 120'	Very Poorly Sorted Pebbles to Very Coarse to Medium Sand
	120 to 125'	Very Well Sorted, Very Fine Sand & Silt
	125 to 130'	Very Well Sorted, Very Fine Sand & Silt W/ Few Gravels
	130 to 155'	Very Poorly Sorted Gravel to Very Fine Sand
	155 to 160'	Very Poorly Sorted Gravels & Dark Silty Clay H_2S Odor
	160 to 170'	Slightly Sticky Dark Clay H_2S Odor
	170 to 175'	Very Poorly Sorted Gravel to Silty Dark Clay
	175 to 180'	Veery Poorly Sorted Very Coarse Sand to Very Fine Sand & Silt H_2S Odor
	180 to 185'	Very Poorly sorted Angular Cobbles and Gravel & Very Coarse to Very Fine Sand
	185 to 190'	Very Poorly Sorted Gravels to Very Fine sand
	190 to 215'	Gray Clay H_2S Odor
	215 to 230'	Very Well Sorted Very Fine "Flowing" Sand and Silt

WELL- AND SPRING-NUMBERING SYSTEM

Wells are numbered according to their location in the rectangular system for the subdivision of public land. That part of the number preceding the slash, as in 22S/39E-4K1, indicates the township (T. 22 S.); the number after the slash indicates the range (R. 39 E.); the number after the dash indicates the section (sec. 4); the letter after the section number indicates the 40-acre subdivision of the section according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision. The area lies entirely in the southeast quadrant of the Mount Diablo base line and meridian.

Springs are numbered similarly, except that the letter S is placed between the 40-acre subdivision letter and the final digit, as shown in the following spring number: 22S/37E-33HS1.

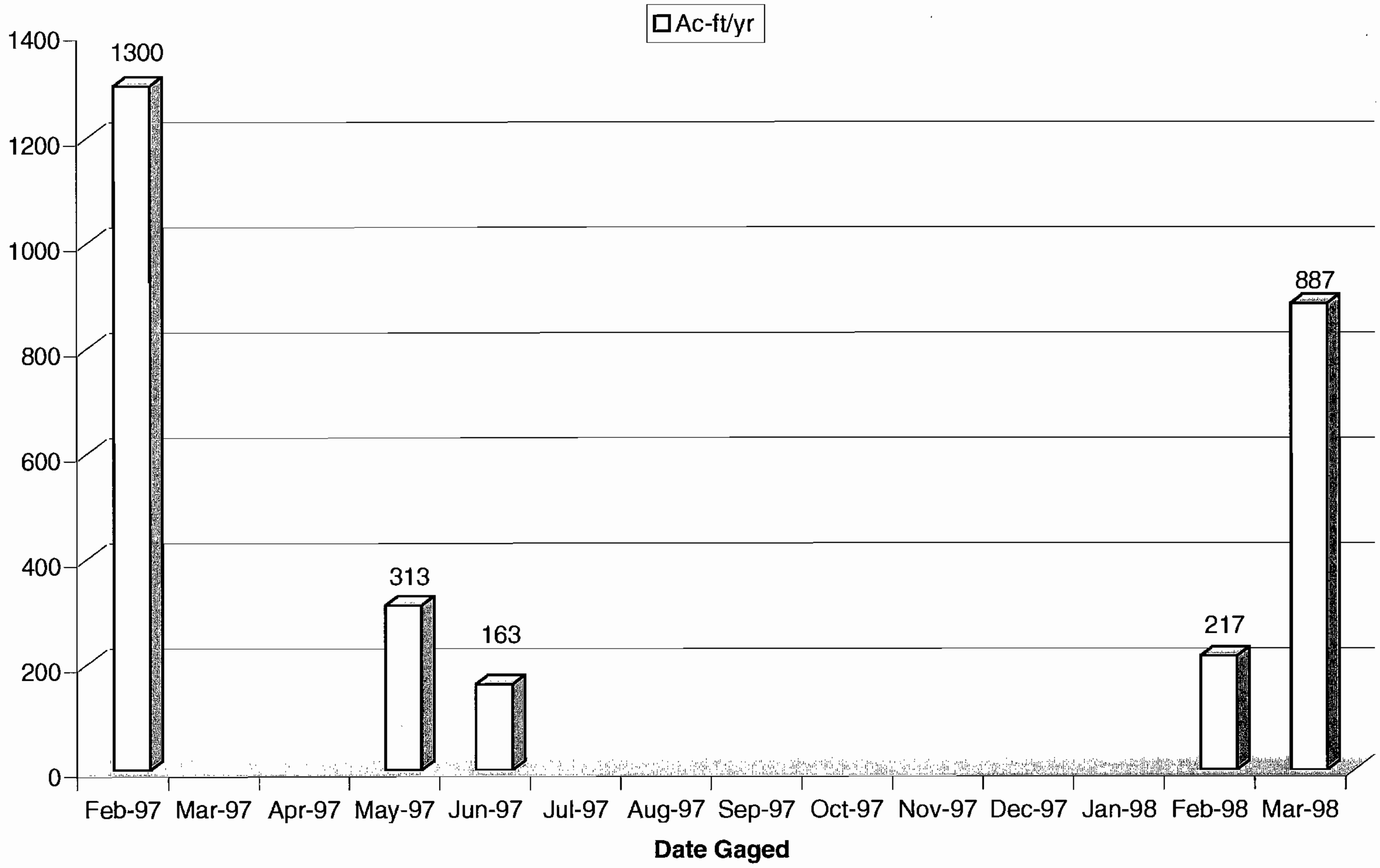


(Reproduced from Moyle, 1977)

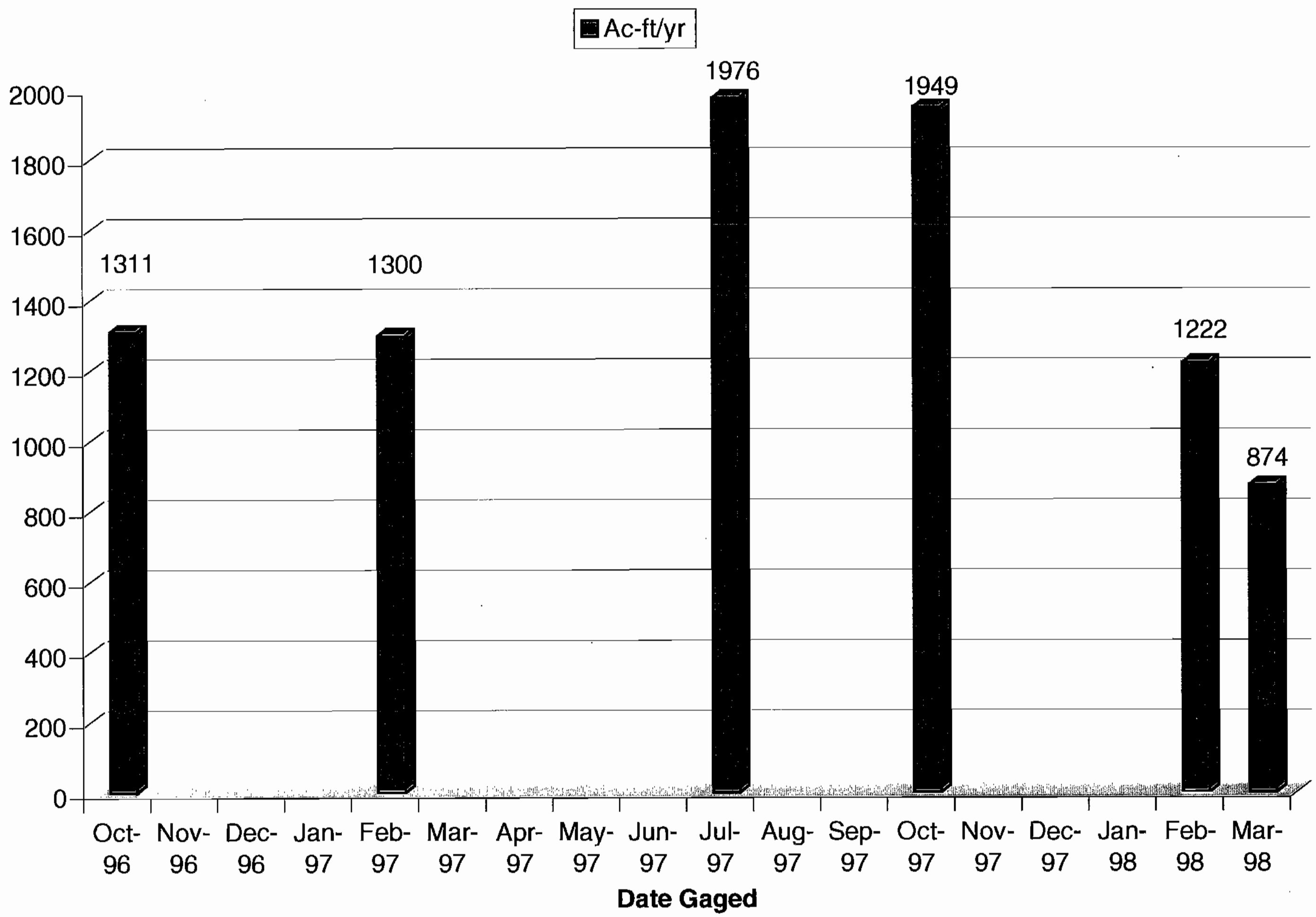
APPENDIX NINE

Surface Water Outflow from Rose Valley

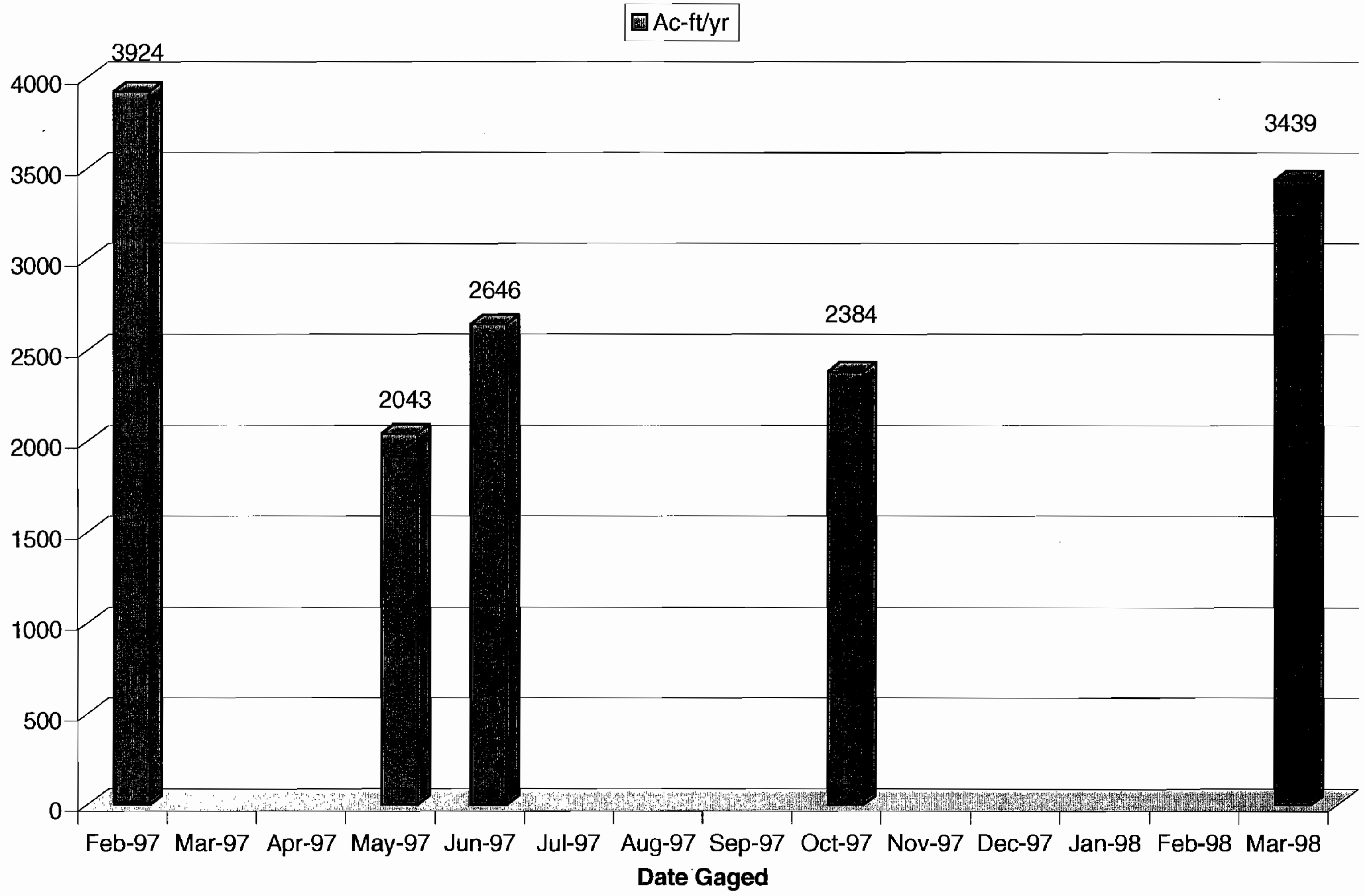
Rose Valley Surface Outflow - Little Lake Weir



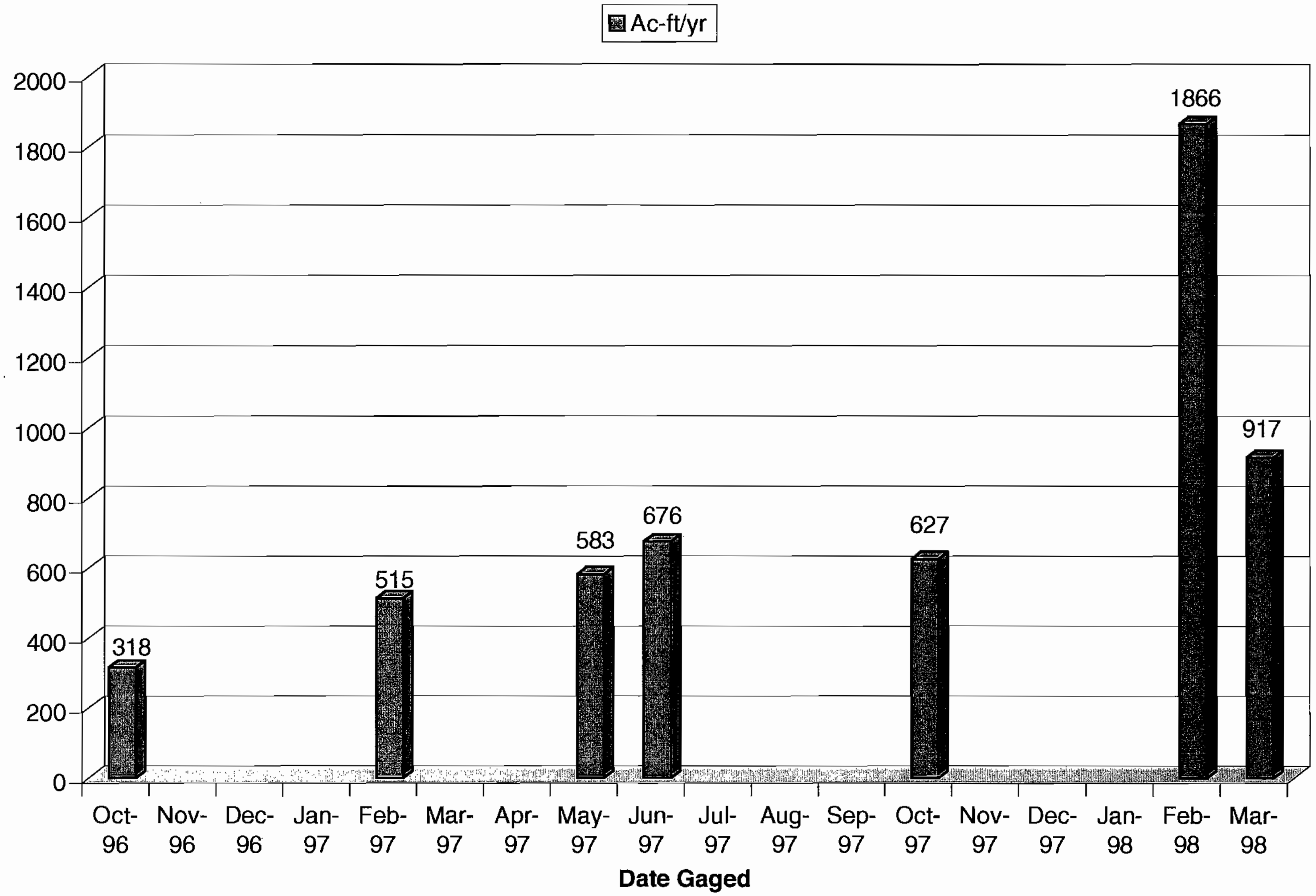
Rose Valley Surface Outflow - Coso Spring



Rose Valley Surface Outflow - Little Lake Gap (North Culvert)



Rose Valley Surface Outflow - South Culvert



APPENDIX TEN

Transmissivity data for five wells located in the
Rose Valley, Inyo County, California.

Rose Valley Well Hydraulics Used to Estimate Average Transmissivity

(Water Well Data Used to Estimate Average Transmissivity for the Rose Valley, Section 2.4.3)

State Well Number	Date	Static Water Level (Feet)	Pumping Water Level (Feet)	Drawdown (DD) (Feet)	Yield (gpm)	Specific Capacity (gpm/ft of DD)	Estimated Coefficient of Transmissivity (gpd/ft)
21S/37E-02K1	12/30/1974	10.6	74.6	64.0	290.0	4.50	9,000
21S/37E-11C1	n/a*	n/a	n/a	38.0	493.7	13.00	26,000
21S/37E-26B1	03/18/71	n/a	n/a	240.0	2700.0	11.20	22,400
21S/37E-26K1	06//10/76	215.7	247.0	31.3	1089.0	34.80	69,800
23S/38E-08D1	11/10/1975	n/a	6.1	n/a	60.0	34.00	64,000

* n/a Data Not Available

Source: Rockwell Report, 1980, Dutcher and Moyle, 1977, and Southern California Edison (SCE), 1977.