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Item 4

WATER SUPPLY DEVELOPMENT IN THE KINGSLEY MOUNTAINS, NEVADA

A Water Reconnaissance Study

Prepared For
WESTERN MARBLE CO., LTD.

REGISTERED PROFESSIONAL ENGINEER - STATE OF NEVADA
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PREFACE

Future economic progress of northeastern Nevada depends upon the availability of water. Planning of a broad-based economy must consider the appropriation and use of existing water supplies. Surface water sources, when available, have long since been appropriated. Areas that lack surface water supplies also are without a resident population. The future for these areas depends upon the appropriation of ground waters.

Previous studies provide little insight, either to the availability or to the development of ground water; therefore, existing knowledge pertaining to its development is speculation.

This report describes an investigation completed for Western Marble Co., Ltd., to determine the availability of a water supply for a quarry and mill operation in the Kingsley Mountains of eastern Nevada. The study was limited primarily to determining the availability of a water supply for a company camp and quarry operation in White Pine County near the southern extremity of the Kingsleys, and for a millsite in Steptoe Valley near Highway 50 Alternate.

The report is research oriented, primarily due to the lack of detailed data about the study area. Data pertaining to climate, hydrology, geology, and water resources of the region were obtained and analysed. Personal observation of many hydrologic conditions were used to supplement the regional data.

Ground-water supplies are available for development in the study area. Recommendations were made for permanent water supply development by using drilled wells. Three alternative well locations have been recommended for the quarry operation on a priority basis. The most economical of the three alternatives is recommended for initial development. A well location has also been recommended for the millsite. Cost estimates for each of the sites have been made. Water quality analyses were made of local spring and well supplies to determine expected mineral constituents.

The project leader of this study was Mr. Ronald D. Bernard, a Vice President of Geological Engineering Company and a consulting hydrologist. Geologic mapping information was gathered and prepared

by Mr. Christopher P. Buckley with the assistance of Mr. Edward A. Johnson, staff geologists for Geological Engineering Company. The water analyses were completed by Mr. William G. Smith of the Civil Engineering Staff of San Jose State College. In addition the entire study was reviewed by Mr. Robert L. Nevin, one of the leading consulting hydrologists in the western United States.

Geological Engineering Company wishes to acknowledge the cooperation of Mr. John McKelvie in providing logistical assistance to the project staff. The excellent work of Prof. B. L. Gabrielsen in reviewing the manuscript is also sincerely appreciated.

Section 1

INTRODUCTION

Western Marble Company, Ltd., has acquired from Mr. John McKelvie (of Vancouver, B.C.) a major high-quality marble deposit near Ely, Nevada. Prior to the acquisition, Mr. McKelvie engaged Geological Engineering Company to conduct a study of the water resources in the vicinity of the deposit. The purposes of the study were fourfold:

1) To determine the sources of water for the proposed quarry and mill operations and to recommend a water development program.
2) To determine the water availability for a permanent townsite to meet the eventual needs of the marble operation.
3) To evaluate the water resources and other factors that determine the potential for developing an agricultural economy in the vicinity of the marble operation townsite.
4) To estimate water supply development costs.

Objectives 2 and 3 will be reported in more detail in subsequent phases as the Marble Company development expands. This report presents the findings, conclusions and recommendations, and costs of a water supply for the more immediate needs of the Marble Company.

The research findings (Sections 5 through 8) are presented in detail for two reasons:

1) Previous studies pertaining to the hydrological aspects of developing water resources in eastern Nevada are few in number and are primarily studies of surface-water resources. Available studies are too general to be valuable for water resource development by private enterprise.
2) The economic development of eastern Nevada is entirely dependent upon the local availability of water. Detailed analyses describe conditions controlling movement and storage of water within groundwater basins of the study area. Knowledge of these conditions is valuable to private enterprise and to state and local agencies involved in planning future domestic and agricultural development of Nevada's water resources.

At the request of Mr. McKelvie, this report is directed to Western Marble Company, Ltd.

1.1 Geographical Information

The water reconnaissance study covers an area adjacent to the marble deposit located in eastern Nevada on the Elko-White Pine County Line, at the southern tip of the Kingsley Mountains. Specifically, the area covered by this report includes northern Antelope and southern Goshute Valleys, and a portion of Steptoe Valley near the junction of Highways 93 and 50 Alternate. The area is about 20 miles west of the Nevada-Utah border and lies between Latitudes 39°45' and 40°20' north, and Longitudes 114°07' and 114°45' west. The Kingsley Mountains are about 60 miles from Wendover, Utah; 100 miles from Wells, Nevada; and 85 miles from Ely, Nevada. (See Figure 1)

Goshute Valley is located in the northern part of the study area and is bounded by the Goshute Mountains to the east and Pequop Mountains to the west. The southern extension of Goshute Valley is called Antelope Valley, and is bounded by the southern end of the Goshute Mountains, the Goshute Indian Reservation to the east and the Antelope Range to the west. The Kingsley Mountains are located on the west side of Antelope Valley, and are a northeasterly segment of the Antelope Range. Steptoe Valley is west of the Antelope Range, and is bounded by the Shell Creek Mountains to the west, the Cherry Creek Range to the east, and the Dolly Varden Mountains to the northeast.

1.2 Study Procedure

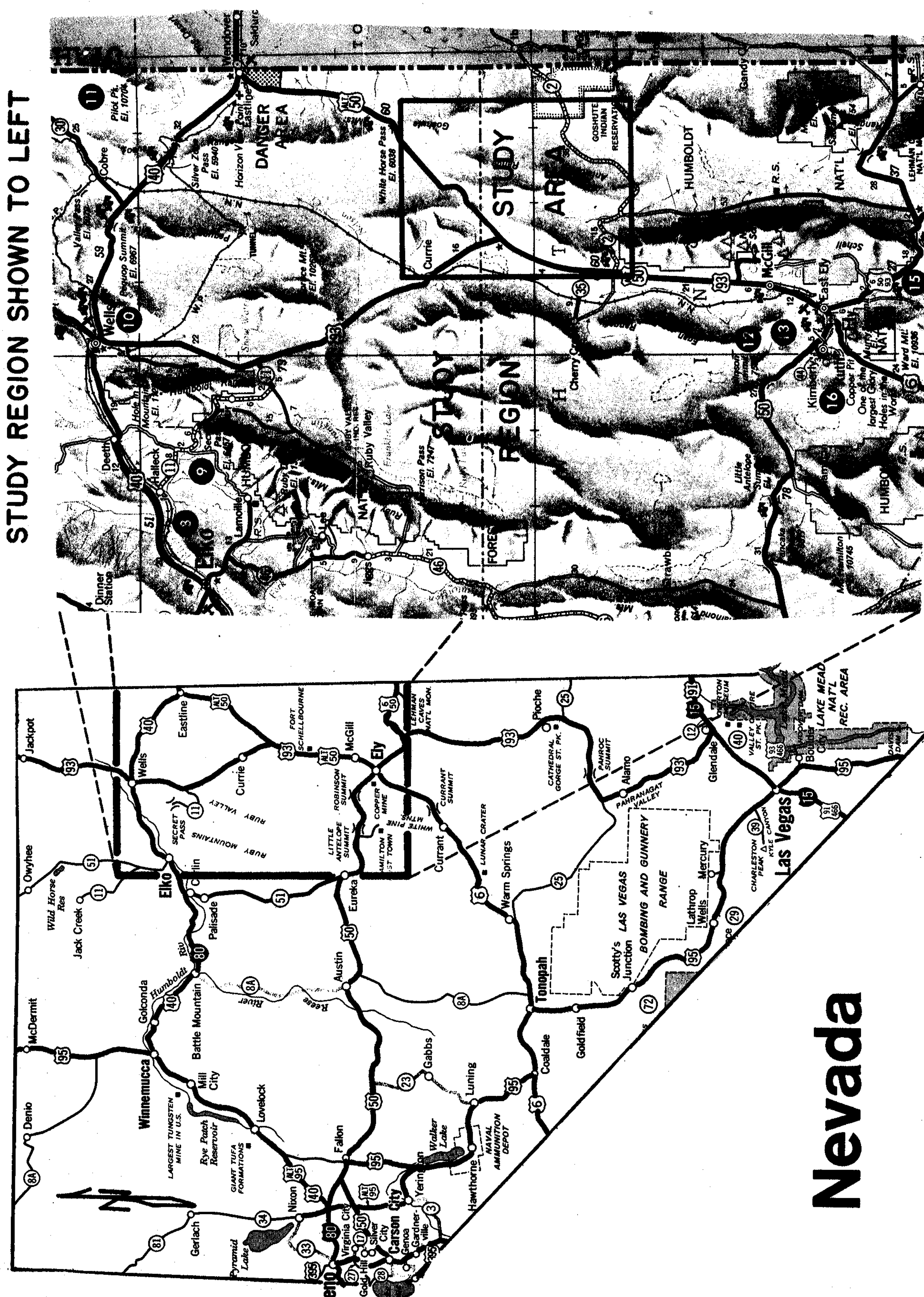
The study was conducted during the summer of 1966, from June 15th to September 15th. The authors spent much of this time examining the study area personally, with the remainder spent interviewing personnel in various public agencies concerned with the water resources of Nevada. Interviews were held with persons from The U. S. Geological Survey, The Bureau of Land Management, The Soil Conservation Service, The U. S. Weather Bureau, The Nevada Department of Conservation and Natural Resources, The University of Nevada, The Desert Research Institute, and with The Nevada State Engineer, County Officials and local residents.

Published reports of the various public agencies were obtained and examined for pertinent information concerning the hydrology and geology of the region. Water resources were evaluated from data in these reports, and personal observations of the hydrology, climate, and rainfall of the region coupled with geologic mapping, as well as from the experiences of public officials and private individuals. Methods of hydrologic analysis were based on the data available and on previous studies conducted in Nevada. Well logs were used to indicate expected ground water depths and potential availability of water from valley sediments. The report was reviewed by individuals familiar with the development of water resources in arid climates.

1.3 Report Organization

The report is organized so that Sections 1 through 4 can be extracted for use as a management brief.

FIGURE I
LOCATION MAP



Sections 5 through 8 contain the detailed research findings. Section 9 lists the major requirements for filing water rights.

Appendices supply a description of the regional geology, tabulations, and numerical calculations. Supplemental figures referred to in the text appear in the pocket.

Section 2

WATER REQUIREMENTS OF WESTERN MARBLE, LTD.

Water supplies will be needed for various uses associated with the development of the marble quarry operation of Western Marble Company, Ltd. Immediate needs will be as associated with quarry development and company living quarters at the quarry site. Future needs are associated with development of a millsite in the vicinity of the Elko-White Pine County Line near Highway 50 Alternate about 5 miles northeast of Lage's Station (Figure 2). Table 1 lists the needs and priorities for water development of the quarry operation.

Table 1

WATER REQUIREMENTS FOR WESTERN MARBLE, LTD.

Priority	Quantity Needed (gpm)
Immediate Needs	
Trailer camp and living quarters for men and families (40 persons)	4
Drilling operation	18
Future Needs	
Mill Site near Highway 50 at Elko-White Pine County Line	200

Source: Geological Engineering Company

The net quantity needed for the mill site is estimated from other milling operations in Nevada, since exact quantities necessary for cutting and finishing marble slab products are not available at this writing.

Section 3

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been made with respect to potential water development for the marble quarry and milling operations of Western Marble, Ltd.

1) Sufficient water is available in the aquifers[1/] of Antelope and Steptoe Valleys to supply the immediate and long-range needs of the quarry and milling operation proposed, with a reserve for domestic use. The aquifers are capable of producing sufficient water supplies for protracted drought periods or high pumping rates for short periods.
2) The alluvial formations are sufficiently permeable and storms frequent enough that the shallow aquifers in the small watersheds near the Kingsley Mountains are recharged on an annual basis. The recharge would be sufficient during the winter to sustain pumping during the summer periods.
3) Water for quarry, domestic and milling operations should be developed by drilling wells. Surface water sources are not sufficiently large to sustain company requirements, or water rights have previously been adjudicated. The absence of a predominant wet season of the year and high permeability of surface soils precludes the construction of surface reservoirs.
4) Estimated recoverable water in the study area portion of Antelope Valley is 8630 acre-feet per year. This amount would supply the average daily demand of a community of 36,000 persons at 200 gallons per person per day, or would be capable of irrigating 2150 acres using an applied rate of 4 acre-feet per acre.
5) Estimated recoverable water in the study area portion of Steptoe Valley is 3930 acre-feet per year. This amount would supply a community of 15,000 persons at 200 gallons per person per day, or irrigate 900 acres at an applied rate of 4 acre-feet per acre, in addition to the estimated 200 gpm needed for the mill operation.

3.1 Recommended Development For The Quarry Site

The immediate needs for the trailer camp and living quarters for initial operation of Western Marble, Ltd. can be developed from Kingsley Spring. The spring flow is estimated at 1 gpm and should be able to supply the immediate domestic needs of the quarry operation. The flow is not sufficient to supply the camp at full development or to supply the drilling operation.

1/ Strata or formations of permeable material that will yield gravity ground water in appreciable quantities.

Emphasis should be placed on developing well water supplies for the quarry operation and for full development of living quarters near the quarry. Three sites have been selected as potential locations for developing a supply. The three sites are listed in the order of priority, and are based on developing 25 gallons per minute. The three locations are shown on the site map, Figure 2, located in the pocket.

Site 1:

This proposed drilling location is in the shallow stream alluvium just south of the Dotty Mine. The drilled well will attempt to intercept the underground flow of water from the watershed that supplies Kingsley Spring. Sediments are estimated between 50 and 100 feet in thickness before penetrating bedrock. Unless the flow in the stream channel sediments is intercepted by one or more faults crossing the stream channel, a supply sufficient for quarry operations can be developed. This site is recommended for initial exploration since development costs are less than for Sites 2 and 3.

Should initial exploration near the Dotty Mine produce water in insufficient quantities, the remaining alternative is to attempt the development of well supplies in Antelope Valley.

Site 2:

This location is approximately 3 miles south of Site 1, near the apex of an alluvial fan on one of the eastward draining small watersheds near the north end of the Antelope Range. The position of the ground water table is not known in this area, but it is expected that sufficient quantities of water can be developed with a 300-foot well. The watersheds in this area are believed to contribute substantial ground water flow to the aquifers of Antelope Valley. By intercepting the flow at elevations higher than the regional water table in Antelope Valley, substantial savings in pumping costs can be made.

Site 3:

This location is about two miles east of Site 1, at the junction of the road heading east near the south end of the Kingsley Mountains, and the north-south road in Antelope Valley. Although this site is nearer to the quarry operation than Site 2, it will be the most expensive in terms of long-term pumping costs.

For each of the sites, it is recommended that a 6-inch diameter well be drilled to determine the availability and depth of the water table.

Should sufficient water be found at any of the sites, it is recommended that the 6-inch hole be bored to 12 inches, and an 8-inch casing be installed with a gravel pack in the space surrounding the casing. The 8-inch casing is recommended to reduce aeration of water cascading into the well casing after prolonged periods of pumping, and to reduce the possibility of sand entering the well and pump bowls. Both situations are more apt to occur in 6-inch or smaller casings. Aeration causes a reduction of both discharge and head, and the presence of fine sand in the pumped water reduces pump life and increases down time and maintenance costs.

3.2 Recommended Development For The Mill Site

Ultimately, the construction of a mill near Highway 50 Alternate at the Elko-White Pine County Line will require a water supply. Site 4 shown on Figure 2 is recommended as a general location for the well needed to supply water for the mill. It is estimated that a net of 200 gallons per minute will be needed to supply water for sawing, grinding, and polishing marble slabs, as well as minor uses at the mill site. The well can be located within the mill site property, minimizing the necessary distribution piping. It is recommended that the well be drilled and then bored to a 24-inch diameter. A 16-inch casing then should be installed and the space around the well casing packed with gravel.

3.3 Recommended Future Studies

The availability of land within the study area capable of sustaining agricultural crops should be investigated. The agricultural potential is not within the scope of this study, but is estimated that 1 to 3 percent of the area is capable of agricultural production and at least 20 percent could be converted to a higher grazing use by sagebrush removal and reseeding with desert-type grasses. Development of high use irrigated agriculture supplemented by utilization of sagebrush lands reseeded to grasses for increased grazing forage would broaden the economy being initiated by the quarry and milling operation of Western Marble, Ltd. An economy based on mining and milling, supplemented by agriculture, increased grazing, and associated commercial and residential development, would do much to broaden the tax structure of White Pine County, and perhaps Elko County.

Section 4

COST ESTIMATES

Cost estimates have been made for developing water supplies. Three alternative sites were selected for the quarry operation, and one site for the mill near Highway 50 Alternate. The costs for the quarry development were based on pumping 25 gallons per minute through a 3-inch pipe line to elevation 6600 to provide sufficient head for drilling operations. Cost estimates for the mill site were based on 200 gallons per minute with a minimum piping distance. A list of the factors used to determine the total discharge head and horsepower required appears in Table 2.

Table 2

DESIGN DATA FOR COST ANALYSES

Site No.	Well Depth (feet)	Well Lift (feet)	Pipe Line Distance (feet)	Pipe Losses (feet)	Elevation Differnce (feet)	Total Discharge Head (feet)	Horse-Power Req'd
Quarry Site							
1	100	75	6000	15	410	600	6
2	350	300	27000	70	430	800	8
3	350	300	19000	50	750	1100	11
Mill Site							
4	400	330	2500	10	60	400	32

Source: Geological Engineering Company

Cost estimates for the separate installations were based on using a two-pump system for the quarry site, and one pump at the mill site. Two 5-HP units would be used for the quarry site regardless of the site selected. Equipment would consist of a vertical turbine pump at the well, which would supply water to a buried 10,000-gallon storage tank. At the tank site, a building would house a horizontal turbine pump to lift the water to an elevation necessary for drilling operations. Thus, the system would contain two 5-HP pumps and motors, a 10,000-gallon tank, a 15-kw generatio, pumping switchgear, piping and appurtenances. The pumps and piping would need to be insulated to prevent freezing during winter months.

Equipment for the mill operation would consist of a 40-HP deepwell turbine pump, motor, switchgear, and piping. Cost estimates for the separate installations are shown in Table 3. The cost estimates include development of the respective wells, and a 48-hour pumping test to determine the aquifer characteristics of the well being tested. In addition, the drilling costs for Site 1 include the drilling of a small-diameter observation well to observe water levels during the 48-hour pumping test. The observation well should be drilled a few hundred feet upstream of the well being developed.

Table 3

COST ESTIMATES OF WATER SUPPLY DEVELOPMENT
FOR WESTERN MARBLE, LTD.

Site and Description of Necessary Equipment	Installed Costs Pump Equip.	Installed Costs Piping	Total
Site 1:			
Two Pumps, Motors-10 HP, A 15-kw Generator, Pump-house, Buried 10,000-gallon tank, Switchgear, and appurtenances for 25 gallons per minute	$10,500		
Piping, 3-inch @ $2.00 per foot including valves and fittings, 6000 feet required		$12,000	
Drill and Develop 8-inch well		$ 1,200	
Total, Site 1:			$23,700
Site 2:			
Same Equipment as Site 1	$10,500		
Piping, 3-inch @ $2.00 per foot including valves and fittings, 27,000 feet required		$54,000	
Drill and develop 8-inch well		$ 4,000	
Total, Site 2:			$68,500
Site 3:			
Same Equipment as Site 1	$10,500		
Piping 3-inch @ $2.00 per foot including valves and fittings, 19,000 feet required		$38,000	
Drill and develop 8-inch well		$ 4,000	
Total, Site 3:			$52,500

Table 3 (continued)

COST ESTIMATES OF WATER SUPPLY DEVELOPMENT
FOR WESTERN MARBLE, LTD.

Site and Description of Necessary Equipment	Pump Equip.	Installed Costs Piping	Total
Site 4:			
One 40-HP pump, Motor, Switchgear, piping and appurtenances for 200 gallons per minute	$ 5,000		
Piping, 6-inch in place with valves and fittings @ $5.00 per foot, 2500 feet estimated		$12,500	
Drill and Develop 16-inch well 400 feet deep		$ 8,000	
Total, Site 4:			$25,500

Section 5

CLIMATE AND VEGETATION

The valleys in eastern Nevada are semiarid, while the mountains surrounding them are considered semihumid. Rainfall varies from about 10 inches per year on the valley floor areas to over 28 inches per year on the higher mountain peaks. Precipitation on the high mountain areas consists of considerable amounts of winter snow that produces much of the runoff. The average number of days of measurable rainfall is 68 at Ely and 76 at Elko.

Temperature data have been recorded at numerous stations. Normals and extremes for Elko and Ely, listed in Table 4, reflect expected temperatures of the valley floor areas. (11)*

The length of the growing season in the study area is approximately 100 days. A tabulation of freeze data for the selected stations is given in Table 5. (11)

Nevada has a generous supply of sunshine. At northern and central locations, the average is between 65 and 75 per cent sunshine. The prevailing wind direction is southwesterly at Elko and southerly at Ely.

Thunderstorms are infrequent in the valley areas, but occur more often in mountainous areas. The average frequency per year is 22 at Elko and 30 at Ely.

Vegetation on the floor of Goshute, Antelope, and Steptoe Valleys consists of big greasewood, shadscale, big sagebrush, white sage, and big rabbitbush. Utah Juniper and singleleaf Pinon Pine are the common species of vegetation on ridges and intermediate mountain areas above 6500 feet in elevation.

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*Numbers in parentheses refer to references in the Bibliography.

Table 4

LONG-TERM TEMPERATURE MEANS AND EXTREMES

Month	Normals: Daily Max	Normals: Daily Min	Normals: Monthly Mean	Extremes: Record High	Extremes: Record Low
Elko Municipal Airport, Latitude 40°50' North, Longitude 115°47' West, Ground Elevation 5075 feet, 27 years of Data					
Jan	34.5	9.2	21.9	58	-43
Feb	40.2	16.6	28.4	67	-37
Mar	49.3	22.8	36.4	73	-9
Apr	60.4	28.7	44.6	82	-2
May	70.5	35.4	53.0	92	15
Jun	79.0	41.5	60.3	101	23
Jul	91.3	49.1	70.2	104	30
Aug	89.1	46.0	67.6	103	24
Sep	79.3	36.3	57.8	99	9
Oct	65.3	28.9	47.4	86	9
Nov	49.1	19.8	34.5	72	-12
Dec	38.9	14.9	26.9	64	-38
Annual	62.3	29.1	45.7	104	-43
Ely Airport, Yelland Field, Latitude 39°17' North, Longitude 114°51' West, Ground Elevation 6257 feet, 19 years of Data.					
Jan	37.4	8.6	23.0	68	-27
Feb	41.4	14.8	28.1	65	-25
Mar	49.3	21.2	35.3	69	-13
Apr	59.1	28.2	43.7	77	6
May	69.2	34.2	51.7	87	7
Jun	78.9	40.3	59.6	99	19
Jul	88.6	48.1	68.4	96	30
Aug	86.2	46.3	66.3	95	27
Sep	77.4	38.1	57.8	93	16
Oct	64.4	29.3	46.9	81	8
Nov	51.1	19.3	35.2	71	-9
Dec	41.0	12.8	26.9	65	-22
Annual	62.0	28.4	45.2	99	-27

Source: U. S. Weather Bureau

Table 5

FREEZE DATA FOR SELECTED STATIONS

Station	Freeze Threshold Temperature (°F)	Mean Date Of Last Spring Occurrence	Mean Date Of First Fall Occurrence	Mean No. Of Days Between Dates	No. Years of Record
Elko WB Airport	32	Jun 6	Sep 3	89	30
	28	May 22	Sep 18	119	30
	24	May 5	Sep 29	147	30
	20	Apr 14	Oct 16	185	30
	16	Apr 2	Oct 25	207	30
McGill	32	May 24	Sept 27	126	30
	28	May 5	Oct 12	160	30
	24	Apr 17	Oct 22	188	30
	20	Apr 3	Nov 4	215	30
	16	Mar 21	Nov 11	236	30
Ruby Lake	32	Jun 3	Sep 10	99	11
	28	May 15	Sep 27	134	11
	24	Apr 24	Oct 5	163	11
	20	Apr 15	Oct 20	188	11
	16	Mar 24	Nov 9	230	11

Source: U. S. Weather Bureau

Section 6

HYDROLOGY OF NORTHEASTERN NEVADA

The migration of water through the atmosphere, on the earths surface, and within soil profiles is a complex interdependent system called collectively the hydrologic cycle (Figure 3). The hydrologic cycle stated in general terms is water evaporated from the ocean, forming clouds that move inland, where the moisture is condensed to fall to the earth as precipitation. From the earth, water returns to the ocean through streams and underground to complete the cycle.

The interrelated elements of the hydrologic cycle affect the occurrence of water in surface streams and underground formations of northeastern Nevada. This section describes the essential elements of the cycle primarily in relation to the geologic and hydrologic conditions found in the study area.

The general geologic features of the Kingsley Mountains and adjacent areas are a major influence on the storage and movement of both surface and ground water in the study area. The regional geology and geologic history are presented in Appendix A. The general geologic features of the study area are shown on the Geologic Map (Figure 4).

6.1 Precipitation

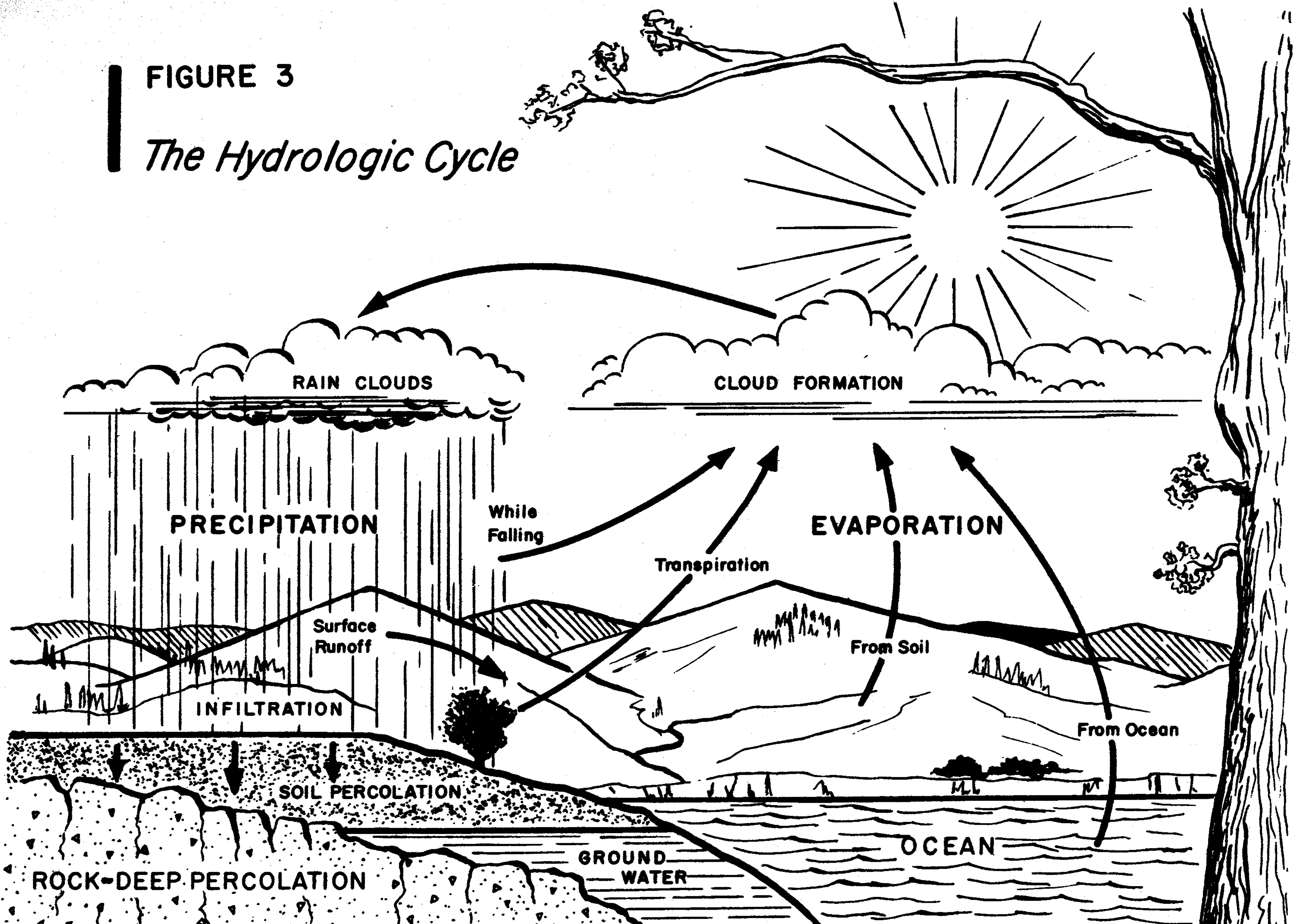
Water resources in Antelope, Goshute, and Steptoe Valleys of Nevada are derived from precipitation in the form of rain or snow. During the months of November through March snow accumulates in the higher mountain areas. In spring the melting snow enters the stream channels as runoff which flows to valley areas. Spring rains occurring during periods of snowmelt have caused damaging floods in populated areas. Little damage occurs within the study area except for road washouts and local inundation.

Much of the runoff is infiltrated into the soil mantle and the stream channel beds, thus recharging the aquifers in the valley alluvium. The portion of runoff that reaches the playas (temporary lakes) of the valley floor is either evaporated or transpired by plants.

Runoff also occurs as a result of regional westerly storm fronts. These fronts occur as rainfall of light to moderate intensity, and often are accompanied by localized thunderstorms. Thunderstorm activity usually occurs as rainfall of high intensity and short duration and may also cause localized flooding. However, even during intense thunderstorms, much of the resulting runoff is infiltrated in the permeable stream beds, with only a minor portion reaching the playas.

FIGURE 3

The Hydrologic Cycle



SOURCE: GEOLOGICAL ENGINEERING COMPANY

Table 6

PRECIPITATION STATIONS IN NORTHEASTERN
NEVADA AND NORTHWESTER UTAH

Station Name	Years of Record	Elevation	Mean Annual Rainfall
Ely Airport	27	6257	8.42
McGill	50	6340	9.15
Shellbourne	5	6720	5.76
Shellbourne Pass*	9	8150	11.02
Lehman Caves	23	6825	12.64
Garrison, Utah	11	5275	6.71
Partoun, Utah	13	4750	5.21
Callao, Utah	25	4339	4.51
Ibapah, Utah	58	5288	11.23
American Beauty*	4	8000	21.50
Harrison Pass*	15	7300	16.38
Overland Pass*	14	6789	9.66
Sadler Ranch*	14	5690	7.48
Jiggs	51	5450	12.07
Lamoille PH	57	6290	17.12
Soldiers Creek	12	7200	16.15
Seventy One Ranch	13	5550	12.38
Doby Summit*	10	6600	10.05
Elko	94	5077	8.79
Wells	63	5633	9.67
Kimberly	22	7230	13.88
Ruby Lake	24	6012	12.72
Angel Lake*	3	8300	26.93
Deeth	10	5343	9.74
Halleck+	33	5229	8.08
Arthur 5NW	48	6500	15.44
Wendover, Utah	42	4235	4.79

* Storage Gages
\+ Record ends in 1915

Source: U.S. Weather Bureau Climatological Data

Table 7
AVERAGE MONTHLY AND ANNUAL PRECIPITATION AT SELECTED STATIONS

	Ely Airport	Elko	Ibapah, Utah	Jiggs
Jan	0.65	1.22	0.70	1.16
Feb	0.59	0.93	0.97	1.06
Mar	0.91	0.92	1.07	1.21
Apr	1.04	0.71	1.24	1.50
May	0.88	0.86	1.59	1.49
Jun	0.80	0.69	0.94	0.85
Jul	0.55	0.35	0.80	0.53
Aug	0.50	0.29	1.01	0.49
Sep	0.64	0.33	0.61	0.60
Oct	0.67	0.66	0.98	1.08
Nov	0.60	0.77	0.65	0.92
Dec	0.59	1.06	0.67	1.18
Annual	8.42	8.79	11.23	12.07

Source: U. S. Weather Bureau *Climatological Data*

6.1.1 Rainfall

There is a paucity of rainfall data from eastern Nevada, and no precipitation stations are located in the study area. Rainfall data used to determine rainfall-runoff relationships were taken from U. S. Weather Bureau records for surrounding stations in northeastern Nevada and northwestern Utah. Records for 27 stations were used to determine the mean annual precipitation for the study area. These stations are listed in Table 6. The nearest long-term record near the Kingsley Mountains is located at Ibapah, Utah, about twenty miles to the east. Long-term monthly distributions for a few select stations are listed in Table 7. These stations were selected because they are representative of monthly rainfall distributions in northeastern Nevada.

The mean annual rainfall for each of the 27 stations in the region was used to determine the mean annual rainfall for the study area. A graphic plot of mean annual rainfall versus elevation (Figure 5) was made on semi-logarithmic paper. Since the plotted points did not describe a straight line, a curve was drawn through the points that best described the trend. Four of the stations were rejected. Stations Partoun and Callao in Utah were rejected because station records reflect the more arid areas of the Great Salt Lake rather than northeastern Nevada. The stations Shellbourne and Shellbourne Pass were rejected because the short-term records were incompatible with remaining applicable stations.

The fitted line through the plot of precipitation versus elevation was then used to provide the data for developing a mean annual railfall map of the study area. By selecting an elevation from a topographic map and assigning a value of rainfall from the fitted curve, a map depicting lines of equal rainfall based on topography was constructed. The map of mean annual rainfall is shown as Figure 6 in the pocket. The relationship of rainfall and elevation used to construct the map was abstracted from Figure 5, and is shown in Table 8. It compares favorably to a similar curve derived for Huntington Valley to the west. (1)

Table 8

MEAN ANNUAL RAINFALL VERSUS ELEVATION FOR NORTHEASTERN NEVADA

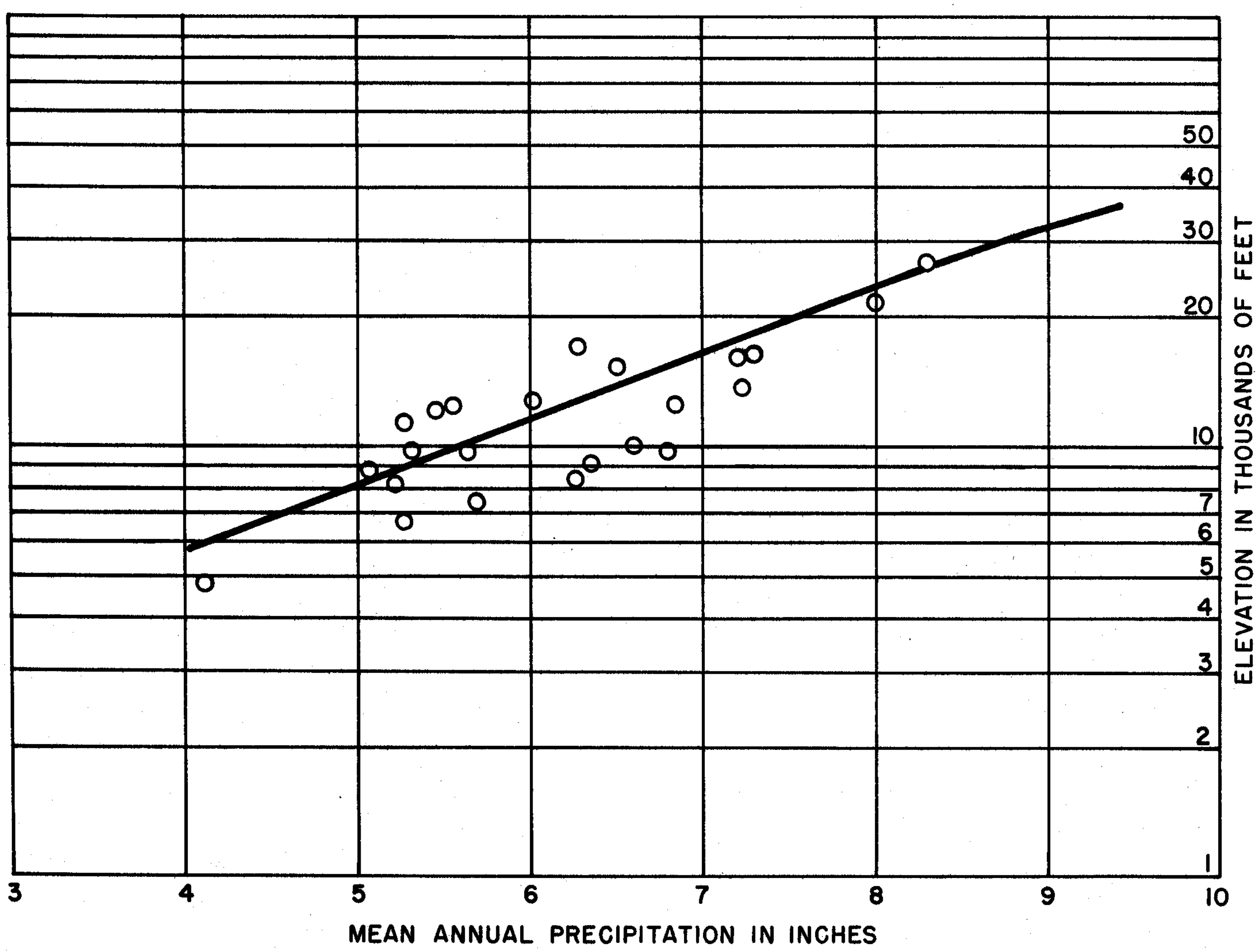
Elevation (feet)	Mean Annual Rainfall (inches)
5000	8.1
5500	10.0
6000	11.8
6500	14.0
7000	16.7
7500	19.8
8000	23.4
8500	27.4
9000	32.0

Source: Geological Engineering Company

GEOLOGICAL ENGINEERING COMPANY
PORTLAND, OREGON

FIGURE 5

PRECIPITATION - ELEVATION RELATION, NORTHEASTERN NEVADA



SOURCE: GEOLOGICAL ENGINEERING COMPANY

6.1.2 Snowfall

The majority of precipitation in the form of snow occurs between November and March. No data pertaining to snow depths are available for the Kingsley Mountains. However, data are abailable for Elko and Ely. Snow depths near the Kingsley Mountains would be expected to be similar to those recorded in southern Steptoe Valley at Ely, since the elevations and exposures are similar. Average monthly and total snow depths for Ely are listed in Table 9 for the period from 1939 to 1965.

6.2 Runoff

The runoff component of the hydrologic cycle includes the distribution and path taken by water after it precipitates on the land. In northeastern Nevada it reaches stream channels and flows a short distance to be returned directly to the atmosphere by evapo-transpiration. No runoff by surface streamflow reaches the ocean to be evaporated.

Table 9
SNOW DEPTHS AT ELY, NEVADA
(inches)

Month of Year	Total Mean Monthly	Maximum Monthly	Maximum in 24 Hours
Jan	8.7	19.3	13.1
Feb	6.9	19.9	10.4
Mar	9.8	24.8	10.6
Apr	5.3	24.5	7.3
May	1.8	10.8	4.7
Jun	0.3	5.6	5.6
Jul	0.0	0.0	0.0
Aug	0.0	0.0	0.0
Sep	0.0	0.0	T
Oct	1.7	7.8	7.3
Nov	4.5	15.3	8.2
Dec	6.8	18.9	7.9
Total	45.8		

Source: U.S. Weather Bureau Climatological Data

In regions of low topographic relief, mean annual runoff is closely related to the size of drainage area. In mountainous regions where the topography changes radically, as in northeastern Nevada, mean annual runoff often is poorly related to size of drainage area, because the magnitudes of rainfall and losses due to evaporation and transpiration change substantially with elevation.

The study area is no exception to the above statements. First, there are no stream gaging measurements of surface water flows available for the study area that would help define mean annual runoff. Further, the topographic relief is such that if runoff data were available, records from gaged watersheds would be of limited value in ungaged areas.

A regional approach was used to determine runoff in the Kingsley Mountains. Riggs and Moore (2) defined a method for determing runoff from ungaged watersheds by relating the runoff from evaluation zones to mean annual runoff from gaged watersheds. This method was applied by them to an area in northern Elko County, Nevada, and a portion of southern Idaho, and involves use of rainfall-elevation curves and estimates of runoff by elevation zones for comparisions to gaged watershed runoff. This method was extended by the authors to the study area near the Kingsleys.

The precipitation-elevation relationship derived for the Kingsleys compared very closely to one of the curves derived by Riggs and Moore. The runoff values by elevation zones for the comparable curve are listed in Table 10. The derived elevation-runoff relationship was used to draft a map of mean annual runoff for the study area. This runoff may is shown as Figure 7 in the pocket. The boundaries of five watershed areas were drafted on the runoff map, and mean annual runoff for the watersheds determined. The watershed boundaries also were transferred to the mean annual rainfall map, Figure 6 and mean annual rainfall for the areas determined. The results of the rainfall and runoff determinations for the watershed areas are listed in Table 11.

Table 10
ELEVATION-RUNOFF FOR THE KINGSLEY MOUNTAINS

Elevation (feet)	Mean Annual Runoff (inches)
5000	0.00
5500	0.25
6000	0.67
6500	1.20
7000	2.00
7500	3.00
8000	4.10
8500	5.50
9000	7.25

Source: Geological Engineering Company, using the method of Riggs and Moore (2)

The results of the rainfall-runoff computations listed in Table 11 indicate about 8.5 percent of the rainfall in Antelope Valley and 10.5 percent of the rainfall in Steptoe Valley appear as runoff. The sequence and duration of runoff in eastern Nevada is important to development of water supplies. Runoff occurs when the rainfall intensities exceed the infiltration capacities of the soil. Thus, runoff occurs only after intense rainfall or during the snowmelt period in the spring. Within a few hours after the conclusion of rainfall or melting snow, runoff ceases due to the permeability of the stream channels. This condition is discussed in more detail in Sec. 6.5.1.

Table 11

MEAN ANNUAL RAINFALL AND RUNOFF FOR SELECTED WATERSHED AREAS

Watershed Subarea	Area (Acres)	Mean Annual Rainfall (inches)	Mean Annual Runoff (Inches-Acre-Feet)	
Chinn Creek	4,198	19.49	3.30	1,156
Southern Antelope Valley	82,483	13.24	1.14	7,930
Kingsley Wash	21,427	13.42	1.31	2,340
Northern Antelope and Southern Goshute Valley	167,706	12.51	0.99	13,800
Total or Weighted Mean of Subareas	275,814	12.90	1.09	25,226
Steptoe Valley	91,336	14.26	1.50	11,400

Source: Geological Engineering Company

6.3 Evaporation

Pan evaporation in northeastern Nevada approaches 60 inches per year. The ratio of lake evaporation to pan evaporation is, for practical purposes, 0.70, and provides a convenient means of estimating reservoir evaporation. Thus, reservoir evaporation would approach 3.5 feet per year, equivalent to 3.8 times average annual rainfall for the floor of Steptoe Valley (11 inches). Evaporation is the major factor in consumption of water and thereby reduces total water available for economic development.

6.4 Evapo-Transpiration

The term evapo-transpiration is defined as water withdrawn from soil by evaporation and plant transpiration, and often is called consumptive use. It is difficult to separate the two components and therefore the term evapo-transpiration is used.

The amount of consumptive use is a function of available water, and type of plant using the water. A summary for desert types of vegetation is listed in Table 12. (8)

The estimates in Table 12 were taken from Water Resource Activities in the United States, Print No. 21 of Select Committee on National Water Resources, U. S. Senate, 1960. Evapo-transpiration estimates made by the U. S. Geological Survey and The Nevada Department of Conservation and Natural Resources vary with vegetation density, but range from 4 to 6 inches. (5) (9) The differences between their estimates and those in Table 12 become apparent when the methods used by the Nevada Department of Conservation and the Geological Survey are compared with U. S. Senate Studies. Their studies in eastern Nevada did not consider total water yield, only the evapo-transpiration necessary to balance watershed runoff, with no allowance for contributions from ground water.

Table 12
ESTIMATED EVAPO-TRANSPIRATION FOR DESERT AREAS

Vegetation Type	Precipitation Range	Water Yield Range	Water Yield Ave.	Evapo-transpiration
Pinon-Juniper	10-20 inches	0-3	0.5	14.5 inches
Semiarid Grass and Shrubs	5-20 inches	0.1-1.0	-/4	10.6 inches

Source: Chow, V.T., Handbook of Applied Hydrology

6.5 Ground Water Recharge

Unconsolidated sediments must meet certain requirements with respect to underground storage and water balance in order that ground-water supplies can be developed. The following requirements are necessary for adequate underground storage, particularly in semiarid areas:

1) Sufficient permeable materials must be exposed in such a location that rainfall and runoff can percolate into the underlying aquifers
2) The aquifer formation must have enough pore space to store necessary amounts of water and contain enough water in storage to meet withdrawal demands and aquifer losses during long drought periods
3) The aquifer formations must have sufficient permeability to supply wells at adequate pumping rates
4) There must be enough watersheds available to provide recharge at an average rate equal to water supply requirements and aquifer losses.

The magnitude of a sustained water yield that can be developed from aquifers composed of unconsolidated sediments depends on these factors:

1) The rate that water can be infiltrated into the underground aquifers
2) The frequency of storms that will make this recharge source available
3) The stored water losses due to evapo-transpiration and aquifer leakage

4) The average rate of recharge, and its adequacy to meet water requirements and losses
5) The volume of storage in the aquifers and their adequacy to meet long-term requirements in periods of drought.

6.5.1 Infiltration Capacity

Ground water recharge occurs when rain or melting snow infiltrates into the soil profile. Water may infiltrate immediately from rainfall or it may flow into temporary storages and infiltrate later. Storage in the soil profile is large, but direct infiltration into the pore spaces occurs at relatively slow rates in most instances. Delayed infiltration may also occur as a result of temporary surface-water storage in depressions and soil fissures. The water in the depressions also has a greater opportunity to evaporate. A detailed discussion of infiltration appears in Appendix A.

Infiltration tests were not conducted during the reconnaissance study, but observations of rainfall infiltration supplemented with data from previous studies will be used to describe local conditions.

The Parker Desert Land Entry, located about one mile northeast of the junction of Highways 93 and 50 Alternate, sustained about 80 acres of oats under irrigation during the summer of 1966. The Parker well produced about 1000 gpm continuosly, or 4.44 acre-feet per day. The water was alternated between two 40 acre plots every other day. The applied water amounted to 1.33 inches over the 40 acres. Since none of the water was excess, the infiltration rate approximates 0.05 inches per hour. The soil is a sandy clay loam containing some gravel with little organic material.

A small watershed on Chinn Creek is located approximately 6 miles southeast of Kingsley Mountain. The watershed area is about 6.5 square miles and contains numerous springs which flow to a small reservoir approximately one acre in area. The reservoir is used to store water for diversion to four separate stock water reservoirs in Antelope Valley. During the summer and early fall months no livestock are in the area, and water is allowed to accumulate in the reservoir. The reservoir is located near the upper end of the alluvial fan where Chinn Creek flows into the valley. In late July 1966 the flow into the reservoir was estimated at 150 gpm. At that rate, the reservoir level remained nearly constant. Thus, about 0.67 acre-feet of water was supplied to the one-acre reservoir each day. If one assumes that the average evaporation during the summer months is equal to 15 inches or 0.17 inches per day for 90 days, about 0.5 feet of water is infiltrated into the silty sediments of the reservoir each day. The hydrostatic head would exert substantial influence on the infiltration rate; nevertheless, about 0.25 inches per hour enters the soil profile.

Stream gaging data are not available for streams in the study area; therefore, estimates of channel losses cannot be made. However, the U.S. Geological Survey conducted spot measurements of discharge from numerous streams flowing into Steptoe Valley. (4) The measurements were made in streams located on the western flank of the Shell Creek Range

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between Ely and Shellbourne, approximately 45 miles north of Ely. The majority of streams with measurable flow at the apex of the alluvial fans had no measurable flow within a distance of two miles downstream. Some of the waters were used for irrigation during the growing season, and much of the flow was absorbed in diversion ditches. Stream flow that did not percolate entirely into the streambed sediments was reduced at least 50 percent before reaching the valley floor.

The presence of highly permeable materials in the alluvial fans of the study area can be qualitatively verified by the absence of surface water reservoirs. Stream gradients are relatively steep, so that little storage can be obtained from reservoir construction, and soils are too permeable to hold water for more than a few days.

The lack of developed water courses in some areas also indicates either high infiltration rates or areas of infrequent precipitation. There are only a few runoff channels in the alluvial deposits on the east flank of the Kingsley Mountains. This may be due in part to the short distance from the ridge crests to the playa in Antelope Valley; however, the distance exceeds two miles in some locations and would be sufficient to contribute runoff for more extensive channel development if the sediments above the valley floor were not highly permeable.

Recent observations of rainfall and runoff patterns near the Kingsley Mountains indicate about 2 inches of rainfall is needed to supply the soil moisture storage in the surface layers of alluvium to initiate runoff. In a four-day period from July 30 to August 2, 1966, more than 2.50 inches of rainfall occurred as a result of thunderstorms accompanying a regional Pacific storm front. The sequence and amounts of rain are tabulated in Table 13.

Table 13

RAINFALL SEQUENCE, JULY 30 TO AUGUST 2, 1966

Date	Amount (inches)	Storm Length (hours)	Runoff Description
July 30	1.10	4	Impervious Areas
July 31	1.02	2	Small Streams and Depression Storage
August 1	0.50	2	All watercourses
August 2	0.16	1	Small Streams and Depression Storage
Total Rainfall	2.78		

Source: Geological Engineering Company

Although sufficient rainfall occurred during the 4 days to cause runoff in the major stream channels, at the end of the first two days it was sufficient to cause runoff only in the channel of Kingsley Wash. No measurable runoff occurred in the stream channel just south of the Kingsley Mountains until the third day. Runoff that occurred in the channel on the third day was insufficient to sustain flow for more than a few hundred feet before percolating into the streambed. The peak flow in Kingsley Wash was estimated between 3 and 5 cubic feet per second at the point where the stream crosses the access road near the south end of the Kingsleys. All of the flow percolated into the stream bed before reaching the access road at the north end of the mountains, a distance of 12 miles.

Infiltration rates for the various types of soils in the study area can be reasonably estimated. The playa areas will not infiltrate water at measurable rates. The valley areas above the playas will allow infiltration at rates between 0.01 and 0.10 inches per hour. The alluvial fans above the valley floor areas will allow water to infiltrate at rates between 0.10 and 0.50 inches per hour. Rates for the upper areas of the alluvial fans may exceed 0.50 inches per hour. The soil materials in these upper areas are primarily angular gravels eroded from the limestone country rock. The Agricultural Research Service in the Southwest Watershed Research Center at Tucson, Arizona, conducted experiments on small plots of gravelly soil similar to eastern Nevada; their results showed infiltration rates from 0.50 to 1.00 inches per hour.

6.5.2 Storm Frequency

The frequency of storms that can produce sufficient rainfall to recharge the water-bearing sediments is important to the sustained yield that can be developed. The intensity and duration of rainfall must be sufficient to supply depleted soil moisture storage, with a reserve for contribution to the ground water reservoir.

Hourly records of rainfall were studied for the U. S. Weather Bureau station at Elko, in order to determine the frequency of rainfall that would produce substantial contributions to ground-water recharge. The period studied was from January 1961 to April 1966. The values of rainfall were adjusted by the ratio of mean annual rainfall at Elko, 8.79 inches to the areal mean for the Kingsley Mountains of 13.00 inches. The values of rainfall recorded for Elko thus were multiplied by a factor of 1.50 to reflect intensities and totals expected in the study area. The results of the study of selected storms are listed in Table B-1 in Appendix B.

The data listed in Table B-1 were used to determine storms that had intensities that would satisfy infiltration rates for at least a portion of the total storm period. The tabulation also includes thunderstorms which occur. The thunderstorms listed for the Elko area would not necessarily occur in the study area, but similar storm activity exists in the study area with greater frequencies and higher intensities than those experienced in valley areas.

Sixty-one storms of various lengths have been tabulated. Of these, twenty-three had maximum intensities greater than 0.20 inches per hour, twelve had intensities greater than 0.30 inches per hour, and four had intensities greater than 0.50 inches per hour. There were at least six and perhaps eight storms that apparently resulted in substantial runoff. It can be concluded that at least twelve storms per year will have hourly rainfall intensities that will exceed infiltration rates in the valley alluvium; at least two storms will have intensities that will exceed the infiltration capacities of the more permeable upland sediments; and about one storm per year will have hourly intensities greater than 0.5 inches per hour, resulting in substantial runoff in the major watercourses.

6.5.3 Annual Recharge and Recoverable Water

With the limited information available, estimates of ground-water recharge were made for the study area. These estimates, based on mean annual rainfall and estimated evapo-transpiration rates from Table 12 were used to compute a simple water balance for the area.

In making water balance studies, the inflow to a watershed must equal outflow; i.e., rainfall must be balanced by evapo-transpiration, streamflow out of the watershed, and water losses. In the study area, streamflow does not convey runoff from the watershed, thus rainfall must be balanced by consumptive use, direct evaporation and aquifer losses. Consumptive use would include soil water evaporation and transpiration by native vegetation. Table 14 contains a simple water balance study with estimated total recharge for the southern portion of Goshute Valley--Northern Antelope Valley, and the portion of Steptoe Valley included in the study area.

Table 14

WATER BALANCE ESTIMATES FOR THE KINGSLEY MOUNTAIN STUDY AREA

Area Description And Size (acres)	Mean Annual Rainfall (inches)	Mean Annual Evapo-transpiration (inches)	Annual Recharge
Southern Goshute--Northern Antelope Valleys--275,814	12.90	11.40	1.50
Steptoe Valley--	14.26	12.19	2.07

Source: Geological Engineering Company

The first two columns are taken from Table 11. Mean annual evapo-transpiration was computed using the values from Table 12 and assuming the watershed area above elevation 6500 is covered with Pinon-Juniper type vegetation, and vegetation below that elevation is the semiarid desert shrubs and grass. This assumption is not entirely correct, since some desert shrub vegetation is present in the higher elevations, and the Pinon-Juniper extends below elevation 6500 in some locations. Nevertheless, the division of potential evapo-transpiration at 6500 feet is consistent with mean annual rainfall changes with elevation and expected increases in water yield with increases in rainfall.

Recharge values computed for the two areas must be further refined in order to determine net recharge to ground water and to estimate potential ground water that can be developed without "mining" water in storage within the aquifers. Table 15 lists estimated aquifer losses assuming fifty percent of recharge is direct evaporation from rainfall and runoff that accumulates in the valley floor areas, as well as aquifer loss due to ground water movement out of Antelope and Steptoe Valleys. Of the remaining recharge, fifty percent is assumed to be economically recoverable for economic use.

Table 15

ESTIMATED AQUIFER LOSSES AND RECOVERABLE WATER

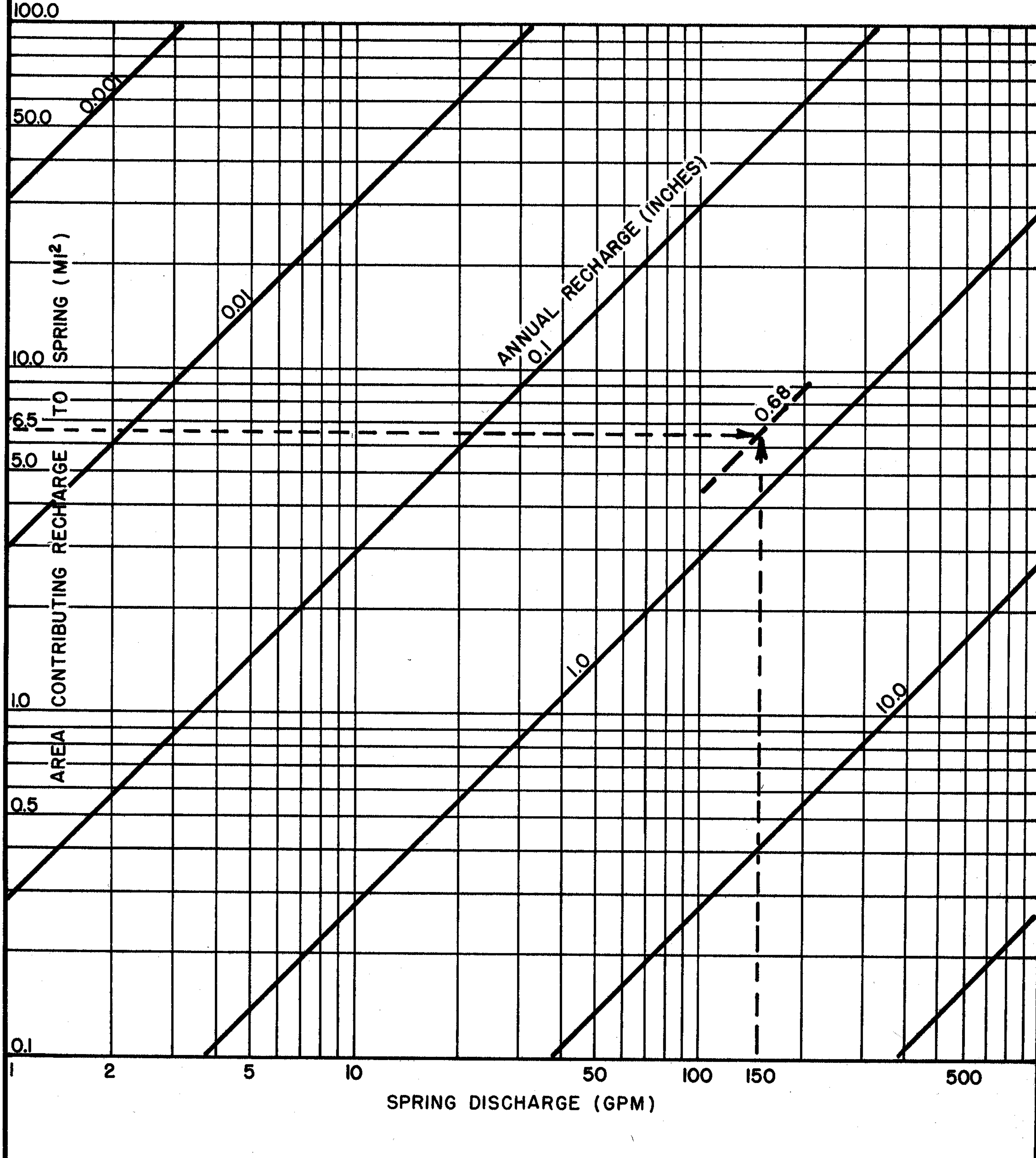
Area Description	Aquifer Recharge Inches	Acre-Feet	Aquifer Losses (acre-feet)	Net Recoverable Water (acre-feet)
Southern Goshute Northern Antelope Valleys	1.50	34,500	17,250	8,630
Steptoe Valley	2.07	15,700	7,850	3,930

Source: Geological Engineering Company

A qualitative check was made of the water-balance study using data from the Chinn Creek Watershed. In July 1966 the flow was estimated at 150 gpm, and the watershed area is approximately 6.5 square miles or 4200 acres. With these values, annual recharge can be estimated using a graphical relation suggested by Davis and De Wiest. (3) This relation shown as Figure 8 results in an annual recharge of 0.68 inches. A number of springs in the watershed area combined to make up the measured flow. Some of the flow percolates into the stream channel before reaching the reservoir, and numerous springs in the watershed do not contribute flow to the reservoir. Total recharge in the watershed is greater than the estimated amount. During the first eight months of 1966, rainfall in eastern Nevada was 37 percent of normal; thus, recharge on an annual basis would be expected to exceed 0.68/0.37 or 1.80 inches approximately. This value compares favorably with the 2.07 inches of total recharge for the Steptoe Valley area and is a conservative estimate when consideration is given to the fact that only three percent of the Chinn Creek watershed is less than 6500 feet in elevation, and mean annual rainfall on the watershed is greater than 19 inches.

FIGURE 8

SPRING DISCHARGE, WATERSHED AREA, ANNUAL RECHARGE RELATION



SOURCE: HYDROLOGY, S.N. DAVIS AND R.J.M. DE WIEST

The net recoverable water for the two listed in Table 15 can be converted to common consumption terms. Average daily demand for domestic water approaches 200 gallons per capita per day (gpcd), and an average figure of 4 acre-feet per acre is common for irrigated agricultural crops. Thus, 8630 acre-feet of recoverable water in the Antelope Valley area would be sufficient for irrigating 2150 acres, or supplying the demands of 36,000 people. The 3930 acre-feet of recoverable water in Steptoe Valley would irrigate 900 acres of land, or supply a community of 15,000 people, in addition to the estimated 200 gpm needed at the proposed mill site of Western Marble. It should be kept in mind that the study area includes only portions of Antelope and Steptoe Valleys.

6.5.4 Aquifer Storage

The portions of the study area in Antelope Valley comprised of valley alluvium is approximately 140,000 acres; with an average specific yield (see Appendix A for definition) of ten percent for the alluvium, the ground water reservoir would yield 14,000 acre-feet for each foot the water table would be lowered. The uniform lowering of the water table is not possible by using pumped wells, but the estimate indicates a large volume of water is available as storage in the valley sediments. Thus, an adequate supply is available for economic development during drought periods, and for periods of short duration when high pumping rates may be necessary. This analysis would also hold true for Steptoe Valley, where the valley sediments are more extensive than in Antelope Valley.

The yield of ground water is limited by the average annual recharge only a portion of which can be recovered practicably and economically. Overwithdrawals would result in "mining" of water. It should be pointed out that the foregoing analyses are estimates at best, and actual quantities of ground water available for development can be determined only after a number of years of withdrawal records and water level measurements from wells producing water from the aquifers.

The foregoing discussion of aquifer storage refers primarily to the extensive valley sediments where the carry-over storage is sufficient to allow for protracted periods of drought. Groundwater yield from small watersheds such as Chinn Creek and other small drainages requires a different approach to determine available supplies.

The small watershed just south of the Kingsley Mountains which contains Kingsley Spring covers an area of 3.5 square miles. The average annual rainfall on the watershed is estimated at 13.00 inches, and mean annual runoff is about 1.50 inches. The stream channel sediments to the east of Kingsley Spring are believed to contain enough water for initial quarry operations and domestic consumption. If an average annual recharge of 1.50 inches is assumed, according to the analyses described in Section 6.5.3, about 25 percent of the recharge can be economically developed. Thus, average net recoverable water would approximate 70 acre-feet per year. Storage carry-over is probably one year for this and similar small watersheds between the Kingsley Mountains and the Chinn Creek watershed. That is, sufficient rainfall occurs in the upper portions of the watersheds to recharge, on an annual basis, the shallow stream sediments above the point where the streams debouch onto the valley alluvium.

The regional ground water tables in Steptoe, Antelope and Goshute Valleys are relatively flat. Eakin (5) states that the water tables are flat due to relatively small amounts of annual recharge. Ground-water gradients of 6.5 feet per mile in Antelope Valley and 4 feet per mile in Steptoe Valley near Lage's Station do indicate recharge is limited; however, the high permeabilities of the upper areas of the alluvial fans allow the infiltration of water at rates sufficiently rapid to preclude steep gradients. In many of the vally sediments ground water is found perched above silt and clay layers near the surface. Many dug wells have encountered water at shallow depths. These saturated sediments are rarely extensive, and may of the dug wells are dry during prolonged droughts.

Section 7

OCCURRENCES OF SURFACE WATER

Ordinarily, surface-water sources consist of perennial streams, intermittent streams, lakes, and springs. In the study area, no perennial streams or lakes exist. Intermittent streams flow only after intense rainfall or during the spring snowmelt. Numerous small springs in the study area are used for stock water purposes.

7.1 Potential Surface Water Development

The potential for surface-water development on sustained economic basis is nearly nonexistent in the area surrounding the Kingsley Mountains. There are no perennial streams which could be developed using reservoirs or off-channel storage. The lack of adequate surface water sources is due to two reasons. First, the semiarid climate with nearly uniform precipitation throughout the year precludes a definite wet season when sufficient surface water would be available. Second, the alluvium in the valley areas and the upland sediments are sufficiently permeable that reservoirs would not be capable of water storage for more than a few days without large expenditures for sealing.

Of the five exisintg reservoirs in the study area, four of them located in Antelope Valley are used for stock water purposes. The fifth, a holding reservoir on Chinn Creek, is used to divert water to the other four. Without temporary diversion and storage, the reservoirs in Antelope Valley would contain water only infrequently when rainfall is of sufficient intensity and duration to initiate substantial runoff. The reservoirs, constructed in the soils of ancient lake beds, retain water for short periods until it is evaporated. Many of the lake playas are saline, which causes waters collected there to be unfit for other than stock water purposes.

7.2 Potential Use of Springs

Springs occuring in the valleys of eastern Nevada are the result of ground-water recharge in the soil mantle above the spring outlet. Most of the springs in the vicinity of the Kingsley Mountains occur at the contact between carbonate rocks and overlying volcanics. The volcanics are permeable due to fracturing, while the carbonates are relatively impermeable forming a barrier to the downward percolation of water. Percolating water flows along the contact until reaching a surface outlet. Four such springs occur near the Kingsley Mountains. They are listed with pertinent data in Table 16.

Table 16

PERENNIAL SPRINGS NEAR THE KINGSLEY MOUNTAINS

Name	Location	Estimated Flow (gpm)	Magnitude[1/]
Kingsley	NW1/4 Sec 24 T26N, R67E	1	Sixth
Chinn Creek[2/]	Secs 23, 24, 26 27 T25N, R67E	150	Fourth
Lookout	Sec 29 T26N, R67E	30	Fifth
Boone	Sec 29 T27N, R67E	5-10	Sixth

1/ For a definition of Magnitude, see Appendix A.

2/ Chinn creek is fed by numerous small springs. The estimated flow is the combined flow of a number of these springs at a point located above the reservoir.

Source: Geological Engineering Company

Numerous small springs exist in the vicinity of the Kingsley Mountains, but their discharge is insufficient for other than stock water, and their locations are widely scattered such that their development would be uneconomical. Kingsley Spring is less than one mile from the quarry site of Western Marble, and is the only spring that could provide water for operation. The flow rate is insufficient for uses other than on an interim domestic basis, even though one half of the water right is reserved for mining purposes. The appropriation of water from Chinn Creek, Lookout, or Boone Springs would be uneconomical. Flow rates are too small to justify construction of a 6-mile pipe line and associated pumping facilities. The legal problems associated with the purchase of water rights on Chinn Creek would also involve purchasing the rights to the reservoirs in Antelope Valley.

7.3 Surface-Water Quality

The quality of water from springs in the area is adequate for domestic and mining purposes. None of the water is acceptable for boiler feed water without treatment. Water quality analyses are listed in Table B-2, Appendix B, which show comparisons with well waters in the area. Water quality recommendations for domestic and agricultural purposes are included in Table B-2. The spring waters are rather consistent in mineral constituents, except for Kingsley Spring which contains nearly double the constituents of other waters sampled. No previous records of water samples from local springs were found, except Collar And Elbow Springs in Steptoe Valley which was tested in 1918. (4) Table B-3 Appendix B lists general descriptive data pertaining to the analysed water samples.

Section 8

OCCURRENCES OF GROUND WATER

In semiarid areas such as northeastern Nevada, ground water occurs in the zone of saturation below the water table in the valley alluvium. The valley alluvium consists of nonindurated sediments which, by definition, are unconsolidated sediments.[1/] The search for ground water in the study area led to exploration of these sediments because of the lack of surface-water sources. Much of the effort expended during the course of the study has been a search for ground-water data pertaining to the valleys of northeastern Nevada.

There are a number of reasons for ground-water exploration in unconsolidated sediments:

1) The deposits are relatively easy to drill, so that exploration can proceed relatively fast
2) The deposits are primarily found in valleys where ground water is relatively near the surface so pumping lifts are not extreme
3) The deposits are usually in favorable locations for recharge from precipitation, streams and lakes
4) The deposits have higher specific yields than other native materials
5) Permeabilities are higher than other materials except highly fractured volcanics and cavernous limestone.

Figure 9 is a simplified sketch typifying the hydrogeology of desert ground water basins. The features are typical of sediment formations found in Steptoe, Goshute and Antelope Valleys.

8.1 Potential Ground Water Development

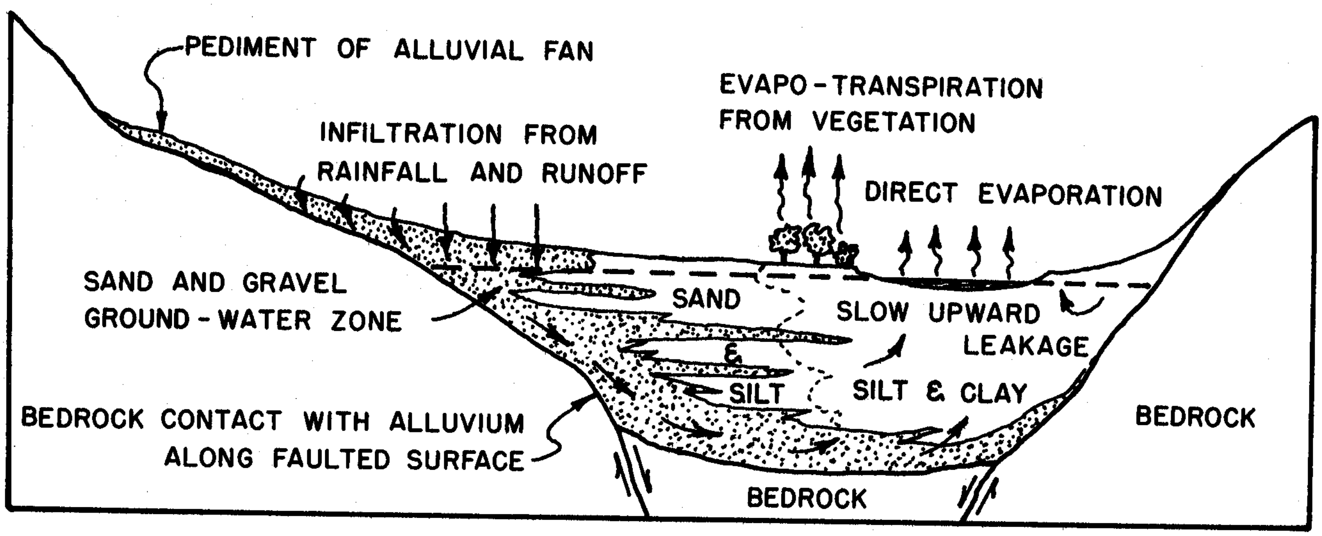
Ground water occurs in unconsolidated formations under two distinctly defined conditions. These conditions are significant to development of supplies for Western Marble, Ltd. First, water that is in direct contact vertically with the atmosphere through the pore spaces in overlying sediments is classified as unconfined water. This condition often is referred to as a water-table aquifer formation. The second condition is confined water which is separated from the atmosphere by an impermeable formation. The formation may be a saturated clay or silt layer or a semiconsolidated material. The division between confined and unconfined water is not distinct, and often the term semiconfined is used for intermediate conditions.

A well that taps a confined aquifer where the static water level rises above the bottom of the confining layer is called an artesian well. Flow from a well penetrating confined or artesian aquifers is called artesian flow. Artesian flow rarely occurs in the valleys of eastern Nevada.

1/ A description of terms used in this section is located in Appendix A.

FIGURE 9

HYDROGEOLOGY OF DESERT GROUND WATER BASINS



DASHED LINE INDICATES THE ELEVATION AT WHICH WATER WOULD OCCUR IN DRILLED WELLS (THE WATERTABLE)

SOURCE: HYDROLOGY, DAVIS AND DE WIEST, MODIFIED BY GEOLOGICAL ENGINEERING COMPANY

In the valley areas adjacent to the Kingsley Mountains aquifers are primarily unconfined, although some wells penetrate confined formations. Most of the dug wells in Steptoe and Goshute Valleys penetrate unconfined formations, and many in shallow water-table formations do not provide water supplies through drought periods.

Drilled wells usually pass through the unconfined layers and penetrate semiconfined or confined formations. In eastern Nevadan valleys few wells drilled in the unconsolidated sediments are producing water from confined aquifers. Most are semiconfined, and hydrostatic pressure causes water levels to rise a few feet above the confining formation.

The most promising source of water for developing a broad-based economy would be from deep wells. The underground aquifers in Goshute, Antelope, and Steptoe Valleys are known to be extensive, and the sediments extend to considerable depths. (5) (4) In many areas water has been obtained from deep wells for agricultural development, stock water, and domestic purposes. Primary difficulties occur in some areas due to saline conditions and to locating wells in alluvial deposits that are sufficiently permeable to develop supplies greater than minimum requirements for stock or domestic purposes. The alluvial deposits will yield the greatest supplies since they are more permeable. Lake sediments are composed of fine silts and clays which do not readily yield water to wells.

In searching areas for ground-water development, playa areas or other slack-water locations should be avoided. The playas are primarily silt and clay deposits with low permeabilities. Efforts should be centered nearer recharge sources where greater thicknesses of the more permeable materials occur.

8.2 Inventory of Existing Wells

A tabulation of records for selected wells in Goshute, Antelope, and Steptoe Valleys is listed in Table B-4, Appendix B. The majority of the wells listed in Table B-4 are used for stock water purposes and are small in diameter. Data from well logs and other information were used to draft a map of expected depths to the regional water table in portions of the study area. The map is shown as Figure 10. The contours of depth to the water table shown on Figure 10 are inferred and estimated from available data. Insufficient data were available to determine water-table depths with any accuracy, and the contour information should be used with caution.

Logs of selected wells from Table B-4 are tabulated in Table B-5, Appendix B, and includes logs for wells in other areas which were used for comparative purposes. In general the logs listed in Table B-5 are poor. The descriptive data concerning the formations encountered during drilling operations are so poorly described, that water-bearing formations are not readily determined.

Information from two wells in Steptoe Valley was used to determine water-bearing characteristics of sediments, as a guide to expected conditions for future drilling. The two wells, Parker Well (25/65-4D) and U.S. Geological Survey Well (19/63-12A) are described below in Secs 8.2.1 and 8.2.2. For the Parker Well, the number 25 indicates Township 25 North, the number 65 indicates Range 65 East, the number 4 indicates Section 4 in the Township, and the letter D indicates the Southwest Quarter of Section 4. The letters A, B, C, and C, refer to the Northeast, Northwest, Southwest and Southeast Quarters, respectively, of the section.

8.2.1 Parker Well

The Parker Well was drilled in 1965 for irrigating a Desert Land Entry near Lage's Station. The well is 284 feet deep, with a 16-inch-diameter casing for its total depth, perforated from 65 to 284 feet. The well was test pumped for a short period in November 1965, with the flow rates and drawdown listed in Table 17.

Table 17

CAPACITY-DRAWDOWN DATA FOR PARKER WELL (25/65-4D)

Flow Rate (gpm)	Water Level Distance Below Top of Casing (feet)
825	130
1065	162
1352	205
1600	245
1640	263

Source: Mr. Parker

The first water-bearing formation was located 65 feet below the surface and had a thickness of 5 feet. The major water-bearing formation was 30 feet thick, located between 250 and 280 feet below the surface. The standing water level in the well when completed was 50 feet below the surface indicating a confined or semiconfined aquifer formation. Calculations[1/] indicated that the major aquifer is a fine sand. This conclusion was qualitatively supported when the well discharge produced fine sand during the 1966 irrigation season.

8.2.2 U.S. Geological Survey Well

Three test wells were drilled by the Geological Survey in the vicinity of Duck Creek in Steptoe Valley in 1918. (4) The wells were the first major effort by a public agency to determine the irrigation potential in Steptoe Valley.

1/ See Appendix C.

The deepest well (19/63-12A) was drilled 916 feet into the sediments of Steptoe Valley. The well was cased to 181 feet with a 12-inch casing, and from 181 to 540 feet with 8-inch casing. The aggregate yield of water-bearing sediments was reported to be 250 to 300 gallons per minute. The log for the well is tabulated in Table B-5, Appendix B, and is a fine example of well logging.

A record was made of each formation as it was penetrated, and the water level in the well was recorded for each water-bearing stratum as the drilling progressed. Some interesting conclusions drawn from the well log data can be applied to future drilling operations:

1) Water-bearing formations were encountered at numerous locations
2) Water-bearing formations were a small portion of the total sediments penetrated
3) There appeared to be no measurable water obtained from the sediments below 500 feet
4) Clay layers constituted the majority of the sediments and were as much as 138-feet thick
5) The sediments became more consolidated with depth
6) Water quality was similar to samples tested from springs and wells in the Kingsley Mountain study area.

In general, the first water encountered in well drilling in eastern Nevada is unconfined or at water-table conditions. As wells are drilled deeper and penetrate sediments at greater depths, semiconfined or confined water is encountered, and the depth to water measured from the surface is less than at water-table conditions.

8.3 Ground-Water Quality

Five samples were taken from wells in Steptoe and Antelope Valleys and water-quality evaluations were made. The results are listed in Table B-2 together with spring water sample results discussed in Sec. 7.3. Of the samples, two were dipped from unfinished irrigation wells, one from an unused, recently completed irrigation well, one from a stock-water well, and one from Parker's well. Mineral constituents are fairly consistent for all well water samples. It is interesting to note that the sample from the recently finished irrigation well (25/65-8A) has mineral constituents in similar quantities to the sample taken from Collar and Elbow Spring. The temperature is warmer by a minimum of 11°F than the other well samples, including the Parker Well nearby, indicating the well water may be from the same source that supplies the spring.

The water quality of wells in Steptoe, Goshute, and Antelope Valleys is adequate for domestic , irrigation, and many industrial purposes. Treatment would be necessary for use as boiler feed water. The majority of wells are drilled in the alluvium near the valley margins, with the remainder adjacent to but not within the silty clays of of the playas. The playas are often underlain with saline waters near the surface. Wells drilled to depths below the water table in playa areas may encounter water of a quality comparable to well water from the valley margins.

Section 9

WATER RIGHTS

Water rights in the study area are open for application except for existing springs whose rights have long since been appropriated. Under Nevada State Law, water rights do not become final until proof of beneficial use is shown.

Application Procedures

Complete details of requirements for filing water rights applications in Nevada can be found in Chapter 533 of the Nevada Water Laws. Major considerations are listed below.

1) All unappropriated waters in Nevada, both surface and underground, are considered public waters. Applications for their use must be submitted to the State Engineer.

2) Applications are limited to waters of one source for one purpose, but individual domestic use may be included in any application.

3) Applications must be submitted with specified information, including maps showing point of appropriation and use.

4) Applications must be accompanied by a deposit of $25 to cover cost of publishing a notice of filing. Publication will take place within 30 days of receipt of application.

5) The State Engineer will either approve or reject an application within one year except for duly authorized postponement.

6) The approval of applications will be accompanied by beginning and completion dates, times of construction, and complete applications of water for beneficial use.

   a) Time allowed for beginning of construction shall be not more than one year.

   b) Time allowed for completion of construction shall be not more than five years.

   c) Time allowed for proof of beneficial use shall be not more than ten years.

7) Additional requirements for contents of applications to appropriate water for certain specific uses:

   a) Irrigation---Number of acres to be irrigated and description by legal subdivision

b) Domestic Use--- The appropriate number of persons to be served and approximate future requirements

c) Mining---The proposed method of applying and utilizing the water.

8) All maps, surveys, and measurements of water required under Chapter 533 shall be made by a licensed State Water Rights Surveyor. Any corporation, association, the United States, the State, and any person may apply to appropriate water.

APPENDIX A

GEOLOGY AND GROUND-WATER MOVEMENT

REGIONAL GEOLOGIC SETTING

The general geologic features of the Kingsley Mountains and adjacent valley areas are a major influence on the storage and movement of both surface and ground water in the study area.

Eastern Nevada is located in the Basin and Range Physiographic Provinee. Mountains are generally North-South trending and probably were blocked out by high-angle faults. Valleys are formed by alluvium-filled depressions created by down-dropped blocks. According to Fenneman (1931) the distinctive features of the provice are "Isolated nearly parallel mountain ranges (commonly fault blocks) and intervening plains made in the main of subserial deposits of waste from the mountains. These deposits, although locally absent, are often very deep and are generally unconsolidated."

Paleozoic Sediments (PUD)

Paleozoic sediments (see geologic map, Figure 4) in the area of this report consist predominantly of carbonates with minor sandstones and shales. Fossil age determinations by the author indicate that the limestone and dolomite of the Kingsley Mountains is Middle Cambrian north of Kingsley Cañyon and Middle Permian to the South. Carbonate outcrops northeast of the Kingsley mountains in the Goshute Range are of Carboniferous age. The age of the limestone outcrop 5 miles west of the Kingsley Mountains was not determined because of the lack of identifiable fossils.

Subsurface drainage probably would be controlled mainly by the attitude of the bedding in the Paleozoic sediments. Fracturing may play a minor role, but since no preferred orientation of fractures is apparent, the overall effect can be considered negligible.

Mesozoic Intrusives (Mi)

Quartz monzonite stocks were intruded into the carbonates of the Kingsley Mountains and White Horse Mountains located about 20 miles to the Northeast, probably during the Cretaceous period. In some areas, such as the south and southeast contact to the Kingsley Pluton, the country rock has been contact metamorphosed to a marble. Almandine and grossularite garnet (a metamorphic mineral) appear as manifestations of the reaction of the quartz monzonite with the wall rock in some areas, particularly near the west margin of the Kingsley Pluton and northeast margin of the White Horse Pluton.

The quartz monzonite is less resistant to erosion than the carbonates in an arid climate, and therefore is topographically lower (has eroded more). Apart from this physiographic effect on runoff, the intrusive areas would exert little control over ground water. There is a possibility, however, that the White Horse Pluton may extend a small distance west of its outcrop, resticting ground-water movement to the north on that side of

Antelope Valley. If this is the case, water movement below the surface would be at a higher velocity closer to the north end of the Kingsley Mountains than in the west margin of the White Horse Mountains (see Figure A-1).

Tertiary Volcanics (Tv)

Volcanic outporings ranging in depth to several thousand feet were accumulated during the Tertiary period and, as indicated by the continuous sequence formed by the various flows, were deposited in a narrow geologic time range.

The lithology of the volcanic intrusives consists mainly of dark brown-colored rhyolite and quartz lattice flows resting on a buff-colored tuffite. Minor sills or surface flows of obsidian also were observed in several areas.

Due to block faulting and regional tilting, the volcanic beds dip to the east at an attitude of between 15 and 25 degrees. This structure probably has no effect on the subsurface drainage because of the imperviousness of the volcanic rock. Several springs occur where the impermeable volcanic rock impedes the sub-surface water flow and thereby forces water to the surface.

Quaternary Alluvial Deposits

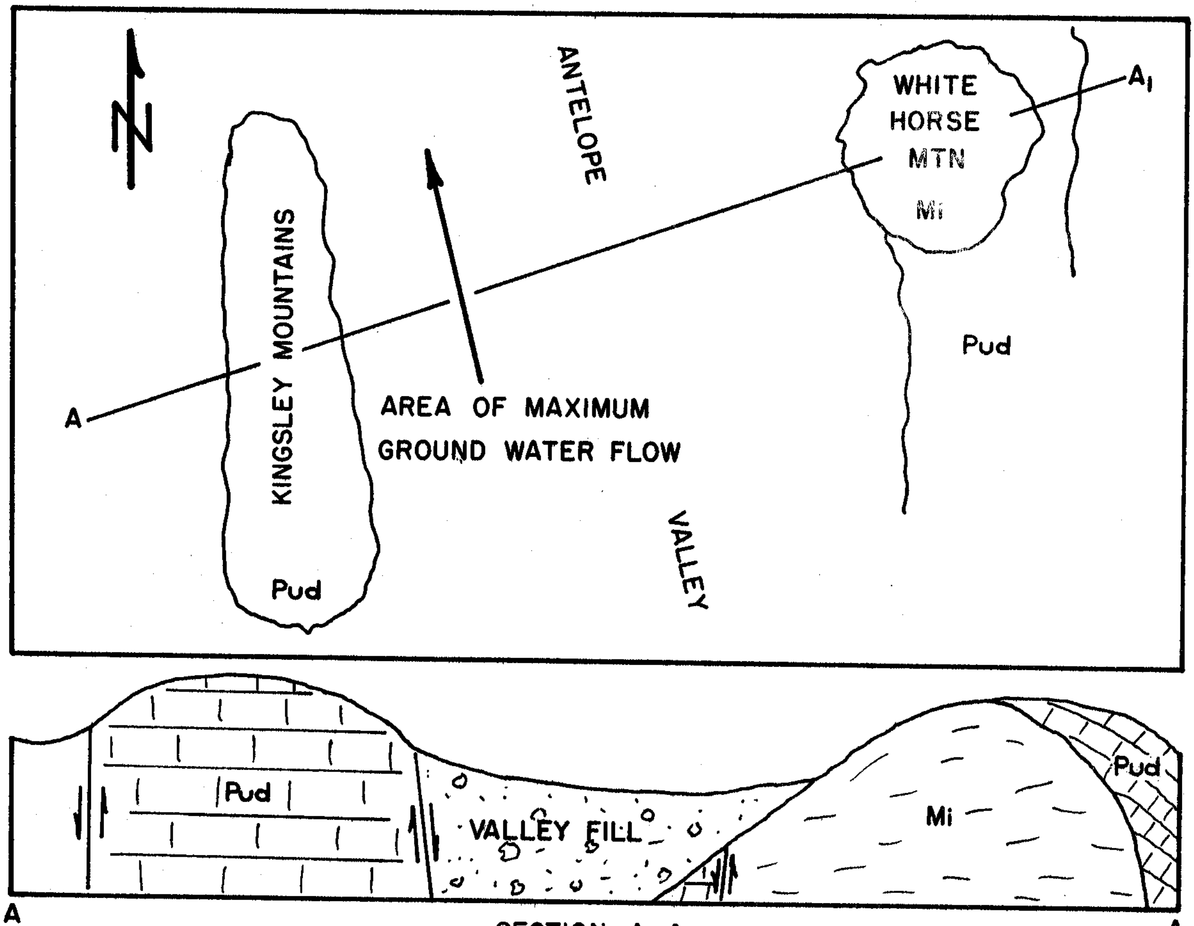
Quaternary alluvium in the area was mapped as several units which were categorized according to their individual physical properties that have a bearing on the hydrology (see Section 6.5.1). It is important to note that running water is the primary geologic agent of transportation and, as such, exerts the controlling factor over the characteristics of a particular alluvial deposit. Distance of transportation gradient, degree of weathering and the competency of the individual stream provide the modifying factors. Further modification of the hydrological properties of the deeper alluvial deposits, is the degree of compaction and cementation with burial and time.

Quaternary Alluvium (Qal) includes stream alluvium, talus (gravity deposited debris) and residual alluvium which has accumulated over a large area. It is obvious then, that one would find QAL in stream channels, at the foot of steep slopes, and a residual veneer overlying rocks disintegrating in place.

The physical properties of the unit mapped as "Qual" are therefore heterogenous in nature. However, this classification of sediments can be expected to offer an unimpeded channel way and reservoir to ground water and with the exception of the infrequent intervals when water flows at the surface, transmits most of the ground water to the low-lying basins. During the rare instances when water is running down the stream channels and gullys, sediments are transported by the water as a suspended load and by streambed movement. Where a stream descending a steep slope debouches from

FIGURE A-1

GROUND-WATER MOVEMENT IN ANTELOPE VALLEY



SECTION A-A1

Pud = UNDIFFERENTIATED PALEOZOICS
Mi = MARBLE INTRUSIVES

SOURCE: GEOLOGICAL ENGINEERING COMPANY

the mountains on to a plain or wide valley, its velocity decreases, and a large part of the sediment load is deposited and spreads out, forming a fan-shaped deposit (alluvial fan).

Quaternary Alluvial Fans (Qaf) are the cone-shaped stream-deposited alluvium that has formed at the base of elevated areas. As the deposit accumulates, its thickness becomes greatest at the mouth of the ravine or gully through which the stream flows. In general, coarser material is deposited at the apex of the fan, and finer material with increasing distance.

The clast (individual particle) size of alluvial fan material varies from boulder to sand size, and is typically both unsorted and unstratified. The heterogenous nature of the alluvial fans is not a detriment to the passage of ground water.

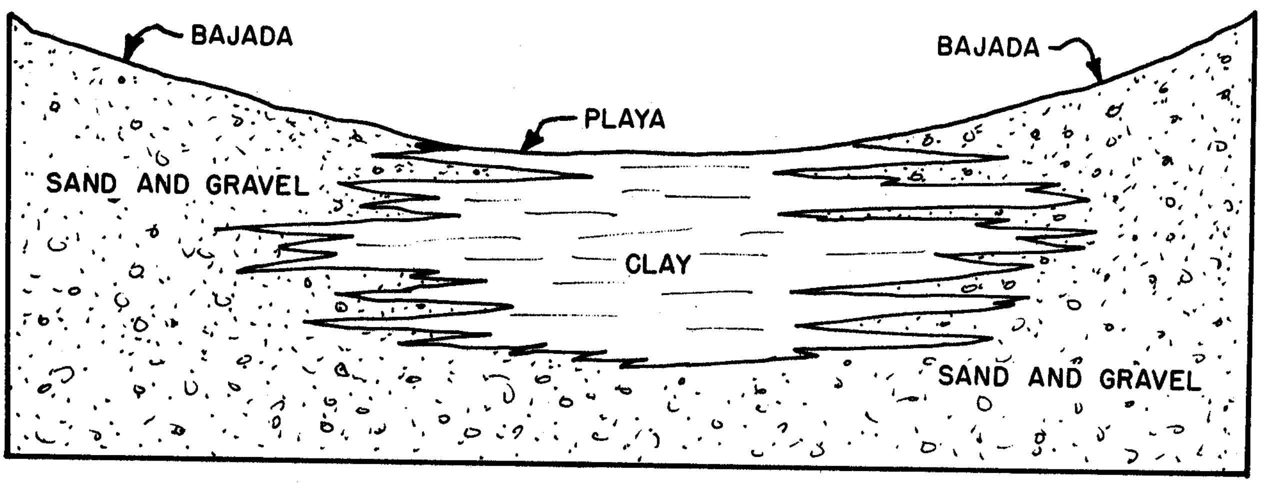
Quaternary bajada, (Qb) or piedmont slope, forms where streams discharge near each other on the same plain, and their alluvial fans coalesce and form a continuous sheet of aggraded sediments. As one would expect, the physical characteristics of this unit are similar to the alluvial fans but important differences do exist.

Clasts are smaller, better sorted, and also are more likely to be stratified. Depth of alluvium is also greater--up to several thousand feet. Because of these factors, Quaternary bajada may be expected to form the major reservoir of ground water in the area.

The environment of deposition of the bajada overlaps onto the Quaternary playa (Qp), the sediments of which are comprised mainly of clays and fine silts. Therefore, it is reasonable to expect that with depth, the contact between bajada and playa sediments will interfinger with one another (see Figure A-2). A drill hole located between the two units may encounter both the water-bearing sand and gravels of the bajada, and the impervious clay of the playa.

FIGURE A-2

INTERFINGERING OF VALLEY SEDIMENTS



SOURCE: GEOLOGICAL ENGINEERING COMPANY

GEOLOGIC HISTORY

The geologic features of the Kingsley Mountains are a major influence on the storage and movement of water. However, a reconstruction of the geologic processes in their historical sequence can better describe the effects on the hydrology.

Although no sediments older than the Middle Cambrian Age are exposed in the area of this report, it is known that this region of Nevada is underlain by metasediments (memamorphosed sedimentary rocks) and igneous rocks of the Pre-Cambrian era that are over one billion years old (Eardley, 1961). These first sediments that were deposited from an ocean devoid of recognizable life have undergone a history so complex that in all probability the sequence of events that formed them will not be interpreted for many years to come.

For several hundred million years, the region was above sea level undergoing an erosional cycle that left no record--a hiatus in the early history. When once again the ocean encroached on the land, it deposited great thicknesses of sediments in the basin areas and life flourished. Fossilized remains of these primitive Cambrian organisms, such as the trilobite genus Elrathia sp., can be found in the limestone of the Kingsley Mountains. Throughout the Paleozoic Era this region of the western United States subsided slowly in an elongated north-south trending trough accumulating a thick blanket of sediments.. Humphrey (1960) has determined that the White Pine District of Nevada received a total accumulation exceeding 18,000 feet in depth. The lithology of these Paleozoic rocks, which are predominantly shale, limestone and dolomite, indicates that the continental platform to the east was some distance away and of low relief.

At a later time, probably during the Cretaceous Age of the Mesozoic Era, the Paleozoic sediments were intruded by plutons (large igneous masses) composed of quartz monzonite. In the proximity of these stocks, (Kingsley and White Horse Plutons) carbonates were mineralized and contact metamorphosed to marble. Minor folding, fracturing and faulting also occurred in the country rock adjacent to the plutons as a result of the intrusion. The lack of marine Mesozoic sediments indicates that the area was above sea level, undergoing erosion at this time.

The next major event that occurred in the geologic history was the volcanic extrusions and associated ejectamenta of early (?) Tertiary Period. (5) These lava and tuffite beds are now exposed over a wide area, particularly to the west and south of Kingsley Mountain. The regional dip of the flows towards the east suggests that the area has been tilted in that direction along a north-south axis.

Later, toward the close of the Tertiary Period, north-south trending block faulting created the basin and range physiography that exists at present. Vertical displacement of the faults has been several thousand feet, resulting in a thick accumulation of eroded debris in the down-dropped valleys. Some of the valley fill was deposited when the low-lying areas were occupied by Pleistocene lakes, and is composed of clays and silts. These fine elastic materials grade laterally into fluvial gravels and sand, and finally into the boulder-sized detritus of the alluvial fans bordering the upthrust mountain blocks.

Finally, dessication of the most recent lakes resulted in a thin veneer of alkali-saline clays on the playa areas. As the lakes receded, they exposed wave-cut beaches and shingle beaches. One of these old Pleistocene beaches can be seen striking northwest from Kingsley Mountain to Highway 50 Alternate in Antelope Valley.

GROUND-WATER MOVEMENT

Introduction

Ground water is the subsurface portion of water movement in the hydrologic cycle. Under the soil surface, all gradations exist from freely flowing water to water firmly attached in the crystal structure of rocks.

Subsurface water is usually divided into several more or less distinct categories. Figure A-3 describes one of the suggested classifications of subsurface ground waters. (3)

The soil-water zone of Figure A-3 can be distinguished from water in deeper zones only by the wide variations in quantity and quality of water, due to evaporation and transpiration. The volume of water in the upper few inches varies with temperature, vapor pressure, radiation and resultant condensation of dew, and circulation of capillary moisture to the surface.

The intermediate zone is called suspended, gravitational or vadose water which, by definition, is water in downward motion under the influence of gravity. This zone may be nonexistent in moist environments, or many hundred feet thick in arid climates. In arid regions, recharge rainfall rarely is sufficient to exceed the storage capacity of the zone.

The capillary zone is a transition between the intermediate zone, and the ground-water reservoir. The transition to the capillary zone is abrupt in coarse-grained sediments, and very gradual in silts and clays. The surface of the capillary fringe varies constantly with changes in water levels due to recharge or ground-water draft.

The ground-water zone or phreatic water zone is divided from the capillary fringe by the water table. It is a theoretical surface which is approximated by the standing water level in wells which penetrate the saturated zone a short distance. An exact definition would be the surface in unconfined material where the hydrostatic pressure would equal atmospheric pressure.

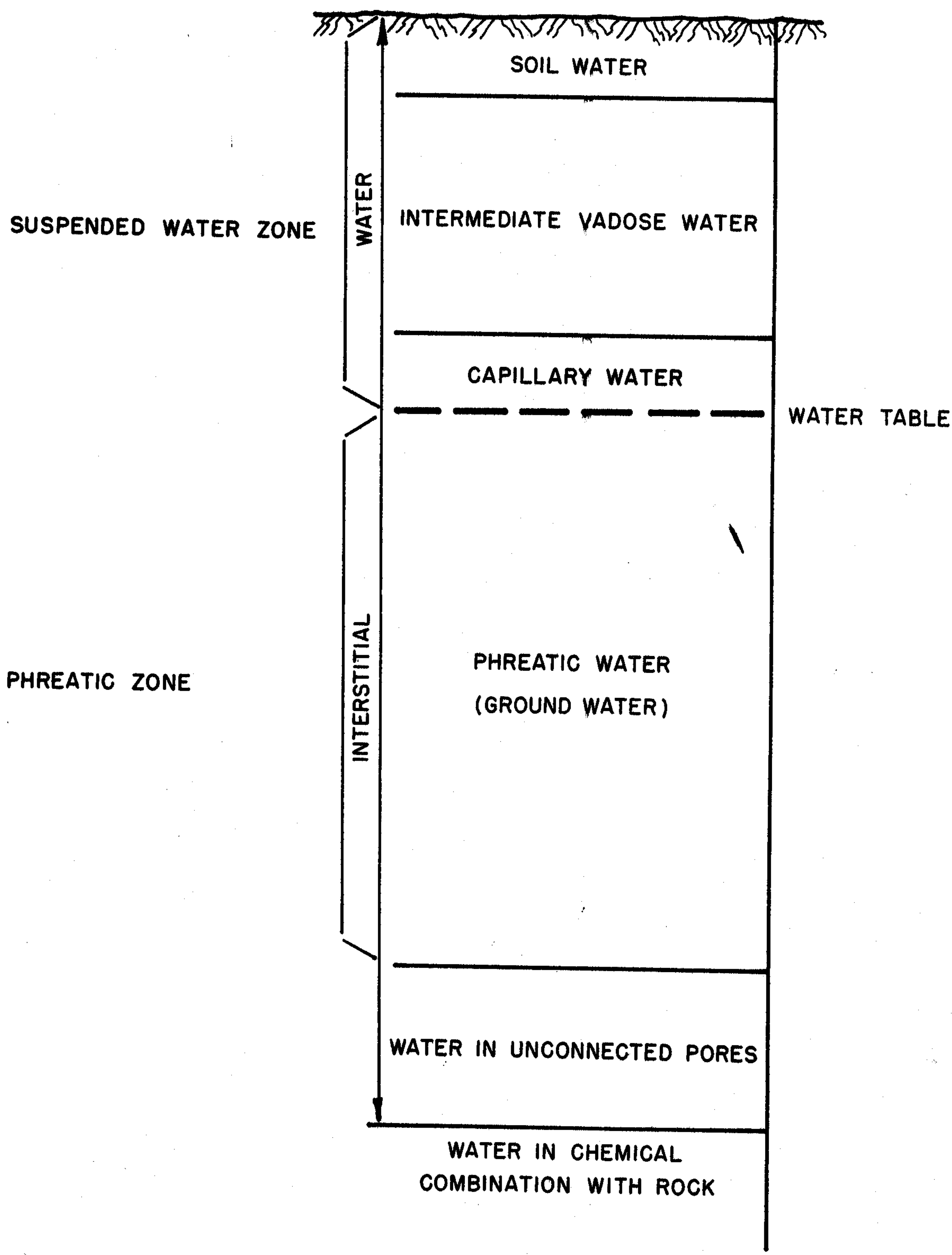
The phreatic-water or ground-water zone is the portion of saturated sediments that will yield water freely to a well. This zone is the most important to developing water supplies from ground water. The zone of phreatic water merges with the zone which contains water in unconnected pores. Since the development of ground-water supplies depends primarily upon the phreatic zone, no further discussion of deeper zones will be made.

Ground Water in Unconsolidated Sediments

Ground water in the pore spaces (interstitial water) occurs in unconsolidated sediments called nonindurated sediments. These sediments

FIGURE A-3

CLASSIFICATION OF GROUND WATERS



SOURCE: HYDROLOGY, S. N. DAVIS AND R. J. M. DE WIEST are classified according to their basis of origin. The sediments found in eastern Nevada consist primarily of the following:

1) Alluvium---sand, silt, or similar material deposited by flowing water.
2) Colluvial deposits---soil consisting in part of alluvium and angular fragments of the original rocks. It is made up of talus material from the mountains above, and other heterogenous material.
3) Lacustrine Deposits---material deposited under water in lake beds. In Nevada these material are primarily clays, sands, and some silts.

There are three major characteristics of nonindurated sediments that determine water yielding capabilities of the sediment material:

1) Porosity---the ratio expressed as a percentage of the volume of interstices or void spaces in a given quantity of material to the total volume of the material.
2) Permeability---the property of a sediment that permits water movement through it. The rate is measured by the quantity of water passing through a unit area in a unit time, with a hydrostatic head of unity.
3) Specific Yield---the quantity of water, expressed as a percentage that unit volume of permeable material after being saturated will yield when drained by gravity. The total amount of water in the pores of a material cannot be drained; the remaining portion retained is called specific retention. The sum of specific retention and specific yield equals porosity.

Permeability values in common units of square feet or square centimeters are very small numbers, and are commonly referred to as darcys. The darcy unit is described as follows:

$$1 \text{ darcy} = 0.987 \times 10^{-8} \text{ square centimeters}$$

or

$$1 \text{ darcy} = 1.062 \times 10^{-11} \text{ square feet.}$$

Table A-1 contains a list of a few sediments and their water-bearing characteristics. (3)

Table A-1

WATER-BEARING CHARACTERISTICS OF SELECTED SEDIMENTS

Type of Sediment	Dominant Size	Permeability (darcys)	Porosity (percent)	Specific Yield (percent)
Alluvium	Fine Sand	26.4	51.1	45.5
Alluvium	Fine Sand	13.2	45.7	39.0
Loess	Silt	0.33	49.3	33.1
Marine	Clay	0.000016	48.5	3.6
Marine	Medium Sand	38.5	41.7	38.3
Alluvium	Coarse Sand	189	33.3	--
Alluvium	Gravel	1130	25.1	--
Alluvium	Fine Sand	5.5	52.2	--
Dune Sand	Medium Sand	28.0	35.8	34.5

Source: Davis and De Wiest, Hydrogeology

The water-bearing characteristics of the sediments listed in Table A-1 vary widely, and general descriptive terms do not adequately describe the sediment materials. It is noteworthy that clays with porosities comparable to sands will yield only a fraction of the water that sands will, due to the small permeabilities.

Classification of Springs

Springs are classified by different methods. The common classifications are based on magnitude of discharge, type of aquifer, chemical characteristics of the water, temperature, and relation to topography. Any natural surface discharge (of water) large enough to flow in a small rivulet can be called a spring. Smaller discharges are considered seepage. Table A-2 is a commonly used classification of springs based on volume of flow.

TABLE A-2

SPRING CLASSIFICATION BY MAGNITUDE OF DISCHARGE

Magnitude	Volume of Flow
First	Greater than 100 cubic feet per second
Second	10 to 100 cubic feet per second
Third	1 to 10 cubic feet per second
Fourth	100 gallons per minute to 1 cubic foot per second
Fifth	10 to 100 gallons per minute
Sixth	1 to 10 gallons per minute
Seventh	1 pint per minute to 1 gallon per minute
Eighth	Less than 1 pint per minute

Source: U. S. Geological Survey Water Supply Paper 494

Ground-Water Infiltration

The term "infiltration" is used to describe the process that allows rainfall to percolate downward into the soil profile toward the water table. A general often-used definition of infiltration is the difference between rainfall and runoff. This definition is not strictly true, since a portion of rainfall, runoff, and infiltrated water is subject to evaporation and transpiration. Runoff often percolates into permeable streambed formations to reappear downstream.

Infiltration capacity varies with time, the intensity and duration of rain, the porosity of soil and other factors. Infiltration capacity is high at the start of rain and decreases rapidly during the first hour. It then gradually declines to a fairly constant rate after one and one-half to two hours of continuous rainfall equal to or greater than the infiltration capacity of the soil. The shape of a curve defining infiltration rate as a function of time is similar over a wide range of conditions and can be described by the equation:

$$f = f_c + (f_o - f_c)e^{-kt}$$

where:

- f = the infiltration rate (iph) at any time, t (hours)
- f_o = the infiltration rate at the start of rain
- f_c = the infiltration rate at maximum saturation approximately equal of $0.9f_1$
- t = the time (in hours) since the start of rain
- k = a constant, approximately equal to 4 $hours^{-1}$ in many cases.

Equation A-1 is shown in Figure A-4 for a range of soil conditions. The infiltration rate after one hour of rainfall, f_1, is generally used to characterize the infiltration capacity of a particular soil. Table A-3 lists some typical infiltration characteristics of soils, using the curves from Figure A-4.

TABLE A-3

TYPICAL SOIL INFILTRATION CHARACTERISTICS

Infiltration Rate At One Hour, f_1 (inches per hour)	Total Infiltration (inches)		
	During 1st Hour	During 2nd Hour	During 3rd Hour
0.1	0.23	0.09	0.09
0.2	0.45	0.19	0.18
0.3	0.68	0.28	0.27

Source: Adapted From Hydrology Handbook, ASCE Publication No. 28

Infiltration rates that have been defined for various soil groups are listed in Table A-4

TABLE A-4

INFILTRATION RATES FOR VARIOUS SOIL GROUPS

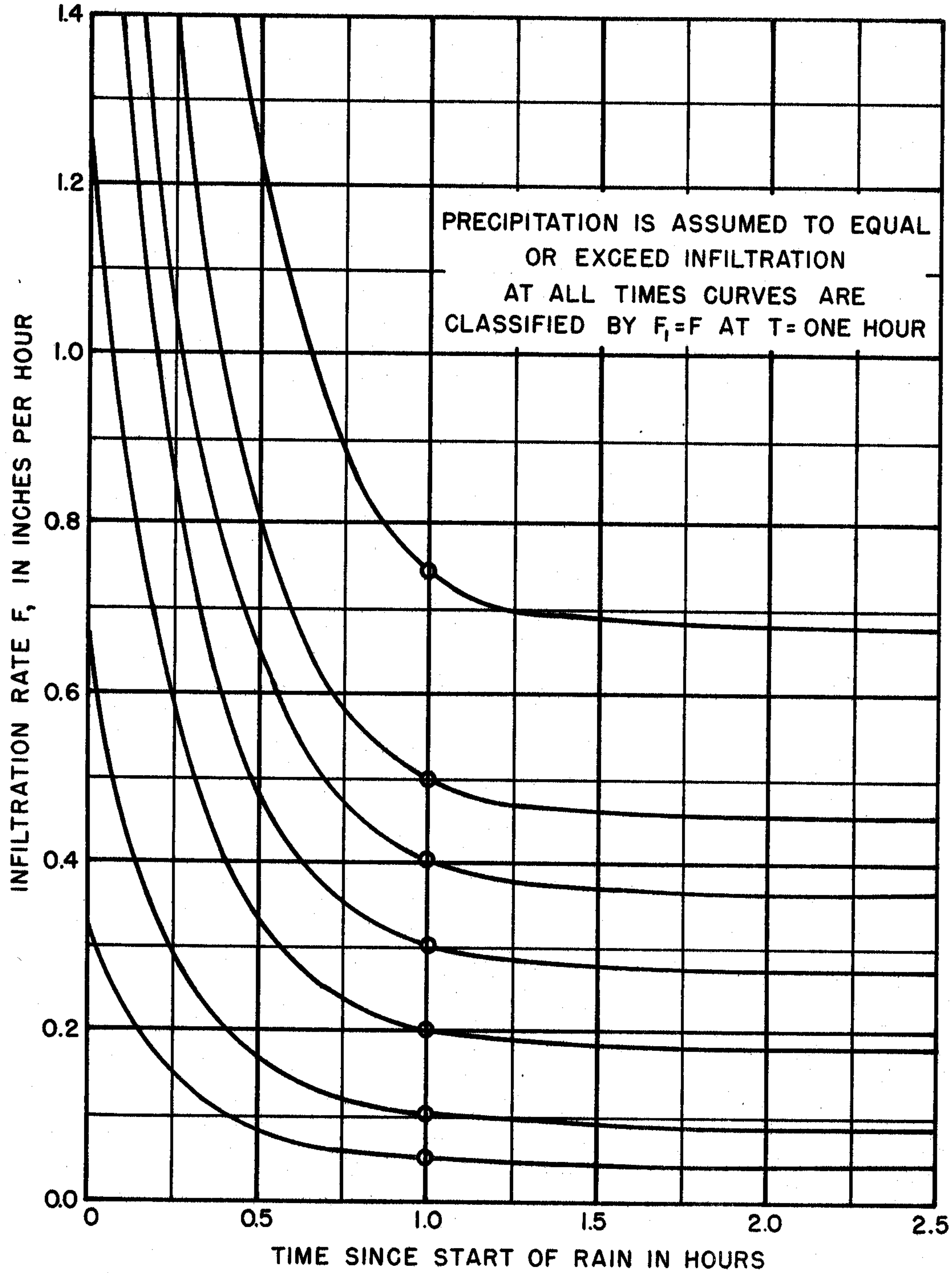
Soil Type	Infiltration Rate, f_1 (inches per hour)
High	0.50 to 1.00
Intermediate	0.10 to 0.50
Low	0.01 to 0.10

Source: Hydrology Handbook, ASCE Publication No. 28

FIGURE A-4

TYPICAL INFILTRATION RATES

(ACCORDING TO EQUATION A-1)



SOURCE: ADAPTED FROM HYDROLOGY HANDBOOK, ASCE PUBLICATION NO. 28

The high group in Table A-4 embraces soils that range from loose porous sandy materials to low clay content highly organic soils with a high degree of aggregation. The intermediate group emgraces soils that contain considerable clay and much silt, but are highly aggregated and friable at average moisture conditions. The lower group are those soils that range from clay loams to clayey soils, and characteristically crack when allowed to dry.

APPENDIX B

SELECTED TABULATED DATA

Table B-1

SELECTED STORMS FROM THE ELKO, NEVADA, RECORD

Date	Max Hourly Intensity* (inches per hour)	Hours of Rain*	Total Storm Rainfall* (inches)	Preceded By Amt.* (inches)
1961				
Feb 9	0.12	3	0.24	0.22
Mar 25	0.15	6	0.31	0.37
Mar 27	0.12	4	0.22	0.10
May 15	0.27	3	0.33	----
May 30	0.15	3	0.23	0.12
Jun 3	0.18	4	0.33	T
Jul 3	0.36	3	0.63	----
Aug 5	0.57	4	0.82	----
Aug 6	0.82	3	1.18	0.82
Aug 23	0.16	6	0.51	T
Oct 21	0.08	16	0.59	T
Nov 20	0.06	13	0.45	----
Nov 26	0.09	8	0.36	----
Dec 2	0.15	9	0.34	0.24
Dec 19	0.12	7	0.51	0.12
1962				
Jan 19	0.12	17	0.55	0.15
Feb 10	0.12	12	0.86	0.10
Mar 6	0.15	3	0.24	----
Apr 20	0.15	2	0.20	T
Mar 14-15	0.31	21	1.84	0.22
Mar 27	0.13	7	0.46	0.09
Jun 15	0.27	12	1.30	----
July 13	0.20	4	0.45	----
Aug 5	0.12	5	0.31	----
Oct 14	0.06	4	0.18	----
Nov 10	0.10	5	0.19	----
1963				
Jan 29-30-31	0.12	46 (Snow)	2.52	----
Feb 1	0.15	6	0.44	2.52
Mar 1	0.15	10	0.60	T
Apr 27	0.18	20	1.17	T
May 9-10	0.15	20	0.93	T
May 24	0.30	9	0.84	T
Jun 3-4-5	0.22	38	1.78	0.31
Jun 9	0.21	6	0.45	0.06
Jun 14	0.10	8	0.33	0.15
Sep 13	0.12	4	0.28	----
Sep 19	0.33	5	0.60	0.27
Oct 12	0.33	13	1.68	T

Table B-1 Cont'd

SELECTED STORMS FROM THE ELKO, NEVADA, RECORD

Date	Max Hourly Intensity* (inches per hour)	Hours of Rain	Total Storm Rainfall*(inches)	Preceded By Amt.*(inches)
Oct 29-30	0.15	10	0.75	----
Nov 6	0.27	8	0.52	0.36
Nov 15	0.18	9	0.84	T
Nov 23	0.12	9	0.66	0.44
1964				
Jan 18-19	0.10	23	0.81	0.03
Mar 1	0.15	10	0.59	----
Apr 1	0.09	13	0.46	----
Apr 29	0.34	5	0.63	----
May 26-27-28	0.24	17	0.98	T
Jun 9	0.24	7	0.45	0.31
Jun 15-16-17	0.30	21	1.90	T
Oct 29-30	0.09	18	0.72	----
Nov 12	0.12	13	0.50	0.59
Dec 23-24-25	0.28	31	2.38	0.04
1965				
Jan 11	0.12	9	0.37	0.25
Apr 1-2	0.20	10	0.90	T
May 31	0.21	7	0.51	T
Jun 15-16	0.74	12	1.14	----
Jul 14	1.17	2	1.46	0.17
Oct 15	0.14	11	0.95	----
Nov 23-24	0.33	22	1.85	----
Dec 29	0.15	7	0.30	----
1966				
Apr 17	0.18	12	0.81	----

Source: Compiled from U.S. Weather Bureau Data by Geological Engineering Co.

*The maximum hourly intensity is the maximum value of hourly rainfall during the storm. Hours of rain is the total number of hours of rainfall excluding trace amounts. Total storm rainfall is the total amount of rain that occurred during the storm. The last column is an indication whether rain occurred in the previous 2 days, and is a measure of antecedent soil moisture conditions. All rainfall vaues are adjusted to reflect expected rainfalls near the Kingsley Mountains. T equals trace amount.

Table B-2

WATER QUALITY ANALYSES AND PUBLISHED STANDARDS

Constituent	Standards For Drinking	Standards For Household Use		Standards For Irrigation		1	2	3	4	5	6	7	8	9	10	11	12
		Good	Poor	Good	Poor												
Calcium Ca++	200	40	100			134.9	92.7	113.3	98.1	110.8	116.6	126.1	67.6	138.0	10 120.3	100.1	290.0
Magnesium Mg++	125	20	100			72.3	15.5	30.9	35.4	79.5	54.0	69.2	42.8	43.1	51.0	22.7	78.3
Sodium Na+	200	100	300	50	300	10.0	28.5	20	21	24	10.5	10	32	24.5	9.2	19	62
Potassium K+						1.8	3.8	3.4	6.2	3.2	8.6	2.8	7.8	10.0	3.4	5.3	3.2
Chloride Cl-	250			100	300	9.2	28.5	20.7	33.6	31.9	5.4	5.7	17.9	17.8	5.8	27.7	142.4
Bicarbonate HCO_3^-	500	150	500	200	500	192.2	109.6	144.3	107.3	167.4	172.6	186.9	141.5	199.7	173.9	114.5	213.2
Carbonate CO3=						0	0	0	0	0	0	0	0	0	0	0	0
Sulfate $SO_4^{=}$	250	100	300	200	500	21.5	23.5	23.0	26.5	29.0	20.5	20.5	19.0	29.5	20.0	17.0	77.0
Silica SiO_2		10	50			14	35	40	54	16	55	21	68	18	17	53	40
Fluoride F-	1.5					0.25	0.45	0.52	0.09	0.12	0.04	0.42	0.52	0.25	0.34	0.2	0.45
Iron Fe	1.0	o.2	0.5			0.11	0.09	0.13	0.10	0.08	0.08	0.12	0.13	0.13	0.23	0.09	0.07
pH						8.15	7.82	7.98	7.90	7.94	7.70	7.75	8.09	7.65	8.00	7.73	7.92

Mineral Constituents in ppm = parts per million

* See Table B-3 for name of spring or well corresponding to sample number

Note: Ca++, Mg++, HCO_3^-, CO_3^-, are in parts per million as Calcium Carbonate.

Source: Standards by U.S. Public Health Service, Analyses by Mr. William G. Smith, Department of Civil Engineering, San Jose State College, San Jose, California.

Table B-3

LOCATIONS AND DESCRIPTIONS OF ANALYSED WATER SAMPLES

Sample No.	Name	Location	Temp (°F)	Remarks
1	Chinn Creek Spring	NE1/4 Sec 27 T25N R67E	67	Sample taken from one springs 2 Mi. above Reservoir. Flow=10gpm Stockwater
2	Flat Spring	NE1/4 Sec 11 T25N R66E	61	Flow = 1-2 gpm. Stockwater
3	Lages Station Tap Water	NE1/4 Sec 11 T25N R65E*	67	Sample taken from faucet--piped about 2 miles from Becky* Springs. Flow5-6gpm.
4	Itcaina North Well	NW1/4 Sec 33 T28N R67E	55	Sample dipped from 30" corrugated metal pipe dug well. Water 23'4" below top of pipe which is 2' above ground. Well located next to drilled well 63' deep with 6" casing.
5	Boone Springs	SE1/4 Sec 29 T27N R67E	67	Flow approx. 10 gpm. Stockwater
6	Parker Well	SE1/4 Sec 4 T25N R65E	60	Irrigation Well 16" diameter, 284 feet deep. Flow approx 800 gpm.
7	Collar and Elbow Spring	NE1/4 Sec 33 T26N R65E	86	Hot spring used for Stockwater
8	Unfinished Well	NW1/4 Sec 20 T26N R65E	53	Sample dipped from 16" casing 1' above ground. 16'9" to water from top of casing, Depth 26'4" from top of casing.

Table B-3 Cont'd

LOCATIONS AND DESCRIPTIONS OF ANALYSED WATER SAMPLES

Sample No.	Name	Location	Temp (°F)	Remarks
9	Unfinished Well	NE1/4 Sec 20 T26N R65E	52	Sample dipped from 16" casing 0'8" above ground. Water 20' 0" from top of casing, 24'7" to bottom of well.
10	Unused Well	NE1/4 Sec 8 T25N R65E	71	Sampled from 16" well, casing 1'8" above ground, 42'10" to water surface. Well reported 300 ft deep.
11	Lookout Spring	SW1/4 Sec 29 T26N R67E	67	Spring and pond on abandoned homestead.
12	Kingsley Spring	NW1/4 Sec 24 T26N R67E	60	Sample taken from standpipe, spring used for stockwater.

Source: Geological Engineering Company

Table B-4

RECORDS OF SELECTED WELLS IN ANTELOPE AND STEPTOE VALLEYS

Number[1/]	Date Drilled	Depth (feet)	Casing Diameter (inches)	Aquifer Zone Depth (feet)	Water Level Depth (feet)	Well Use[2/]	Remarks
29/68-6C	4-62	178	6	140-160	110	S	24gpm
28/67-33A	12-58	63	6	27-63	27	S	30gpm
28/68-8D	-----	---	6	-------	99	C	-----
29/67-1A	Dug	113.5	--	-------	98	S	-----
31/67-26D	-----	---	6	-------	79	S	-----
24/68-8	5-64	200	6	160-200	160	S	-----
23/67-12D	5-65	175	6	140-175	110	S	40gpm
24/68-17	5-65	285	6	256-285	256	S	10gpm
27/67-25A	2-63	75	6	31-75	28	S	30gpm
26/64-28D	5-49	250	16	27-100	27	I	-----
26/66-30	2-51	200	8	170-185	135	C	-----
25/65-31	1-51	220	8	50-52	50	C	-----
28/64-34A	3-59	275	6	253-275	10	D	40gpm
29/65-8B	2-53	158	6	95-115	95	U	-----
24/64-16C	6-48	65	6	45-48	40	S	Incomplete
24/65-8D	6-48	21	6	18-20	10	S	-----
26/66-17B	3-63	192	6	137-192	137	S	17gpm
25/65-8A	-66	300*	16	-------	43	U	*Reported
25/65-4D	-65	284	16	65-70 250-280	50R	I	1000gpm

1/ Coded as follows:
Number 29/68-6C, Township 29 North, Range 68 East Section 6;
A,B,C, and D are northeast, northwest, southwest, and southeast quarters of sections respectively.

2/ Coded as follows:
R = Reported
S = Stockwater
I = Irrigation
C = Highway construction
D = Domestic
U = Unused

Source: Well logs of Nevada State Engineer and other records

Table B-5

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
STEPTOE VALLEY		
25/65-4D Parker Well		
Silty Sand	65	65
Silt-sand, water bearing	5	70
Silt and clay	40	110
Clay	15	125
Sandy Loam/mix	50	175
Clay	35	210
Clay and Sand	40	250
Gravel	30	280
Rock	4	284

Casing, 16 inch for 284 feet, perforated 65 to 280 feet. Water standing at 50 feet.

Formation Description	Thickness (feet)	Depth (feet)
26/64-28D Cordano Well		
Top soil	27	27
Sand-gravel, water	3	30
Clay	15	45
Sand-gravel, water	2	47
Clay	28	75
Sand and Gravel	1	76
Clay	22	98
Sand and Gravel	2	100
Clay	150	250

Casing, 16 inch for 170 feet, perforated 30 to 160 feet chief water-bearing formation from 27 to 100 feet. Water standing at 27 feet.

Formation Description	Thickness (feet)	Depth (feet)
26/66-3C Highway Construction Well		
Cemented Sand and gravel	135	135
Clay	5	140
Sandy Clay	30	170
Gravel, waterbearing	15	185
Sandy Clay and Water	15	200

Casing, 8 inch for 192 feet, perforated from 140 fo 185 feet, chief waterbearing formation from 170 to 185. Water standing at 1351/2 feet.

Table B-5 Cont'd

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
25/65-31 Highway Construction Well		
Cemented sand and gravel	50	50
Gravel and water	2	52
Sandy clay	168	220

Casing 8 inch for 140 feet, perforated from 50 to 140 feet, chief waterbearing formation 50 to 52 feet. Water standing at 50 feet.

Formation Description	Thickness (feet)	Depth (feet)
28/64/34A Nevada Highway Department at Currie		
Surface Soil	3	3
Gravel	9	12
Creek gravel and water bearing sand	12	24
Black and Red lava formation	41	65
Medium Hard Black and red lava formation	75	140
Red Rock, very abrasive	62	202
Conglomerate, blue green and gray clay	3	205
Light red rock firm	70	275

Casing, 6 inch for 59 feet 4 inches, not perforated, chief water-bearing formation 253 to 275 feet, water standing at 10 feet, bailed at approximately 40gpm, with 20 feet of drawdown.

Formation Description	Thickness (feet)	Depth (feet)
29/65-8B Gulf Oil Co. Tulsa, Oklahoma		
Soil and clay	5	5
Cemented Gravel	90	95
Sand and Gravel	20	115
Clay and Gravel	25	140
Sand and Gravel	18	158

Casing, 6 inch to 158 feet, perforated from 90 to 158 feet, chief water bearing-formation from 95 to 115 feet, water standing at 95 feet.

Table B-5 Cont'd

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
ANTELOPE VALLEY		
29/68-6C Sorenson Well		
Light Grey Clay	105	105
Blue Clay	35	140
Sandy Blue Clay	20	160
Light Grey Clay	18	178

Casing, 6 inch to 178 feet, perforated from 115 to 175 feet, chief water-bearing aquifer from 140 to 160 feet, water standing at 110 feet.

23/67-12D Location uncertain, about 1 mile north of Tippets. Owned by Bureau of Land Management		
Top Soil	12	12
Silt and gravel, Dry	128	140
Silt and Gravel	35	175

Casing, 6 inch for 175 feet, perforated from 135 to 175 feet, gravel-packed, chief water-bearing aquifer from 140 to 175 feet, water standing at 110 feet, bail tested at 40 gpm with no drawdown.

24/68-17 6 miles north of Tippetts, owned by BLM		
Lava Wash	10	10
Lava Rock	110	120
Lava wash	165	285

Casing, 6 inch for 285 feet, perforated from 245 to 285 feet, water-bearing formation from 256 to 285 feet, water standing at 256 feet, bailed at 10 gpm with 9 feet drawdown.

27/67-25 Private Stock Well		
Yellow Clay	31	31
Boulders, Gravel and Clay	44	75

Casing, 6 inch at 65 feet, perforated from 6 to 62 feet, chief water-bearing aquifer, 31 to 75 feet, water standing at 28 feet, bailed at 30 gpm with 28 feet drawdown.

Table B-5

STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
19/63-12A Us Geological Survey, drilled 1918 near McGill, Nevada		
Clay and Gravel	5	5
Sand and Gravel (water at 9.6 feet)	6	11
Sand, gravel, and clay	8	19
Sand and gravel (water-bearing, tested capacity 25gpm)	3	22
Clay, sand and gravel	5	27
Clay	2	29
Sand and Gravel (water-bearing tested capacity 8 gpm)	2	31
Clay	12	43
Gravel and sand (water-bearing, tested capacity 10 gpm)	1	44
Clay and sand	2	46
Clay	8	54
Gravel and sand (water-bearing, tested capacity 15 gpm)	3	57
Clay	12	69
Gravel and Sand (water-bearing, water level 17.3 feet below surface)	1	70
Clay	7	77
Gravel and Sand, (water-bearing, tested capacity 20 gpm, Water level 15.3 feet below surface)	3	80
Clay	24	104
Sand and Gravel (water-bearing tested capacity 35 gpm, water level 10.8 feet below surface)	1	105
Clay	18	123
Gravel, (water bearing, water level 15.7 feet below surface)	1	124
Clay	138	262

Table B-5

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
19/63-12A (Cont'd)		
Sand, (water-bearing, water level 4.9 feet below surface, tested at 86 gpm, drawdown 20 feet)	5	267
Fine Yellow Clay	15	282
Sand and Gravel (very little water)	3	285
Clay	15	300
Sand (no water)	1	301
Clay, gravel, and sand	4	305
Clay	10	315
Clay and sand in thin beds (Water-bearing, water level 4.7 feet below surface)	10	325
Pale Yellow Clay	51	376
Fine Gravel, sand, and clay	3	379
Clay	2	381
Fine Gravel, sand, and clay	4	385
Clay	37	422
Sand	2	424
Clay	16	440
Sand and Clay	4	444
Clay	35	479
Sand and Clay	6	485
Sand (water-bearing)	1	486
Sand and clay	4	490
Clay	10	500
Sand	1	501
Clay	8	509
Sand	1	510
Clay	9	519
Sand	1	520
Clay	41	561
Sand and Clay	1	562
Sand and Clay	33	595
Cemented sand and clay	1	596
Sandy clay	5	601
Cemented gravel and clay	4	605
Sandy Clay	23	628

Table B-5 (Cont'd)

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
19/63-12A (Cont'd)		
Gravel and sand	2	630
Sandy clay	19	649
Dry brown sand and clay	4	653
Clay	7	660
Cemented Sand	9	669
Clay and Sand	3	672
Cemented Sand with some Clay	28	700
Sandy Clay	16	716
Cemented Sand	4	720
Sandy Clay	7	727
Cemented Sand	8	735
Clay and Sand	15	750
Cemented Sand	4	754
Gravelly Clay	5	759
Clay	64	823
Sandy Clay	1	824
Sticky Clay with a little gravel	6	830
Cemented Sand	8	838
Clay	13	851
Cemented Sand	9	860
Clay	8	868
Cemented Sand	2	870
Clay	10	880
Sand	8	888
Sandy Clay	12	900
Gravelly Clay	13	913
Blue Clay with odor of hydrogen sulphide	3	916

Casing 12 inch to 181 feet, 8 inch to 540 feet, aggregate yield of water bearing sediments estimated at 250 to 300 gpm.

Table B-5

SELECTED DRILLERS' LOGS OF WELLS
STEPTOE AND ANTELOPE VALLEYS OF NEVADA

Formation Description	Thickness (feet)	Depth (feet)
34/67-6A Western Pacific Railroad at Shafter, (Goshute Valley)		
Clay, yellow	23	23
Clay, blue, little sand	17	40
Clay, yellow	10	50
Clay, hard	10	60
Clay, hard, fine gravel	8	68
Clay, yellow	27	95
Clay and gravel	9	104
Clay gravel and sand	9	113
Gravel, cemented, very hard	10	123
Gravel, cemented, light	37	160
Limestone	5	165
"Rock Dust" and lime stone White	20	185
Clay, light sandy, some water	41	226
Clay and sandy water	25	251

Well drilled in 1925, 251 feet deep, casing 14 and 12 inch, perforated 117 to 250 feet depth to water 27.5 feet. Yield 204 to 1000 gpm reported at different dates.

Source: Well logs of Nevada State Engineer, and U.S. Geological Survey.

APPENDIX C

PARKER WELL, AQUIFER FORMATION COMPUTATIONS

CALCULATIONS TO DETERMINE THE COMPOSITION OF THE PARKER WELL AQUIFER

From the Parker well log data, the transmissivity[1/] of the total water bearing formation was approximated by: (6)

$$T = \frac{1.22\ Q}{s} \qquad \text{(EQ C-1)}$$

Where

T = Transmissivity (gallons per minute per foot of aquifer)
Q = Discharge of the well (gpm)
s = Drawdown at the discharge rate (feet).

During the irrigation season the well produced about 1000 gallons per minute. From the test data in Table 17, the well would produce about 1065 gallons per minute at 112 feet of drawdown. Since the data were obtained from a short-term test, a flow rate of 1000 gallons per minute at 120 feet of drawdown will be used.

Thus

$$T = \frac{1.22\ (1000)}{120} = 10.2 \text{ gallons per minute per foot.}$$

Assuming the water-bearing formation to be the 30-foot-thick aquifer near the bottom of the well, one can estimate the hydraulic conductivity[2/] of the aquifer from the relation

$$T = Kb \qquad \text{(EQ C-2)}$$

Where

K = Hydraulic conductivity (gallons per day per square foot)
b = Aquifer thickness (feet)

Thus

$$K = \frac{T}{b} = \frac{10.2(1440)}{30}$$

$$= 490 \text{ gallons per day per square foot}$$

Table C-1 lists average values of hydraulic conductivity (K) for various geologic aquifer classifications.

1/ Transmissivity is an aquifer formation constant, and is used in this case to represent the flow in gallons per minute through a section one foot wide and the thickness of the aquifer under a unit slope of one foot per foot.

2/ Hydraulic conductivity is the discharge in gallons per day through an area of one square foot under a unit slope of one foot per foot.

Table C-1

AVERAGE VALUES OF HYDRAULIC CONDUCTIVITY (K) FOR VARIOUS SOIL TYPES

Geologic Classification	Value of K
Clayey sands, poor aquifers	0.1 to 10
Very fine sand, well sorted	180
Medium sand, very well sorted	4,600
Coarse sand, very well sorted	58,000
Gravel, very well sorted	788,000

Source: Hydrogeology, Davis and De Wiest

The hydraulic conductivity value of 490 indicates that the major aquifer is a fine sand.

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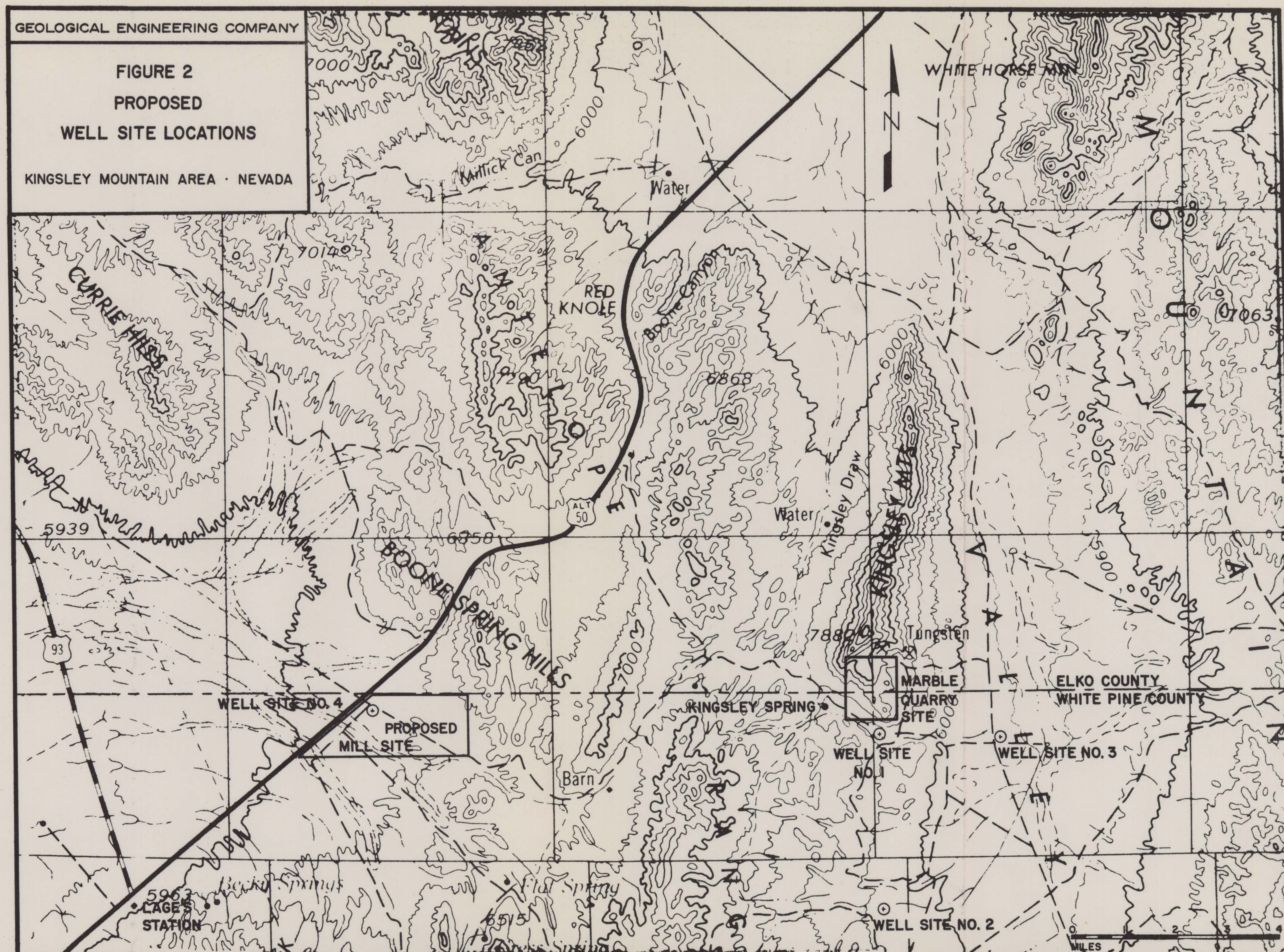

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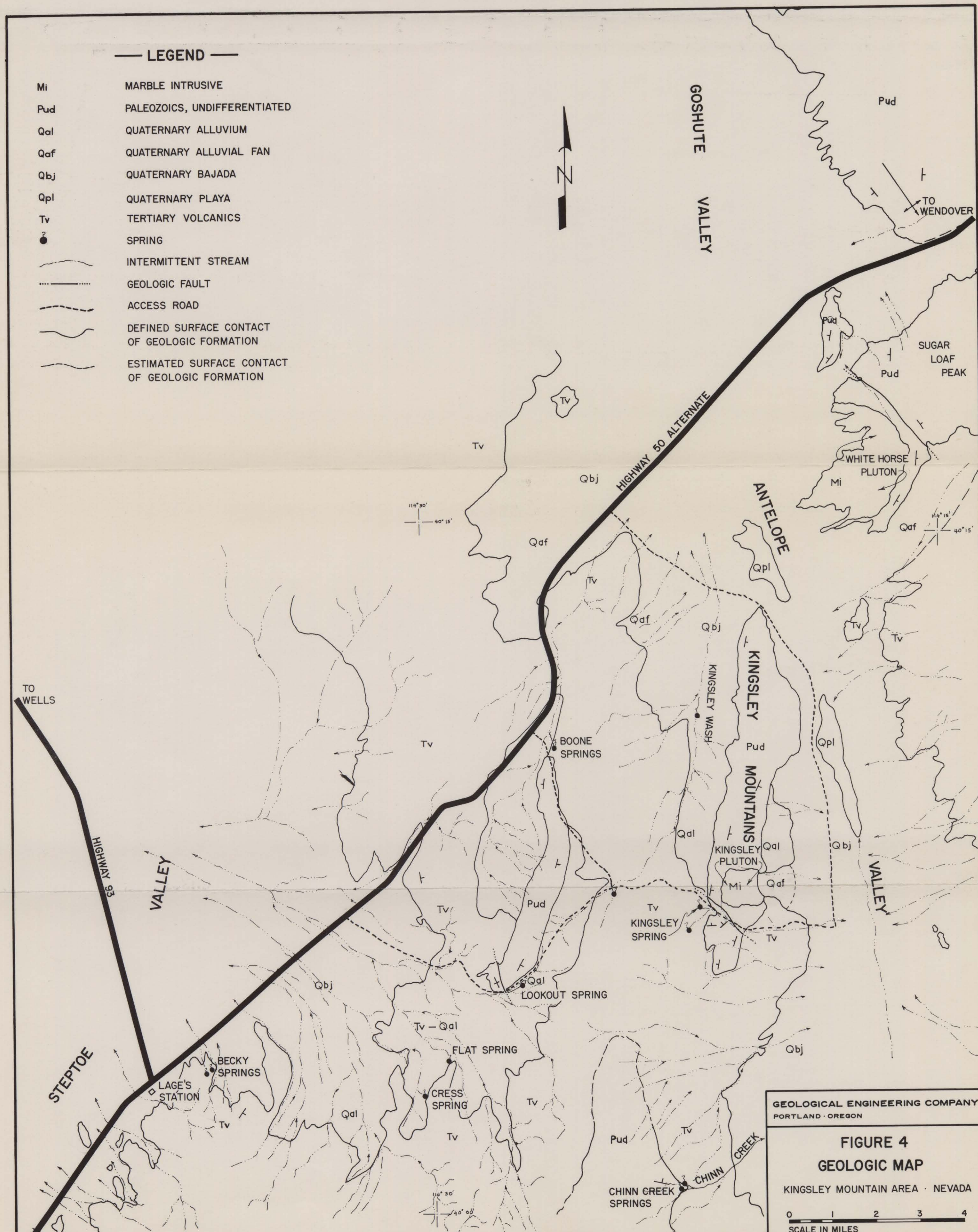
FIGURE 2
PROPOSED
WELL SITE LOCATIONS

KINGSLEY MOUNTAIN AREA · NEVADA

26600004 (after 13/84)



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PORTLAND · OREGON

FIGURE 4
GEOLOGIC MAP
KINGSLEY MOUNTAIN AREA · NEVADA

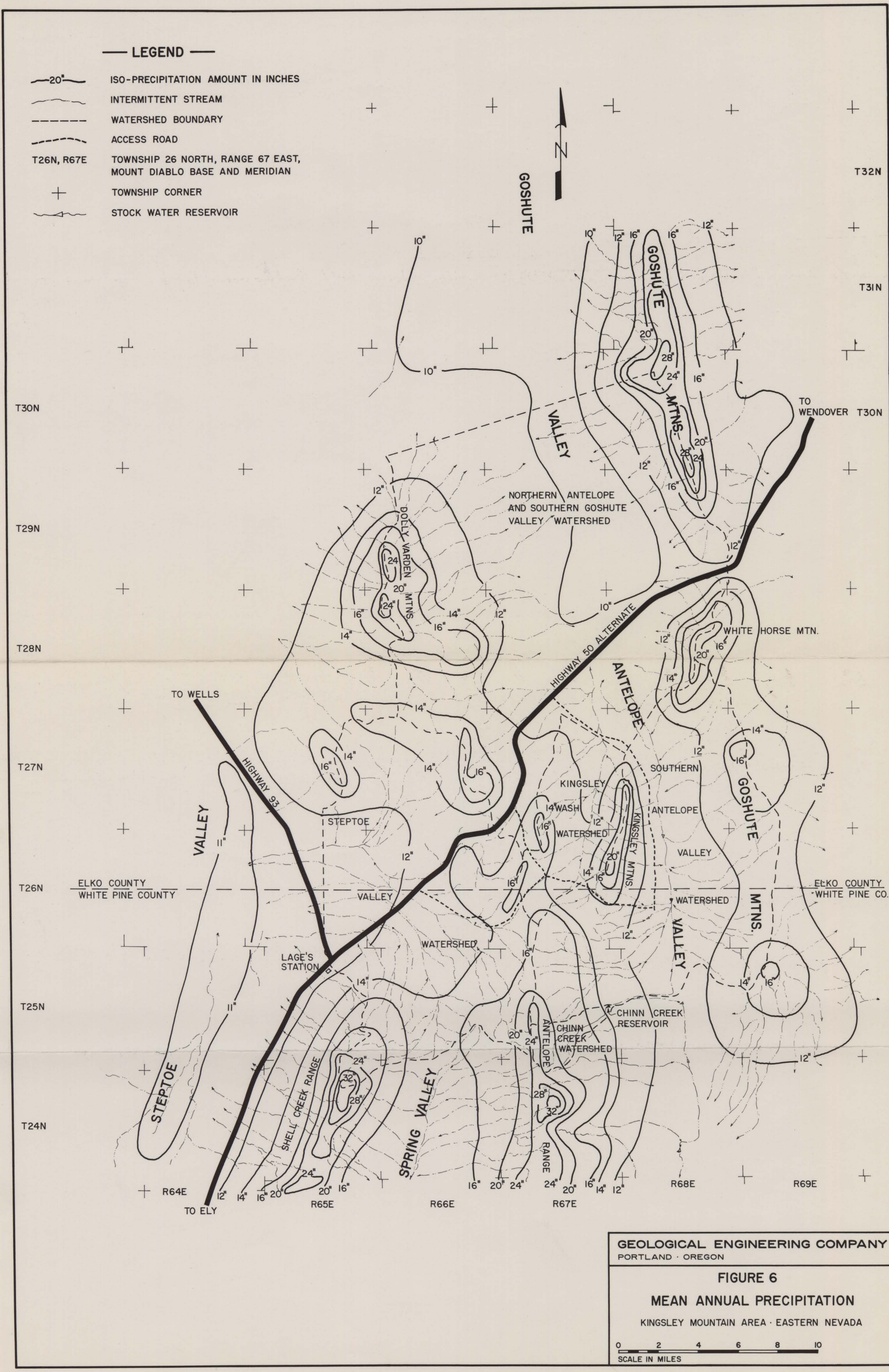

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FIGURE 6
MEAN ANNUAL PRECIPITATION
KINGSLEY MOUNTAIN AREA · EASTERN NEVADA

0 2 4 6 8 10
SCALE IN MILES

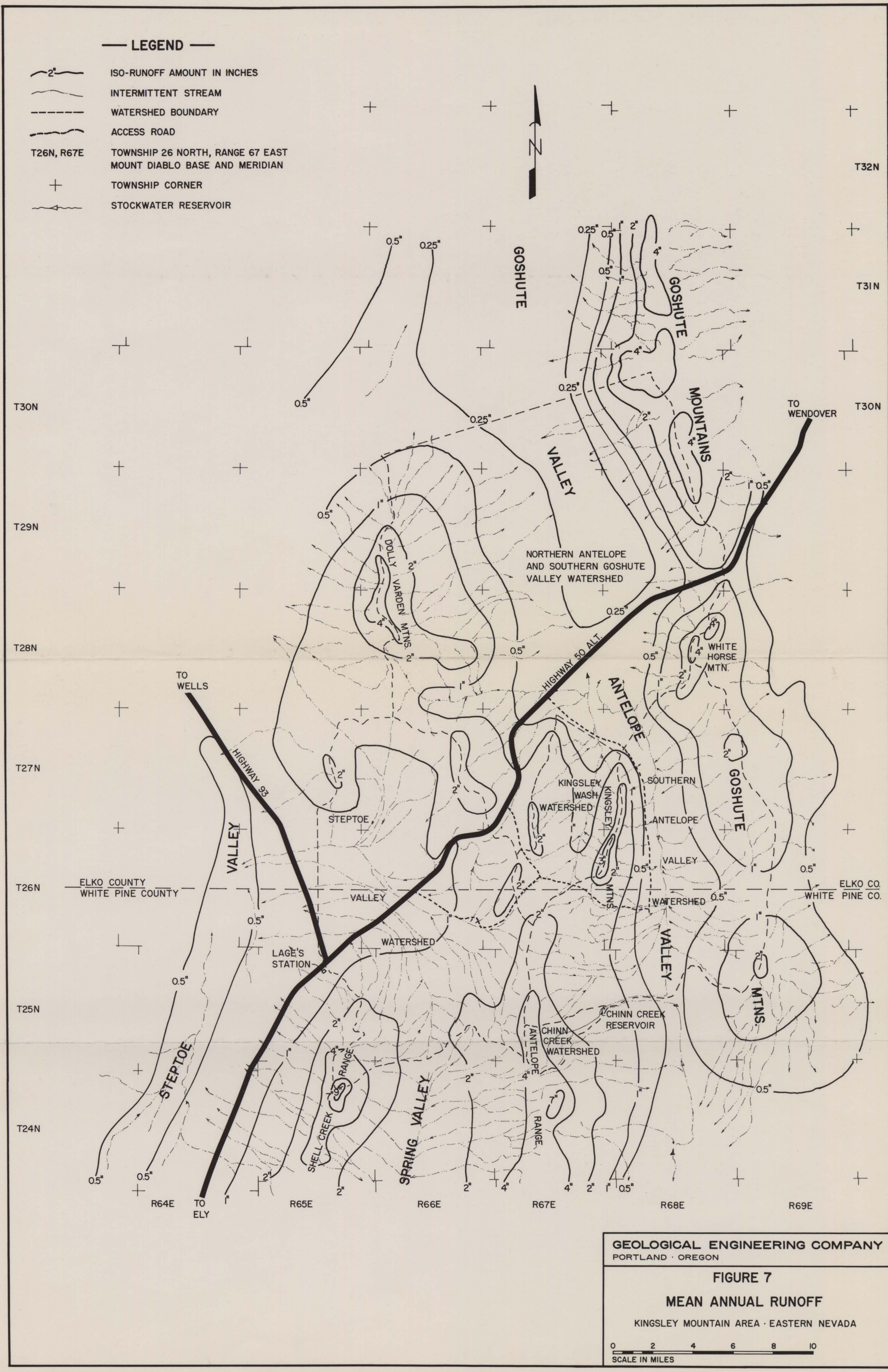

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FIGURE 7

MEAN ANNUAL RUNOFF

KINGSLEY MOUNTAIN AREA · EASTERN NEVADA

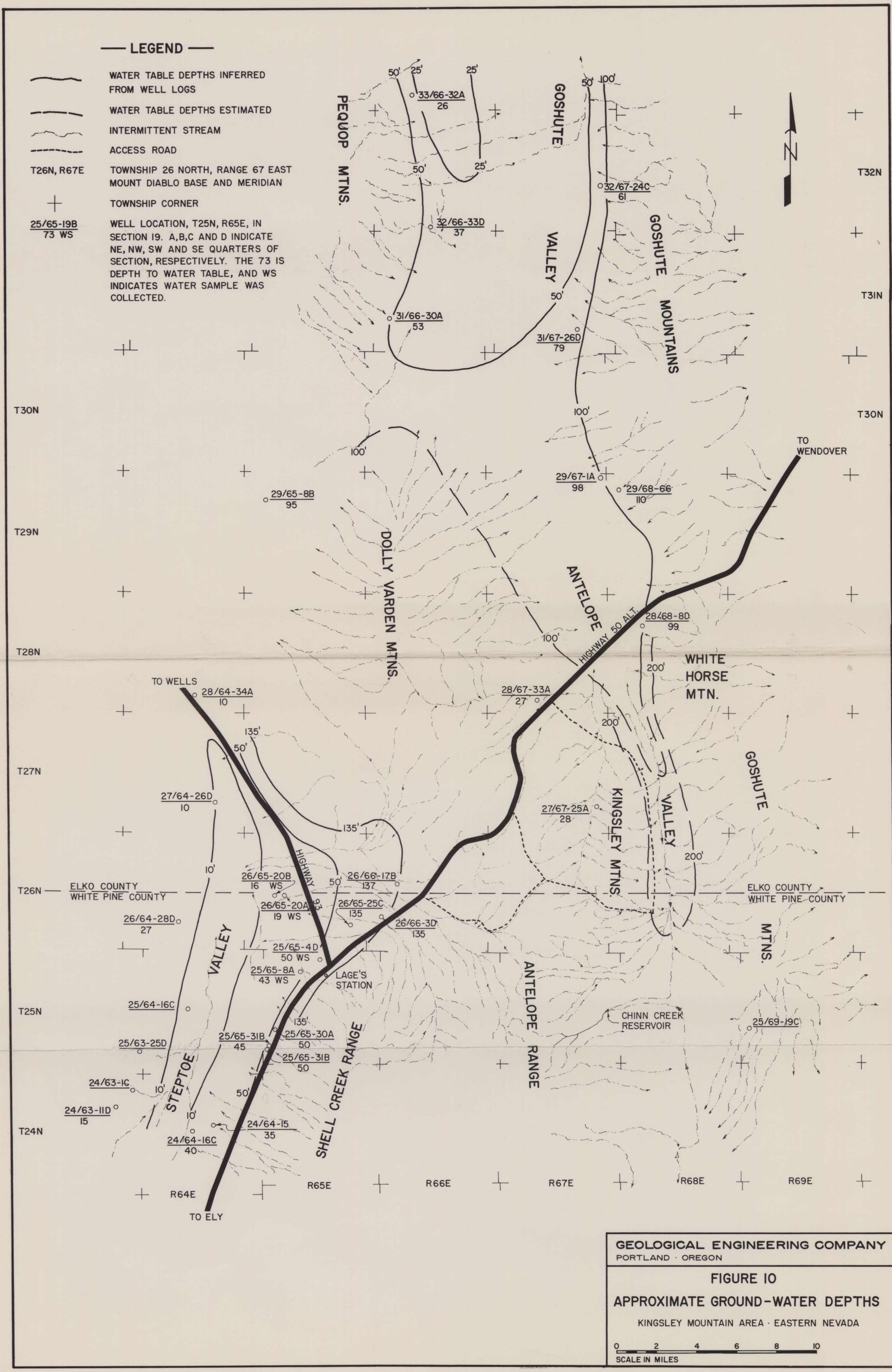

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FIGURE 10
APPROXIMATE GROUND-WATER DEPTHS
KINGSLEY MOUNTAIN AREA · EASTERN NEVADA