000158

NWC TP 6025

Hydrogeologic Investigation of Coso Hot Springs Inyo County, California

by
Frank A. Spane, Jr.
Hydro-Search, Inc.
for the
Public Works Department

MAY 1978

Approved for public release; distribution unlimited.

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center
AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

The Naval Weapons Center is conducting a continuing program to determine the geology, geophysical signature, and geothermal potential of the region known collectively as the Coso geothermal area. The investigation reported in this publication was conducted for NWC by Hydro-Search, Inc., Reno, Nevada, as that company's Project 1151-78, under contract N62474-77-C-6727.

This publication is a facsimile of the contractor's final report. It is published in facsimile to make readily available to other workers involved with the Coso geothermal area the data, conclusions, and interpretations developed by Hydro-Search in the course of their investigation.

The investigation, conducted October 1977 through January 1978, was funded under Task S0362-SL.

Approved by
R. B. WILSON
Capt., CEC, U.S. Navy
Public Works Officer
5 April 1978

Under authority of
W. L. HARRIS
RAdm., U.S. Navy
Commander

Released for publication by
R. M. HILLYER
Technical Director

NWC Technical Publication 6025

Published by . . . . Technical Information Department
Collation . . . . Cover, 31 leaves
First printing . . . . 220 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC TP 6025	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HYDROGEOLOGIC INVESTIGATION OF COSO HOT SPRINGS, INYO COUNTY, CALIFORNIA		5. TYPE OF REPORT & PERIOD COVERED Final October 1977-January 1978
		6. PERFORMING ORG. REPORT NUMBER Project 1151-78
7. AUTHOR(s) Frank A. Spane, Jr.		8. CONTRACT OR GRANT NUMBER(s) N62474-77-C-6727
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hydro-Search, Inc. 333 Flint Street Reno, NV 89501		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS S0362-SL
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, CA 93555		12. REPORT DATE May 1978
		13. NUMBER OF PAGES 56
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydrology
Geothermal
Coso Hot Springs
Hydrogeology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See back of form.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(U) *Hydrogeologic Investigation of Coso Hot Springs, Inyo County, California,* by Frank A. Spane, Jr., Hydro-Search, Inc. China Lake, Calif., Naval Weapons Center, May 1978. 56 pp. (NWC TP 6025, publication UNCLASSIFIED.)

(U) Hydro-Search, Inc., was under contract to the Officer in Charge of Construction, NWC, China Lake, Calif., to perform a hydrologic investigation of Coso Hot Springs and vicinity, Naval Weapons Center, China Lake, Calif. Objectives were to determine the effects on Coso Hot Springs of anticipated geothermal development in the Coso Known Geothermal Resource Area (KGRA) to the west of the hot springs and to determine how close to the former Coso resort area geothermal fluid extraction could be conducted on a large scale without adversely affecting the so-called hot springs.

(U) This investigation included (1) review of existing geologic, geophysical, and hydrologic information; (2) field examination of geologic rock units and springs and other features of hydrologic significance and sampling of waters for chemical analysis; (3) determination of the local Coso Hot Springs and regional groundwater hydrology, including consideration of recharge, discharge, movement, and water quality; and (4) determination of the possible impact of large-scale geothermal development on Coso Hot Springs.

TABLE OF CONTENTS

TABLES

FIGURES

LIST OF PLATES

1.0 FINDINGS

1. Principal rock units which occur within the area are: granitic intrusives, Tertiary volcanics, Coso Formation, Quaternary volcanics, and Quaternary alluvial deposits.

2. Based on widespread areal distribution and overall favorable hydrogeologic characteristics, Quaternary alluvial deposits constitute the most important geologic units with respect to recharge and occurrence of ground water within the local, shallow ground-water flow system of the Coso Hot Springs sub-basin.

3. Although no on-site precipitation records are available, precipitation-elevation relationships for nearby climatological stations indicate a long-term average precipitation of 5.2 inches at Coso Hot Springs.

4. Recharge to the local ground-water system within the Coso Hot Springs sub-basin is derived from infiltration of intra-basin precipitation and probably subsurface underflow from Upper Cactus Flat ground-water basin on the north. Local ground water moves to the south from intra-basin recharge areas, ultimately discharging to Coso ground-water basin.

   Average recharge to shallow ground water is estimated to be 390 acre-feet per year.

5. Deep regional ground water, with primary recharge areas along the Sierra Nevada on the west, flows from west to east through the Coso Hot Springs sub-basin. The quantity of subsurface regional ground-water flow through the sub-basin is estimated to be approximately 2800 acre-feet per year. Ground water in the regional flow system increases in temperature as a result of deep convective circulation, including heating by the magma body which underlies the Coso area. The circulating ground water may also receive thermal fluids which rise from the magma.

6. In the immediate vicinity of Coso Hot Springs, a pervious north-south trending fault allows deep-seated geothermal fluids to rise to shallow depths. Cold ground water of local origin moves laterally and intermingles with rising high temperature fluids.

7. Field inspection of the spring indicates that considerable man-related modification has occurred. Past activities probably have increased thermal manifestations at Coso Hot Springs by increasing communication between local ground water and geothermal fluids.

8. Available hydrologic data indicate that the regimen of Coso Hot Springs, including temperature, water level, and discharge characteristics, is variable over time. This variability is largely determined by variations in the contribution of local ground water

which in turn is determined by recharge of precipitation and surface runoff within the Coso Hot Springs sub-basin.

9. Extraction of geothermal fluids for a 50 megawatt generation plant within the anticipated area of geothermal development to the west of Coso Hot Springs is not expected to cause a major change in the regimen of Coso Hot Springs. Factors which indicate a relatively minor, or negligible, change in regimen include:

   a. absence of pervious cross-tying geologic structures which could afford easy hydraulic communication between Coso Hot Springs and the proposed area of geothermal development,

   b. a projected quantity of net removed geothermal fluid less than the estimated deep regional ground-water flow through the area, and

   c. the apparent principal dependence of Coso Hot Springs on local, shallow ground-water contribution.

10. In the event that it is necessary to minimize possible impact on Coso Hot Springs, preventative measures could include:

    a. limitation of geothermal production wells to the extreme western portion of Coso Hot Springs sub-basin,

    b. selective reinjection of degraded geothermal fluids between the geothermal development and Coso Hot Springs, and

    c. limiting removal of geothermal fluids to the deepest aquifer zones.

Geothermal development exceeding 50 megawatts could require large scale selective reinjection of degraded geothermal fluids to maintain the regimen of Coso Hot Springs.

2.0 RECOMMENDATIONS

Collection of data on the hydrologic regimen of Coso Hot Springs should be initiated prior to regionwide geothermal development. This would provide baseline information for eventual evaluation of the effects of geothermal development. In addition, such information could lead to an improved understanding of the hydrology of the springs.

The monitoring program should include the following elements.

1. Modification of existing spring discharge features to channelize all major discharge to a centralized outflow point.

   This would permit accurate determination of total surface discharge of the spring and aid in water chemistry sample collection.

2. Establishment of an on-site climatological station.

   Meteorological data collected at the station should include precipitation, atmospheric pressure, and air temperature. This would assist in evaluation of ground-water recharge and confined aquifer effects.

3. Establishment of a hydrologic monitoring network.

   This would include temperature, water level, and discharge measurements and sampling/analysis for major and trace chemical parameters on thermal water points in the vicinity of Coso Hot Springs.

   Simple peak runoff gages should be installed on major ephemeral stream channels near the hot springs.

As appropriate, data collections would be both monthly and by continuous recording. Results of the data program would be evaluated at the end of 12 months. Required changes to increase the effectiveness and to redirect the purpose of the program could be made at that time.

3.0 INTRODUCTION

3.1 SETTING

Coso Hot Springs area lies within the Coso Hot Springs sub-basin (a division of Coso ground-water basin) in southeastern Inyo County, California (Figure 1). Fumarole and hot spring manifestations occur primarily within Sec. 4, T.22S., R.39E. Coso Hot Springs is approximately 28 miles northwest of China Lake, California and 12 miles southeast of Haiwee Reservoir. Access is by U.S. Highway 395 to Coso Junction, California, and thence eastward by gravel road to the hot springs area.

The climate is hot and arid. Long-term average precipitation at nearby Haiwee and Inyokern, California is 6.50 and 3.64 inches, respectively. Most precipitation occurs during winter and early spring. No perennial streams occur within the area investigated.

From a geologic standpoint, Coso Hot Springs is located along the western margin of a down-faulted graben structure. Thermal activity occurs along the base of a geologically youthful, north-south oriented fault scarp.

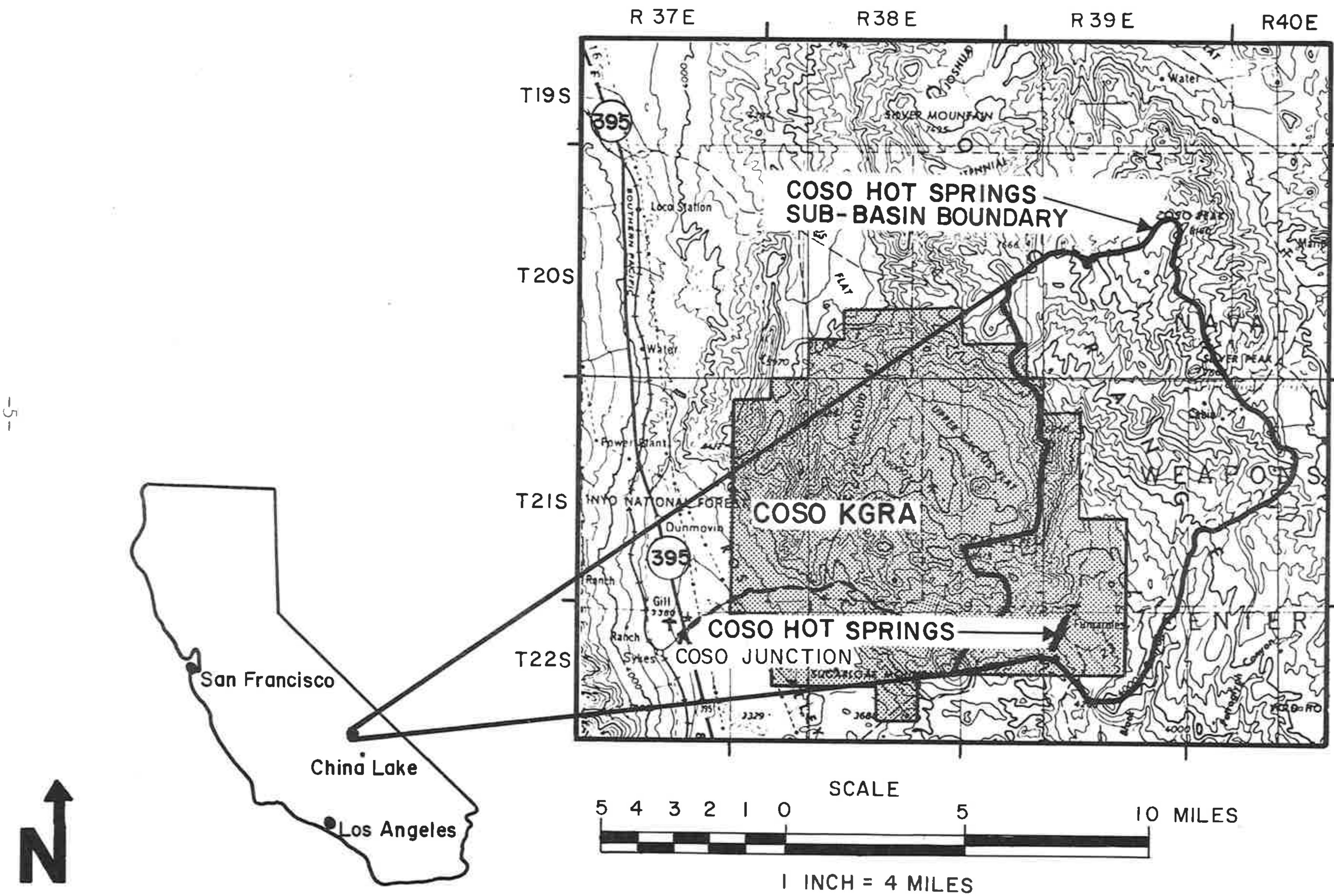


Figure 1. Location Map, Coso Hot Springs, Inyo County, California.

3.2 BACKGROUND AND OBJECTIVES

Hydro-Search, Inc. is under contract to the Naval Facilities Engineering Command, San Bruno, California to perform a hydrologic investigation of Coso Hot Springs and vicinity, Naval Weapons Center, China Lake, California. Objectives are to determine the effects on Coso Hot Springs of anticipated geothermal development in the Coso Known Geothermal Resource Area (KGRA) to the west of the hot springs and to determine how close geothermal development can be conducted without adversely affecting the hot springs.

Content of this investigation included:

1. review of existing geologic, geophysical, and hydrologic information,
2. field examination of geologic rock units and springs and other features of hydrologic significance and sampling of waters for chemical analysis,
3. determination of the local Coso Hot Springs and regional ground-water hydrology, including consideration of recharge, discharge, movement, and water quality; and
4. determination of the possible impact of geothermal development on Coso Hot Springs.

The methods of analysis used in this investigation and the results obtained are appropriate to the quality and quantity of data available.

This investigation was undertaken during the period October 1977 through

January 1978. Personnel of Hydro-Search, Inc. who participated in this investigation include Frank A. Spane, Jr. and Dale C. Bugenig, hydrogeologists, John V.A. Sharp, principal hydrogeologist, and Paul R. Fenske, hydrologic consultant.

3.3 SOURCES OF INFORMATION

Information conçerning Coso Hot Springs is contained in reports of previous investigations (Chapter 8.0). For the most part, these examined the geologic, geophysical, and hydrologic settings from a regional standpoint. Investigations of particular pertinence to the current investigation are mentioned below.

Local geology and structure are covered by regional geologic maps by Jennings (1958), Stinson, et al (1975), and Duffield and Bacon (1977). Lithologic descriptions of geologic materials are contained in reports by Fraser, et al (1942), Chesterman (1956), Austin and Pringle (1970), Babcock and Wise (1973), and Roquemore (1976). Information concerning depth and areal extent of the geothermal reservoir in the vicinity of Coso Hot Springs is included in geophysical studies by Teledyne Geotech (1972), Combs (1975, 1976a-c), Combs and Jarzabek (1977a, b), and Jackson, et al (1977). Basic hydrologic data concerning locations of wells and springs, depths to ground water, and water quality are contained in reports by California State Department of Water Resources (1963, 1964, 1969), Kunkel and Chase (1969), and Moyle (1977).

4.0 GEOLOGY

Plate I shows the regional geology surrounding Coso Hot Springs. Mapping presented in Plate I is a compilation of previous work by Jennings (1958), Stinson, et al (1975), and Duffield and Bacon (1977) and work of the current investigation.

The detailed geology shown in the vicinity of Coso Hot Springs is an improvement over previous regional-scale information. As a result of field inspections and examination of aerial photographs, improvements have been made with respect to location of contacts between Quaternary geologic units and location of areas of hydrothermal alteration. In addition, field inspections have resulted in improved information on lithologic and hydrogeologic characteristics of geologic materials.

4.1 GEOLOGIC STRUCTURE

The geologic structural history has had a profound influence on formation of valleys, depositional patterns of sedimentary materials, drainage development, and location of hot spring - fumarole areas within the Coso Hot Springs sub-basin. The region is dominated by prominent north-south trending fault structures. The location of faults shown in Plate I was taken primarily from Stinson, et al (1975).

Faulting appears to have been active into Recent time. A conspicuous fault scarp marks the eastern limit of hot spring - fumarole activity at Coso Hot Springs. The fault scarp is youthful in appearance with little evidence of dissection by erosion.

4.2 STRATIGRAPHY

Geologic units exposed in the Coso Hot Springs area range from Jurassic (?) to Quaternary in age. They are in chronologic order, i.e., oldest to youngest, granitic intrusives, Tertiary volcanics, Coso Formation, Quaternary volcanics, and Quaternary alluvial deposits. The Quaternary units are, in part, contemporaneous in age. Location and distribution of units described below are shown on Plate I.

4.2.1 Granitic Intrusives

This unit consists of igneous intrusive rocks of Jurassic (?) age, ranging from granite to quartz diorite in composition. Granitic intrusives (Jg) are characterized by porphyritic texture, phenocrysts of quartz, biotite, plagioclase, and orthoclase, and commonly contain mafic inclusions. Granitic intrusives crop out primarily in the mountainous region west of Coso Hot Springs.

The granitic intrusives are cut by numerous younger felsic and basic dikes. A conspicuous glassy basic dike, which ranges in thickness from 3 to 12 feet, crops out along the base of the mountain front immediately west of Coso Hot Springs.

4.2.2 Tertiary Volcanics

Tertiary volcanics (Tb) consist primarily of undifferentiated volcanic flows, breccias, and pyroclastic deposits of basaltic to andesitic composition. Rocks of this unit crop out on the flanks of Coso Peak north and east of Coso Hot Springs. Tertiary volcanics may underlie surficial Quaternary alluvial deposits within the sub-basin.

4.2.3 Coso Formation

The Coso Formation (Tc) includes conglomerates, volcaniclastic sediments, and tuff deposits. The tuff deposits, which are rhyolitic to andesitic in composition, exhibit both lacustrine and air-fall characteristics. On the basis of radioactive age-dating, tuff members within the Coso Formation are reported by Roquemore (1976) to be 2.3 million years B.P. Duffield and Bacon (1977) report dates of 2.5 to 3.1 million years B.P. for similar units.

A composite thickness of approximately 500 feet is exposed along the flanks of Coso Mountains, primarily north and east of Coso Hot Springs. The Coso Formation probably underlies a substantial portion of the valley east of Coso Hot Springs.

4.2.4 Quaternary Volcanics

Quaternary volcanics consist of undifferentiated volcanic flows, breccias, and tuffs of rhyolitic to dacitic composition (Qr) and basaltic to andesitic composition (Qb), perlite domes and rhyolite vent sites (Qrv), and basalt and andesite vent sites (Qbv). The Quaternary volcanics crop out in the mountainous regions surrounding Coso Hot Springs, and may underlie Quaternary alluvial deposits within the sub-basin.

4.2.5 Quaternary Alluvial Deposits

This unit consists of Coso alluvial fan deposits (Qaf) and Recent alluvium (Qal). Coso alluvial fan deposits consist of intercalated layers of unconsolidated sand, gravel, boulders, and clay. These deposits are characterized by their poorly-sorted nature and boulder-strewn surfaces. Coso alluvial fan deposits contain materials of local origin which were deposited by ephemeral streams near the base of mountain areas within the Coso Hot Springs sub-basin.

Recent alluvium (Qal) consists of unconsolidated gravels, sands, and clays deposited in fluvial and lacustrine environments within the valley floors. These deposits are well-sorted and generally contain less coarse materials in comparison to Coso alluvial fan deposits (Qaf). Outside Coso Hot Springs sub-basin, alluvial fan deposits are included within the Recent alluvium designation (Plate I).

4.3 HYDROGEOLOGIC CHARACTERISTICS

Rock types within Coso Hot Springs sub-basin can be assigned to one of two general groupings based on similar hydrogeologic characteristics. Group I includes: granitic intrusives (Jg), Tertiary volcanics (Tb), and Quaternary volcanics (Qr, Qb). Group II consists of the Coso Formation (Tc) and Quaternary alluvial deposits (Qaf, Qal).

Rocks of Group I are of igneous origin. The intrusive and volcanic flow rocks do not contain intergranular openings. Consequently, the ability of these rocks to accept, transmit, and store water is largely a function of the degree of jointing, fracturing, and faulting present. The deep geothermal reservoir is probably contained in well-fractured and well-jointed Jurassic intrusive rocks (Jg). Breccia and pyroclastic rocks of Group I are fragmental and, thus, contain intergranular pore space. However, these rocks are generally impervious because of unfavorable grain size, sorting, and roundness characteristics. As a whole, Group I rocks possess a relatively low degree of permeability and storage capacity as compared to Group II rocks.

Rocks of Group II are unconsolidated to semiconsolidated, sedimentary and volcaniclastic deposits of Tertiary and Quaternary age. These deposits possess intergranular openings for the accommodation of ground water. The grain-size distribution and degree of sorting present, however, exert a strong influence on the relative permeability of these rock types and, thus, on the ability to accept and transmit water. Due to the diversity in grain size and sorting, differences in permeability are evident between rock types of Group II.

The Coso Formation is of variable permeability due to the diversity in rock types. Coarse clastic sedimentary members, e.g., conglomerates and sandstones, appear to be moderately permeable. Tuffs and tuffaceous sedimentary members probably are only slightly permeable due to the preponderance of clay- and silt-sized particles.

The preponderance of coarse, well-sorted sediments within Quaternary alluvial deposits indicates that these materials are pervious. Because of their widespread distribution and apparent thickness, these materials constitute the most important hydrogeologic unit within Coso Hot Springs sub-basin. Poorly-sorted units within alluvial fan deposits and fine-grained lacustrine materials of Recent alluvium are expected to be of low permeability.

Locally, hydrothermal alteration (Qca) of geologic materials reduces permeability. Fraser, et al (1942) and Austin and Pringle (1970) attribute the hydrothermal alteration to reactions of rising acid-sulfate corrosive fumarolic fluids with geologic materials. Localized areas of alteration are particularly prevalent within Group I rock types exposed along the mountain front west of Coso Hot Springs (Plate I). At this locality, granitic intrusive rocks (Jg) have been largely converted to opaline silica, alteration clay, native sulfur, and sulfate minerals. Areas of hydrothermal alteration away from Coso Hot Springs (e.g., Devils Kitchen, Nicol) have not been delineated in Plate I.

5.0 REGIONAL HYDROLOGY

5.1 PRECIPITATION

Long-term precipitation records are not available for the area of investigation. Data for selected nearby climatological stations, however, indicate a long-term average precipitation of 1.82 to 7.52 inches per year (Table 1). For stations with short period of record, long-term average precipitation was projected utilizing a relationship described by Linsley, Kohler, and Paulhus (1949),

$$L_S = R_S \frac{\overline{L}}{\overline{R}} \tag{1}$$

where

L_S = the computed long-term average precipitation at the station,

R_S = the observed short-term average precipitation at the station,

$\overline{L}$ = the long-term average precipitation for a set of representative surrounding stations, and

$\overline{R}$ = the observed short-term average precipitation observed for the set of surrounding stations during the time period represented by R_S.

Precipitation is not distributed uniformly throughout the year. The

Table 1. Summary of Long-Term Precipitation Data for Selected Climatological Stations, California-Nevada.

California Station	Location		Elevation, feet	Precipitation		
	Latitude	Longitude		Years of Record, years	Long-Term Average, inches/year	Computed Long-Term Average, inches/year
Barstow	34° 54'	117° 2'	2160	64	4.13	--
Death Valley	36° 28'	116° 52'	-194	65	1.82	--
Goldstone Echo 2	35° 17'	116° 47'	2950	3	--	3.62
Haiwee	36° 8'	117° 57'	3825	54	6.50	--
Inyokern	35° 39'	117° 49'	2440	28	--	3.64
Panamint City	36° 7'	117° 6'	6240	4	--	7.52
Randsburg	35° 22'	117° 39'	3570	39	5.65	--
Trona	35° 46'	117° 23'	1695	57	3.69	--
Wildrose RS	36° 16'	117° 11'	4100	9	--	5.53
Las Vegas WB, Nevada	36° 5'	115° 10'	2162	40	3.76	--

Precipitation records obtained from "Climatological Data, Annual Summary--California", years 1947-1976; NOAA, Environmental Data Service, National Climatic Center, Asheville, North Carolina.

monthly distribution of long-term precipitation indicates that nearly 73 percent of the annual precipitation occurs between November and March.

Because rainfall within the region is largely controlled by orographic features, areal variation in precipitation is related to differences in elevation. Figure 2 shows the association of long-term average precipitation and elevation for climatological stations listed in Table 1. Average precipitation values for higher elevations were adapted from Rush (1968). Average precipitation at Coso Hot Springs, based on a precipitation-elevation relationship, is estimated as 5.2 inches per year.

5.2 GROUND-WATER FLOW

Ground water migrates from areas of recharge to areas of discharge. Plate II shows the generalized pattern of ground-water movement for shallow (local) and deep (regional) ground-water flow systems. Ground-water flow patterns were developed from hydraulic potential information obtained from wells and springs, areal topographic relationships, and identification of recharge and discharge areas. Ground-water basin and sub-basin boundaries shown in Plate II were adapted from hydrographic drainage designations used by the California State Department of Water Resources.

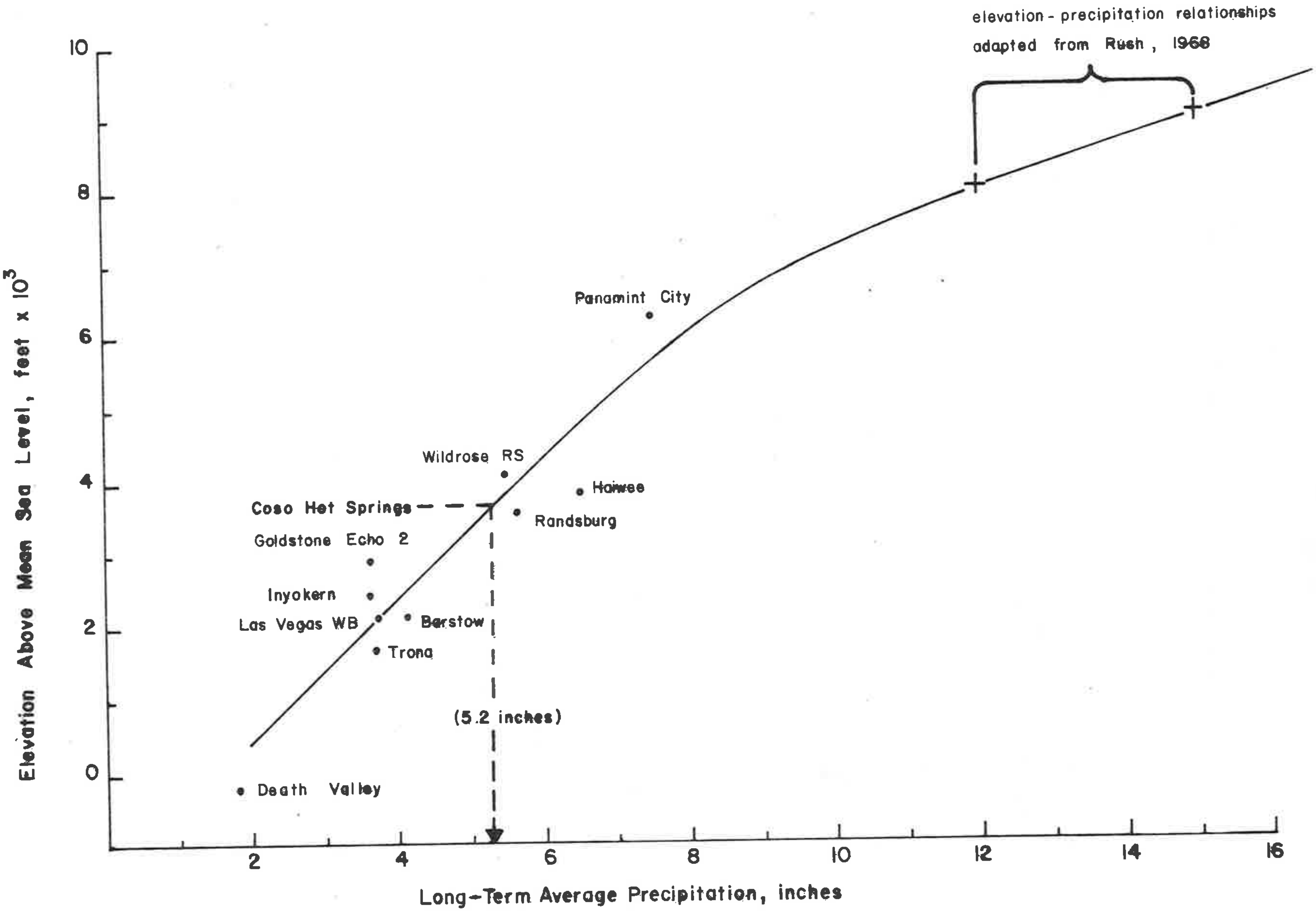


Figure 2. Relationship of Long-Term Average Precipitation and Elevation for Selected Climatological Stations, California-Nevada.

Local ground-water flow is strongly influenced by topography, distribution and hydrogeologic characteristics of geologic materials, and geologic structures. Recharge occurs as a result of infiltration of intra-basin precipitation and runoff and subsurface underflow from adjoining basins. Pervious Quaternary alluvial deposits (Qaf, Qal) along the base of mountain-runoff regions are the primary recharge areas for local ground-water flow systems. Local ground-water discharge areas are characterized by the presence of springs, marshy areas, and playa lakes. Important local discharge areas within valley bottoms of closed topographic basins include Owens, Searles, and Panamint Valleys.

The general patterns of deep, regional ground-water flow are relatively less influenced by local topographic features and local variations in hydrogeologic characteristics. Recharge to the deep regional ground-water flow system within the southern Lahontan drainage occurs primarily by infiltration of precipitation and runoff along the eastern flank of the Sierra Nevada. Deep regional flow of ground water appears to be toward the east with ultimate discharge along the floor of Death Valley. The structural grain of the basement rocks within which this flow occurs is north-south. Consequently, west to east flow is difficult except along structural zones which are both pervious and include a west to east directional component.

The general eastward direction of regional ground-water flow is distorted by the presence of deep-seated geothermal reservoirs. For example, in the Coso Hot Springs area, deep regional ground water intermixes with rising fluids from an underlying body of molten magma and as a result some of this deep ground water moves to the surface.

6.0 HYDROLOGY OF COSO HOT SPRINGS SUB-BASIN

The few data available indicate that ground-water depths within the valley floor of the sub-basin range from 60 to 130 feet below land surface. Recharge to ground water occurs by infiltration of intra-basin precipitation and consequent runoff and possibly by subsurface underflow from Upper Cactus Flat ground-water basin to the north. Ground water flows toward the south, ultimately discharging as inter-basin underflow to Coso ground-water basin to the south (Plate II). Minor quantities of ground water are lost through evapotranspiration and by spring and fumarole discharge at Coso Hot Springs.

6.1 RECHARGE AND MOVEMENT OF GROUND WATER

A technique employed by the U.S. Geological Survey and applicable to ungaged basins was utilized to estimate potential recharge. This method utilizes empirical precipitation-potential recharge percentages for discrete elevation zones. For example, this method was used for estimating potential recharge to Clayton Valley (Rush, 1968) and Amargosa Desert, Nevada-California (Walker and Eakin, 1963). These areas are approximately 150 and 60 miles northeast of Coso Hot Springs.

An estimate of potential recharge to Coso Hot Springs sub-basin utilizing this method is given in Table 2. Acreage listed for discrete elevation zones within the sub-basin was obtained by planimetering U.S. Geological Survey 1:62,500 scale topographic maps. Assigned estimates of average precipitation and potential recharge percentages for various elevation zones were taken from Figure 2 and Rush (1968), respectively.

Approximately 375 acre-feet/year of intra-basin precipitation is available, on average, for recharge to ground water. In addition, one-third of the average estimated potential recharge within Upper Cactus Flat ground-water basin, about (1/3 x 45 acre-feet =) 15 acre-feet per year, may be transferred to Coso Hot Springs sub-basin by underflow. Accordingly, Coso Hot Springs sub-basin receives approximately 390 acre-feet per year of recharge to the shallow ground-water system.

Recharge occurs primarily in pervious Quaternary deposits (Qaf, Qal) which apron mountain-runoff regions within the sub-basin. Based on the distribution of Quaternary alluvial deposits and sub-basin hypsometric characteristics, most recharge occurs immediately west and northeast of Coso Hot Springs. Local ground water moves to the south from intra-basin recharge areas, ultimately discharging to Coso ground-water basin.

Table 2. Estimated Average Annual Precipitation and Potential Recharge to Coso Hot Springs Sub-basin.

		Estimated Precipitation			Estimated Potential Recharge	
Elevation Zone, feet	Area, acres	Range, inches	Average feet	Average acre-feet	Percentage of the total precipitation	Acre-Feet per year
> 8,000	25	12	1.	25	7	---
7,000 - 8,000	4,420	9.6 - 12	.9	3,980	3	120
6,000 - 7,000	11,580	8.0 - 9.6	.74	8,570	3	255
5,000 - 6,000	10,320	6.8 - 8.0	.62	6,400	minor	---
4,000 - 5,000	9,085	5.7 - 6.8	.53	4,815	minor	---
3,480 - 4,000	5,240	4.6 - 5.7	.43	2,255	minor	---
Total	40,670			26,045		375

Assigned estimates for average precipitation taken from Figure 2; estimates of potential recharge percentages for precipitation zones adapted from Rush (1968).

Deep regional ground water flows into the Coso Hot Springs sub-basin from recharge areas along the Sierra Nevada (Plate II). Based on the precipitation-recharge relationship previously described (Table 2), the quantity of regional ground water flow through the sub-basin is estimated to be approximately 2800 acre-feet per year.

6.2 HYDROLOGY OF COSO HOT SPRINGS

The hydrology of Coso Hot Springs is characterized by the mixing of ground waters of deep (geothermal) and shallow (local) origin. Previous regional geophysical and geothermal investigations by Furgerson (1973), Combs (1975, 1976a,c), Combs and Jarzabek (1977a), and Jackson, et al (1977) indicate that the underlying geothermal reservoir is areally extensive, with the majority of the reservoir occurring west of the hot springs area. The eastern boundary of the geothermal reservoir is conjectured to be slightly east of Coso Hot Springs (Combs, 1975, 1976c). In the immediate vicinity, a pervious north-south trending fault structure allows deep-seated geothermal fluids to rise to shallow depths (Plate I). Cold ground water of local origin, moves laterally and intermingles with the rising hot geothermal fluids. Primary areas of local ground-water recharge are within alluvial fan deposits (Qaf) and Recent Alluvium (Qal), immediately west and north of Coso Hot Springs.

Interpretive hydrogeologic cross sections (Figure 3 - A-A', B-B') show

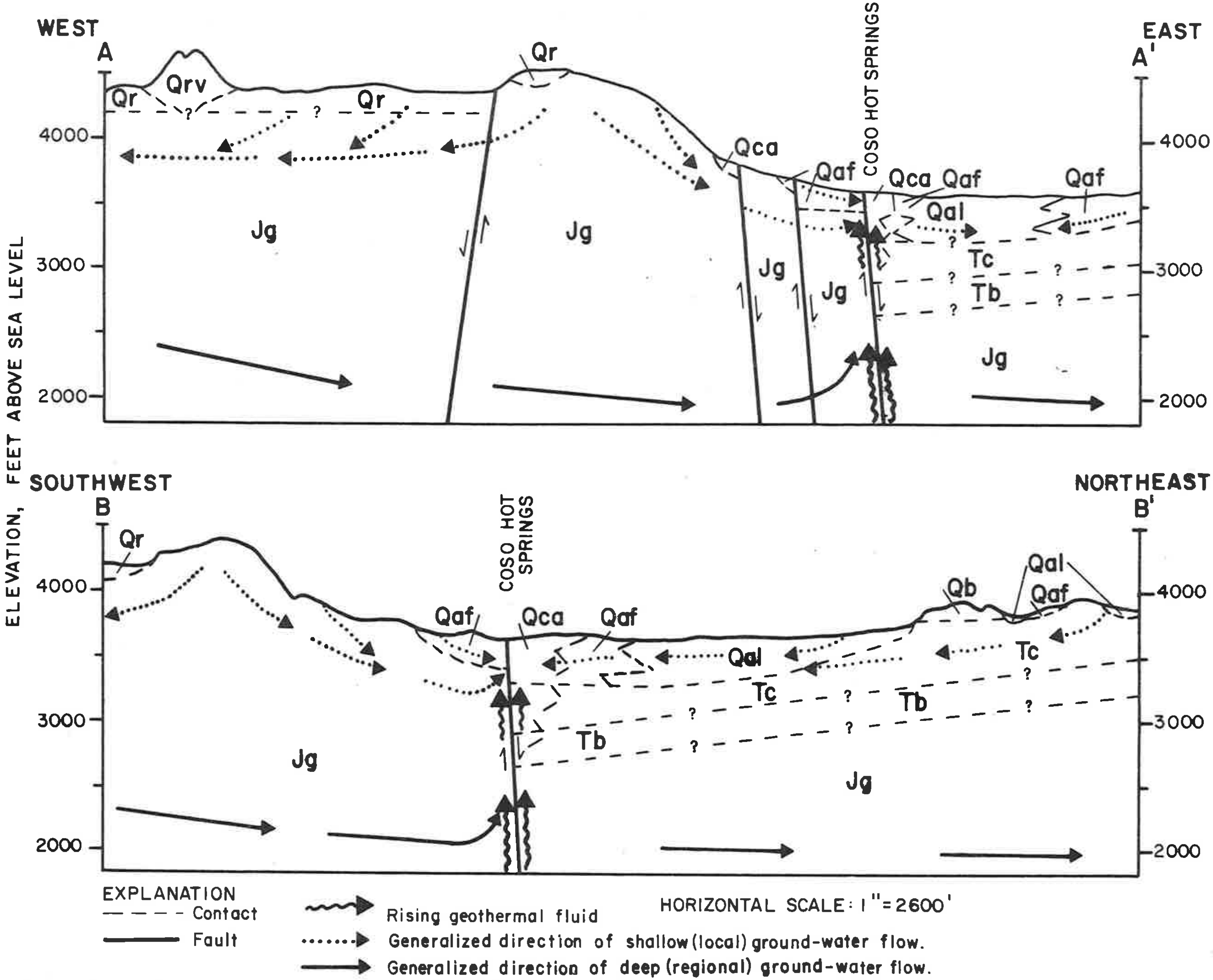


Figure 3. Interpretive Hydrogeologic Cross Sections, Coso Hot Springs and Vicinity.

generalized paths of movement of ground water and subsurface geologic conditions in the vicinity of Coso Hot Springs. Cross section locations are shown in Plate I.

6.2.1 Site Information

Field inspection of Coso Hot Springs suggests that considerable surficial modification has occurred. Past man-related efforts have focused on construction of wells and development of the spring to enhance surface discharge. These activities appear to have increased thermal activity of Coso Hot Springs by increasing communication between the shallow, local ground-water system and the rising geothermal fluids.

During December 1977 surface temperatures for spring discharge and pools ranged between 31 and 91.2° C. Generally, wells of greater depth contained higher water temperatures. Depths to ground water for wells at Coso Hot Springs ranged from one to 110 feet below ground level. Shallow depths to water are attributable to localized perched ground-water conditions.

6.2.2 Fluctuations in Spring Discharge

Characteristics of the fluid discharge at Coso Hot Springs are determined by the relative contribution of geothermal fluids and local ground water. Due to the wide areal extent, deep-seated origin, and current undeveloped condition of the deep geothermal reservoir, contributions by rising geothermal fluids to Coso Hot Springs are expected to be relatively constant with time. Local ground-water contribution, in contrast, would be highly variable with time due to the limited areal extent of the aquifer and the consequent rapid response of the aquifer to precipitation-recharge events.

Observations by Austin (personal communication, 1977) indicate that local precipitation-recharge events have a discernible impact on characteristics (e.g., flow, water levels, temperature) of Coso Hot Springs. To examine the association of local ground-water contribution to variation of hot spring activity, a comparison was made of monthly precipitation and available historical water temperature and ground-water level information. Figure 4 shows the relationship of precipitation at nearby Haiwee, California (Plate II) to temperature and ground-water depth within a shallow well (22S/39E-4K2M) in Coso Hot Springs (Plate I).

Interpretation of Figure 4 assumes that:

1. precipitation at Haiwee is representative of precipitation conditions at Coso Hot Springs,

2. precipitation, recharge, and local ground-water contribution to Coso Hot Springs have a high degree of association, and

3. the shallow well examined is representative of hydrologic conditions within Coso Hot Springs.

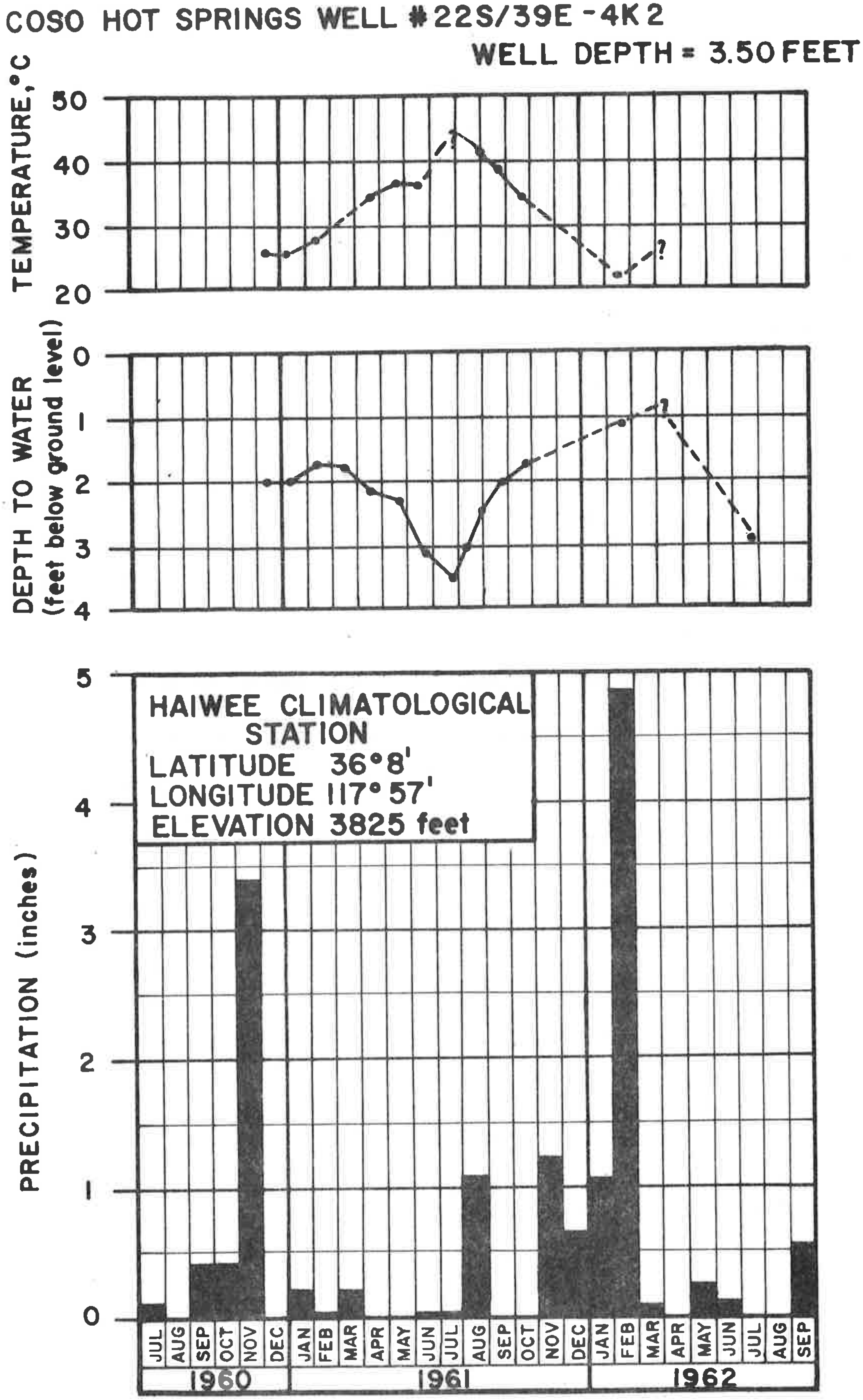


Figure 4. Relationship of Water Temperature and Ground-Water Depth at Coso Hot Springs, and Monthly Precipitation at Haiwee, California.

These are reasonable assumptions from the standpoint of basic hydrologic relationships and observed hydrogeologic features. From the above, we may assume that higher water temperatures and lower ground-water levels are related to decreases in local ground-water contribution; and lower temperatures and higher ground-water levels are associated with increases in local ground-water contribution.

Examination of Figure 4 indicates that water temperature and ground-water levels exhibit:

1. a strong seasonal oscillatory pattern,
2. a strong inverse correlation, and
3. an association with monthly precipitation distribution.

The evident seasonal oscillatory pattern suggests a strong influence of local ground-water contribution within the Coso Hot Springs regimen. As expected, low temperatures and high ground-water levels are associated with and exhibit a lagged response to periods of high precipitation and recharge, while high temperature and low ground-water levels follow periods of low precipitation and recharge.

6.3 GROUND-WATER CHEMISTRY

Water samples were collected during late November-early December from four locations at Coso Hot Springs (CS-5, 6, 7, 8) and at four nonthermal spring locations (CS-1, 2, 3, 4). Locations of sample sites are shown in Plate I.

Samples were filtered in the field to remove particulate matter. Chemical analysis for major inorganic constituents was performed by the Water Chemistry Laboratory, Desert Research Institute, University of Nevada-Reno. A computer printout of analytical results and calculated water-chemistry parameters is included in Appendix A.

Purpose of the water chemistry investigation was to determine if systematic differences exist between chemistry of thermal and nonthermal waters and, if so, whether such differences would provide information as to source and proportional mixing of waters. Nonthermal well sources do not exist in the area and sampling was limited to springs. Whether the spring waters sampled are representative of shallow ground waters at Coso Hot Springs is not known. The nonthermal waters are alkaline with total dissolved solids concentrations less than 1,000 mg/l. Calcium and magnesium are the dominant cations. Bicarbonate is the dominant anion. In one instance (CS-3), sulfate is the dominant anion.

In contrast, three of the thermal waters (CS-5, 6, 7) are acidic. Concentration of total dissolved solids increases with decrease in pH. Sulfate is by far the dominant anion. Calcium is the dominant cation, but sodium is relatively more important than in the case of the nonthermal waters. With increase in temperature, pH decreases and total dissolved solids and silica increase. Poor anion/cation balances for samples CS-6 and 7 are only partially compensated for by hydrogen ions. Other unknown factors contribute to the imbalance.

The waters of samples CS-5 through 7 probably are a composite of waters of local ground water and deep-seated geothermal origin. As such, their water chemistry, along with temperature, should vary with proportional contribution of nonthermal water to the mixture. For example, Pool K-2 (CS-5) at 31.^{o} C is near the minimum temperature recorded in 1960-62 and almost exactly the same temperature as in November-December 1961 (Figure 4). The chemistry of K-2 water along with the temperature and potentiometric level should vary as proportion of nonthermal water varies which in turn responds with lag to precipitation.

The water of Well K-1 (CS-8) appears to be a condensate. The relationship to the other thermal waters is not clear at this time. Wells which derive waters from deeper zones (i.e., below 220 feet) within Coso Hot Springs are reported to be of a sodium-chloride type, with neutral to slightly alkaline pH conditions. The predominance of chloride in deeper thermal waters is suggested by Austin and Pringle (1970) to be related to distillation of incoming local ground water to the Coso Hot Springs system. These deeper wells are not available for sampling at this time.

In summary, discernible differences in chemistry of major constituents appear to exist between thermal and nonthermal waters, and within the group of thermal waters. Investigation over a period of time may disclose that sources and proportions of mixing of waters can be determined from water chemistry data and water temperature measurements. Such data would have to be taken periodically as hydrogeologic conditions vary. Trace constituents and possibly stable and unstable isotopes (oxygen, carbon, hydrogen species) possibly also would be useful in this regard.

7.0 ANTICIPATED IMPACT OF GEOTHERMAL DEVELOPMENT ON COSO HOT SPRINGS

Based on available geophysical investigations and current exploration drilling operations, the anticipated area for geothermal development is located between Cactus Peak and Sugarloaf Mountain (Plate I), approximately 2.5 miles west of Coso Hot Springs. Rodgers (personal communication, 1977) states that planned production well(s) for a possible 50 megawatt generation plant would extract:

Type of Fluid	Flow Required (lbs/hr)	Discarded or Reinjected (lbs/hr)
Steam (saturated)	1,000,000	600,000
Hot Water (20% steam)	2,638,333	2,000,000

Production of geothermal fluids at projected flow rates translates approximately to the removal of 3360 to 8870 acre-feet per year of ground water (@ 1 atm. and 100° C), depending on geothermal fluid type. Development within the area would be confined to removal of fluids of deep geothermal origin, rather than of the shallow local ground-water flow system.

Utilized geothermal fluids would either be reinjected or discarded. If reinjected, the net removal of fluids for geothermal development would range from 1345 to 2145 acre-feet per year.

The impact of geothermal development can be evaluated by looking at conditions under the worst situation. If the impact on the regimen of Coso Hot Springs is acceptable under these conditions, it will be acceptable under all situations of similar production rate. The impact on Coso Hot Springs would be expected to be the greatest under production conditions of a hot-water, dominated geothermal reservoir. Steam production from a vapor-dominated reservoir is not considered to have as severe impact because the total amount of water produced is less, and the demand upon the regional ground-water system would be more dispersed.

Evidence supportive of the second factor is that in a vapor-dominated reservoir the relative permeability to ground water is extremely low. Ground water in the deep regional flow system would be expected to flow around the geothermal reservoir. The only water entering the system would be make-up water required to take the place of the steam produced by natural discharge of Coso Hot Springs and geothermal energy production. In a large vapor-dominated geothermal reservoir, this make-up water would enter over an area the size of the reservoir, and its impact for any small area would, therefore, be extremely small.

The impact analysis of a worst case, water-dominated geothermal system includes the following assumptions:

1. approximately 8870 acre-feet of water will be produced each year and none of this water will be reinjected to the system,

2. the north-south regional permeability is of the order of twenty-five times greater than the east-west regional permeability,

3. recharge and regional flow of ground water is approximately 260 acre-feet per year per mile of Sierra Nevada front, and

4. the geothermal development will be localized at a point approximately 2.5 miles directly upstream of Coso Hot Springs in the regional flow system, the area of current exploration test drilling.

The volume rate of hot water production is based upon the requirements of the hot water geothermal plant given by Rodgers. The presence of anisotropic permeability is inferred from the geological map, which shows strong, preferential, north-south trending structural fabric in the vicinity of the proposed geothermal development and Coso Hot Springs. The ratio between north-south and east-west permeability is probably much greater than the value used. Recharge and regional ground-water flow is based upon the 2800 acre-feet of west to east underflow discussed previously.

An idealized flow net for this system is shown in Figure 5. The important point on the flow net is the projected stagnation point. This point is on the limiting flow line which separates ground-water flow toward Coso Hot Springs from flow toward the geothermal development. Under the conditions assumed, no water would be removed from Coso Hot

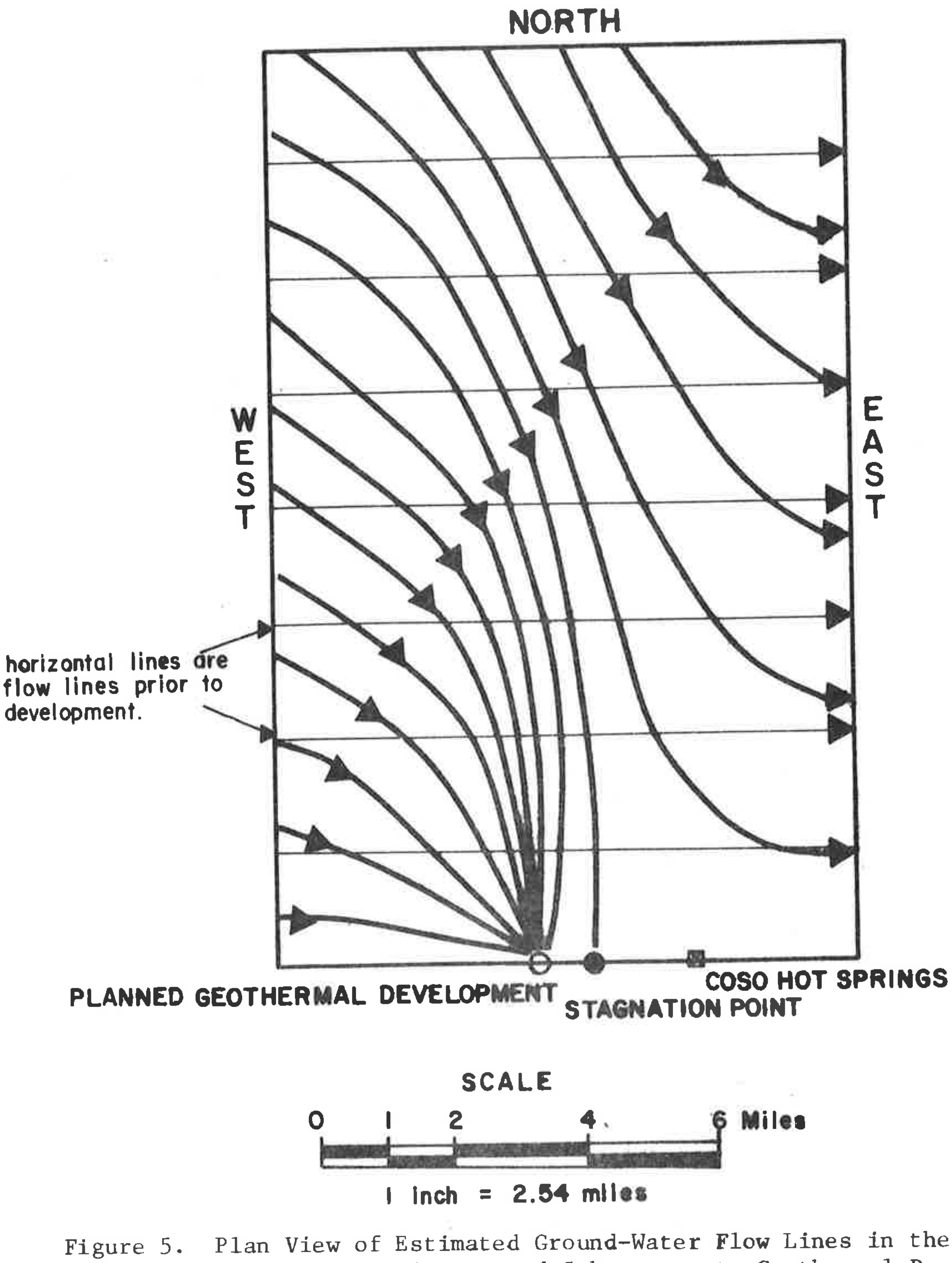


Figure 5. Plan View of Estimated Ground-Water Flow Lines in the Regional Flow System Prior to and Subsequent to Geothermal Development.

Springs area to feed the geothermal development. The stream lines, however, have not completely converged to their original spacing, indicating a lowering of the flow rate and hydraulic gradient at the hot springs and for some distance to the east. This lowering of the hydraulic gradient has two effects:

1. regional ground water would move to the east away from Coso Hot Springs at a rate slower than under natural conditions, and

2. hydraulic head in the deep regional system at the springs would be expected to be lower.

The impact of these two factors on the local hot spring hydrology is difficult to evaluate without detailed knowledge of the local hydraulic gradient in the deep regional ground-water flow system and the nature of the geothermal reservoir. Hydraulic gradients in the regional flow systems, however, are expected to be quite low, and the drop in hydraulic head caused by a local decline in gradient, therefore, would be anticipated to be small. Because the discharge of the springs is largely controlled by the local ground-water flow system, a small lowering of the hydraulic head in the regional system is probably not of consequence to the regimen of the spring system. Furthermore, if this impact is unacceptable, the reduction in hydraulic head could be compensated for by the injection of a portion of the hot water output of the geothermal plant into the regional flow system near the Coso Hot Springs' side of the stagnation point. Regulated injection at this designated area would maintain the hydraulic head at Coso Hot Springs at any desired level, while minimizing recycled water at the geothermal development.

In summary, it appears that the worst conditions of geothermal development, a 50 megawatt plant which would require 8870 acre-feet of hot water per year, would have only minor influence on the local hydrology of Coso Hot Springs. In the event that it is necessary to minimize possible impact, preventative measures could include:

1. limitation of geothermal production wells to the extreme western portion of Coso Hot Springs sub-basin,
2. selective reinjection of degraded geothermal fluids between the geothermal development and Coso Hot Springs, and
3. limiting removal of geothermal fluids to the deepest aquifer zones.

The above analysis of impact is for a geothermal development of 50 megawatts. Geothermal development usually proceeds in stepwise increments, and in the present case development exceeding 50 megawatts would have relatively greater impact on Coso Hot Springs. This greater level of geothermal development could require large scale selective reinjection of degraded geothermal fluids to maintain the regimen of Coso Hot Springs.

8.0 SOURCES OF INFORMATION

Austin, C.F. and J.K. Pringle, 1970, Geologic Investigations at the Coso Thermal Area, Naval Weapons Center, China Lake, California, TP 4878, 40 p.

Babcock, J.W. and W.S. Wise, 1973, Petrology of Contemporaneous Quaternary Basalt and Rhyolite in the Coso Mountains, California, Geol. Soc. America Abstract, with program, v. 5, No. 1, 6 p.

California State Department of Water Resources, 1963, Data on Water Wells in Indian Wells Valley Area, Inyo, Kern, and San Bernadino Counties, California, Bulletin No. 91-9, 243 p.

California State Department of Water Resources, 1964, Ground-Water Occurrence and Quality - Lahontan Region, Bulletin No. 106-1, 439 p.

California State Department of Water Resources, 1969, Water Wells and Springs in Panamint, Searles, and Knob Valleys, San Bernadino and Inyo Counties, California, Bulletin No. 91-17, 110 p.

Chesterman, C.W., 1956, Pumice, Pumicite, and Volcanic Cinders in California, California Division of Mines, Bulletin 174, pp. 62-67.

Combs, J., 1975, Heat Flow and Microearthquake Studies, Coso Geothermal Area, China Lake, California, Final report to Advanced Research Projects Agency, ARPA Order No. 2800, Contract No. N00123-74-C-2099, 65 p.

Combs, J. ed., 1976a, The Coso Geothermal Project, Technical Report #1, Report to U.S. Energy Research and Development Administration, ERDA Prime Contract E(45-1)-1830, 18 p.

Combs, J. ed., 1976b, The Coso Geothermal Project, Technical Report #2, Report to U.S. Energy Research and Development Administration, ERDA Prime Contract E(45-1)-1830, 37 p.

Combs, J., 1976c, Heat Flow Determinations in the Coso Geothermal Area, California, The Coso Geothermal Project, Technical Report #3, U.S. Energy Research and Development Administration, ERDA Prime Contract E(45-1)-1830, 24 p.

Combs, J. and D. Jarzabek, 1977a, Seismic Evidence for a Deep Heat Source Associated with the Coso Geothermal Area, California, The Coso Geothermal Project, Technical Report #4, U.S. Energy Research and Development Administration, ERDA Prime Contract E(45-1)-1830, 13 p.

Combs, J. and D. Jarzabek, 1977b, Preliminary Seismic Wave Attenuation and Poisson's Ratio Studies at the Coso Geothermal Area, California, The Coso Geothermal Project, Technical Report #5, U.S. Energy Research and Development Administration, ERDA Prime Contract E(45-1)-1830, 31 p.

Combs, J. and Y. Rotstein, 1976, Microearthquake Studies at the Coso Geothermal Area, China Lake, California, Report in Proceedings of Second United Nations Symposium on the Development and Use of Geothermal Resources, v. 2, pp. 909-916.

Duffield, W.A., 1975, Late Cenozoic Ring Faulting and Volcanism in the Coso Range Area of California, Geology v. 3, pp. 335-338.

Duffield, W.A. and C.R. Bacon, 1977, Preliminary Geologic Map of the Coso Volcanic Field and Adjacent Areas, Inyo County, California, U.S. Geological Survey Open-File Map 77-311.

Dupuy, L.W., 1948, Bucket-Drilling the Coso Mercury Deposit, Inyo County, California, U.S. Bureau Mines, Rept. Invest. 4201, 45 p.

Fraser, H.J., H.D.B. Wilson, and N.W. Hendry, 1942, Hot Spring Deposits of the Coso Mountains, California, Journal of Mines and Geology, v. 38, pp. 223-242.

Furgerson, R.B., 1973, Progress Report on Electrical Resistivity Studies, Coso Geothermal Area, Inyo County, California, Naval Weapons Center, China Lake, California, TP 5497, 38 p.

Jackson, D.B., J.E. O'Donnell, and D.I. Gregory, 1977, Schlumberger Soundings, Audio-Magnetotelluric Soundings and Telluric Mapping in and Around the Coso Range, California, U.S. Geological Survey Open-File Report 77-120, 50 p.

Jennings, C.W., 1958, Geologic Map of California - Death Valley Sheet, California Division of Mines and Geology.

Jennings, C.W., J.L. Barnett, and B.W. Troxel, 1962, Geologic Map of California - Trona Sheet, California Divison of Mines and Geology.

Koenig, J.B., S.J. Gawarecki and C.F. Austin, 1972, Remote Sensing Survey of the Coso Geothermal Area, Inyo County, California, Naval Weapons Center, China Lake, California, TP 5233, 32 p.

Kunkel, F. and G.H. Chase, 1969, Geology and Ground Water in Indian Wells Valley, California, U.S. Geological Survey, Open-File Report, 84 p.

Lanphere, M.A., G.B. Dalrymple, and R.L. Smith, 1975, K-Ar Ages of Pleistocene Rhyolitic Volcanism in the Coso Mountains, California, Geology, v. 3, pp. 339-341.

Lee, C.H., 1912, Water Resources of a Part of Owens Valley, California, U.S. Geological Survey, Water Supply Paper 294, 135 p.

Linsley, R.K., M.A. Kohler, and J.L. Paulhus, 1949, Applied Hydrology, McGraw-Hill, Inc., New York.

Moyle, W.R., Jr., 1977, Summary of Basic Hydrologic Data Collected at Coso Hot Springs, Inyo County, California, U.S. Geological Survey, Open-File Report 77-485, 93 p.

National Oceanic and Atmospheric Administration, Climatological Data, Annual Summary - California, years 1947-1976.

Roquemore, G., 1976, The Cenozoic History of the Coso Mountains as Determined by Tuffaceous Lacustrine Deposits, Unpublished Master of Arts thesis, Department of Geology, California State University, Fresno, 65 p.

Rush, F.E., 1968, Water-Resources Appraisal of Clayton Valley-Stonewall Flat Area, Nevada and California, Nevada Dept. Conserv. and Nat. Resources--Reconn. Ser. Rept. 45, 54 p.

Stinson, M., P. St. Amand, and G. Roquemore, 1975, Geologic and Structural Map of Part of the Coso Mountains, Inyo County, California, Unpublished Naval Weapons Center, China Lake, California map publication.

Teledyne Geotech, 1972, Geothermal Noise Survey of the Coso Hot Springs Area, Naval Weapons Center, China Lake, California, Technical Report No. 72-6, 18 p.

Troxell, H.C. and W. Hoffman, 1954, Hydrology of the Mojave Desert, California Division of Mines, Bulletin 170, Geology of Southern California, Chapter VI, pp. 13-18.

Walker, G.E. and T.E. Eakin, 1963, Geology and Ground Water of Amargosa Desert, Nevada-California, Nevada Dept. Conserv. and Nat. Resources--Reconn. Ser. Rept. 14, 45 p.

Zbur, R.T., 1963, A Geophysical Investigation of Indian Wells Valley, California, U.S. Naval Ordinance Test Station, China Lake, California, TP 2795, 98 p.

Personal Communication

Austin, C.F., 1977, personal communication, Head, Geothermal Utilization Division, Code 266, Naval Weapons Center, China Lake, California, 93555.

Rodgers, C.R., 1977, personal communication, Geothermal Utilization Division, Code 2661, Naval Weapons Center, China Lake, California, 93555.

APPENDIX A

CHEMICAL COMPOSITION OF SELECTED SPRING AND GROUND-WATER SOURCES, COSO HOT SPRINGS SUB-BASIN, INYO COUNTY, CALIFORNIA.

SUMMARY OF WATER ANALYSIS REPORT DATE 01/16/78

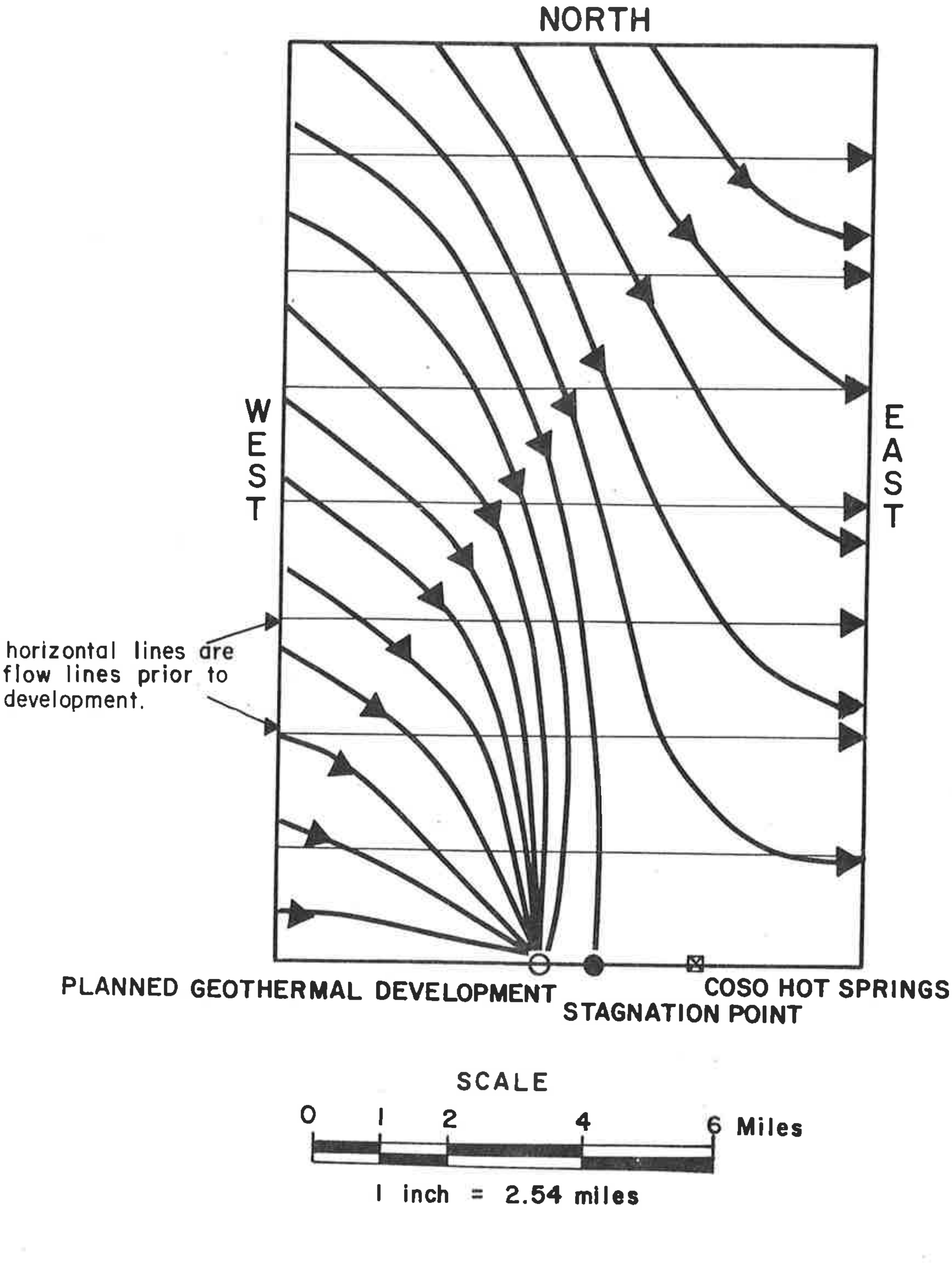
SAMPLE POINT / LOCATION DATA		DEAD END SPRING T21S R40E 7/AS			WILDHORSE SPRING T21S R39E 1/HS			COLES SPRING T20S R40E 32/MS		
SAMPLE NUMBER		CS-1			CS-2			CS-3		
COLLECTION DATE, TIME		11/30/77			11/30/77			12/01/77		
TEMPERATURE (C)		12.50			12.50			9.00		
PH (F=FIELD, L=LAB)		7.29L			7.23L			7.77L		
TDS (SUM OF GROSS PPM)		455.50			442.40			884.10		
TDS (BY EVAPORATION)										
TDS (BY CALCULATION)		328.93			357.01			794.64		
TDS (SUM LESS SIO2)		421.50			412.40			856.10		
SP. COND. (U-MS/CM @ 25C)		525.00L			550.00L			1020.00L		
GROSS ANALYSIS		PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO
HCO3-		249.00	4.081	.725	168.00	2.754	.479	176.00	2.885	.228
CO3=										
CL-		21.00	.592	.105	21.00	.592	.103	37.00	1.043	.083
SO4=		45.00	.937	.167	115.00	2.394	.417	418.00	8.703	.689
F-		.30	.016	.003	.10	.005	.001	.10	.005	.000
NO3-										
PO4---										
TOTAL ANIONS		315.30	5.626		304.10	5.745		631.10	12.636	
NA+		30.00	1.305	.238	27.00	1.175	.210	39.00	1.697	.137
K+		1.70	.043	.008	5.00	.128	.023	4.00	.102	.008
CA++		61.50	3.069	.559	61.00	3.044	.543	135.00	6.737	.543
MG++		13.00	1.069	.195	15.30	1.258	.225	47.00	3.865	.312
TOTAL CATIONS		106.20	5.486		108.30	5.605		225.00	12.401	
SIO2	(PPM)		34.00			30.00			28.00	
TOTAL EPM	(EPM)		11.112			11.350			25.037	
ANIONS / CATIONS	(EPM)		1.025			1.025			1.019	
AG	(PPM)									
AS	(PPM)									
B	(PPM)									
BA	(PPM)									
CD	(PPM)									
CN	(PPM)									
CO	(PPM)									
CR	(PPM)									
CU	(PPM)									
FE	(PPM)									
HG	(PPM)									
MN	(PPM)									
MO	(PPM)									
NI	(PPM)									
PB	(PPM)									
SE	(PPM)									
V	(PPM)									
ZN	(PPM)									
GROSS ALPHA	(PCI/L)									
RADIUM-226	(PCI/L)									
NATURAL URANIUM	(PCI/L)									
CA / MG	(EPM)		2.870			2.419			1.743	
NA / CA	(EPM)		.425			.386			.252	
CA+MG / NA+K	(EPM)		3.069			3.303			5.894	
HCO3+CO3 / CL+SO4	(EPM)		2.669			.922			.296	
SO4 / CL	(EPM)		1.582			4.043			8.341	

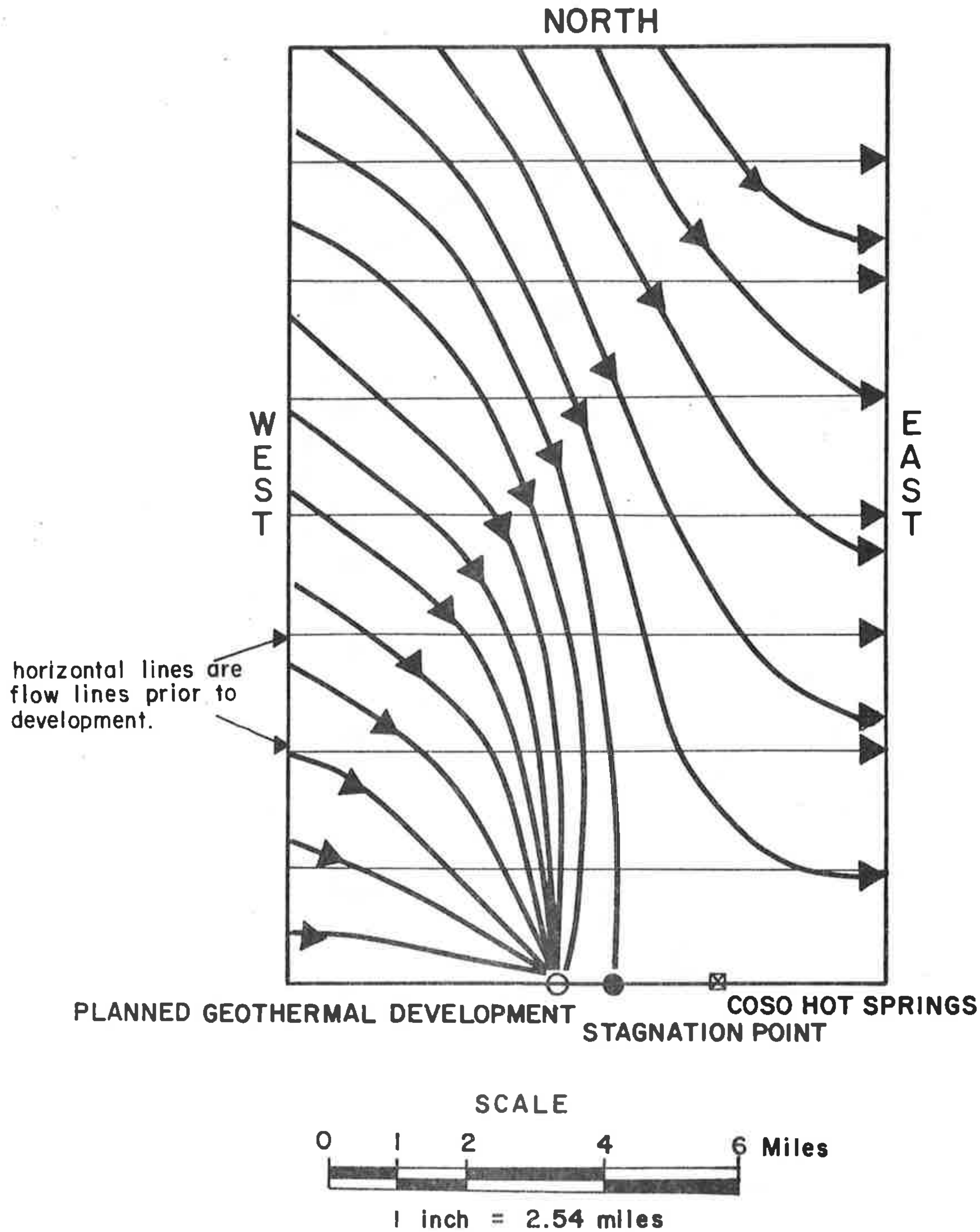
SUMMARY OF WATER ANALYSIS REPORT DATE 01/16/78

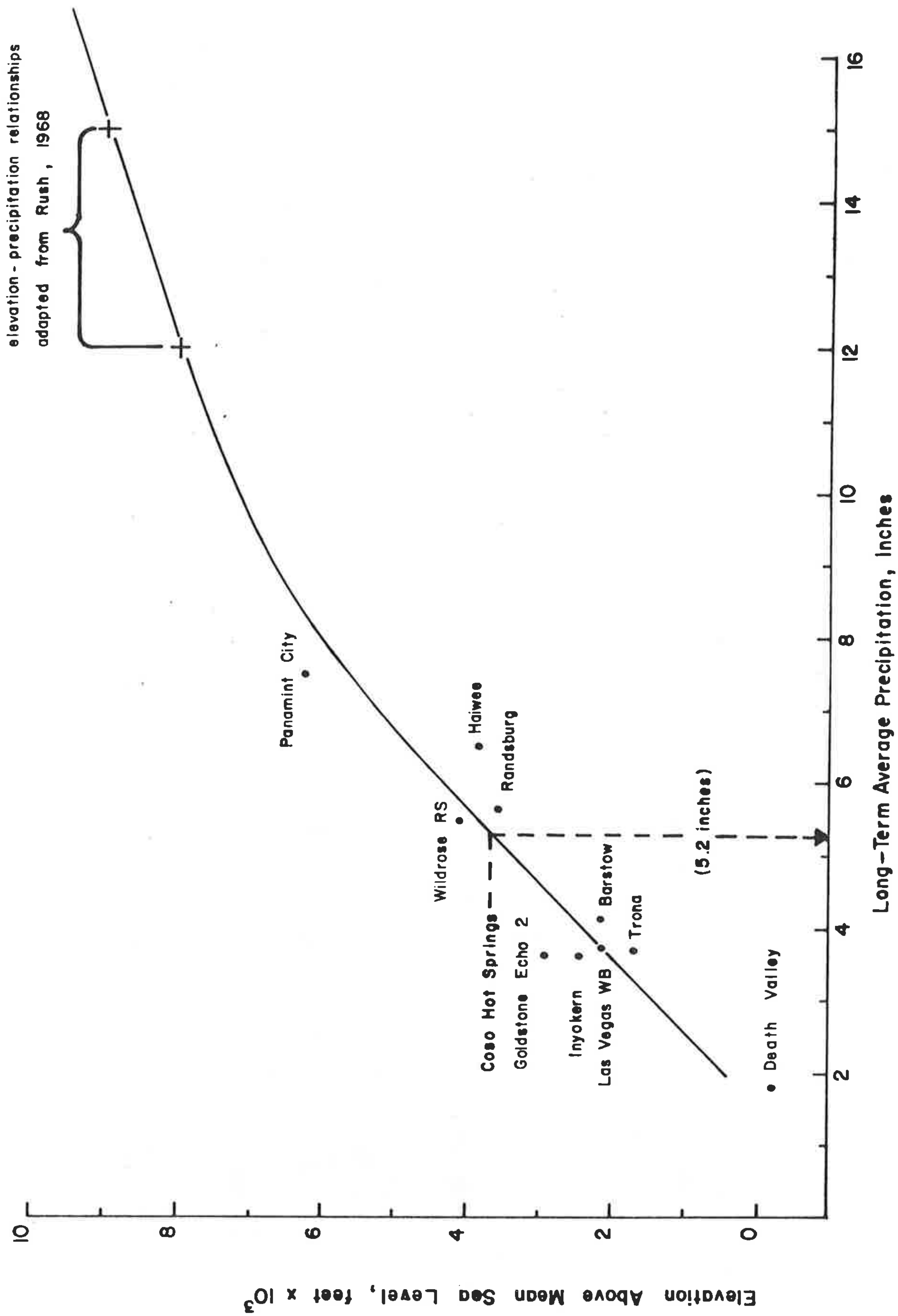
SAMPLE POINT LOCATION DATA			HAIWEE SPRING T21S R39E 10/PS			POOL K-2 T22S R39E 4/K2			POOL K-3 T22S R39E 4/4K3
SAMPLE NUMBER			CS-4			CS-5			CS-6
COLLECTION DATE, TIME			11/30/77			12/02/77			12/02/77
TEMPERATURE (C)			15.50			31.00			78.00
PH (F=FIELD, L=LAB)			7.48L			4.22L			2.62L
TDS (SUM OF GROSS PPM)			387.40			521.60			795.40
TDS (BY EVAPORATION)									
TDS (BY CALCULATION)			309.11			521.60			795.40
TDS (SUM LESS SIO2)			333.40			356.60			590.40
SP. CONC. (U-MS/CM @ 25C)			430.00L			640.00L			1610.00L
GROSS ANALYSIS		PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO
HCO3-		156.00	2.557	.556						
CO3=										
CL-		14.30	.403	.088	1.60	.045	.009	1.00	.028	.003
SO4=		78.00	1.624	.353	250.00	5.205	.988	514.00	10.701	.997
F-		.30	.016	.003	.30	.016	.003	.10	.005	.000
NO3-										
PO4---										
TOTAL ANIONS		248.60	4.600		251.90	5.266		515.10	10.735	
NA+		28.00	1.218	.271	42.00	1.827	.374	30.60	1.331	.396
K+		4.80	.123	.027	10.50	.269	.055	16.20	.414	.123
CA++		34.80	1.737	.387	46.40	2.315	.474	22.50	1.123	.334
MG++		17.20	1.415	.315	5.80	.477	.098	6.00	.493	.147
TOTAL CATIONS		84.80	4.492		104.70	4.888		75.30	3.362	
SIO2	(PPM)		54.00			165.00			205.00	
TOTAL EPM	(EPM)		9.092			10.154			14.097	
ANIONS / CATIONS	(EPM)		1.024			1.077			3.193	
AG	(PPM)									
AS	(PPM)									
B	(PPM)									
BA	(PPM)									
CD	(PPM)									
CN	(PPM)									
CO	(PPM)									
CR	(PPM)									
CU	(PPM)									
FE	(PPM)									
HG	(PPM)									
MN	(PPM)									
MO	(PPM)									
NI	(PPM)									
PB	(PPM)									
SE	(PPM)									
V	(PPM)									
ZN	(PPM)									
GROSS ALPHA	(PCI/L)									
RADIUM-226	(PCI/L)									
NATURAL URANIUM	(PCI/L)									
CA / MG	(EPM)		1.228			4.854			2.275	
NA / CA	(EPM)		.701			.789			1.186	
CA+MG / NA+K	(EPM)		2.350			1.332			.926	
HCO3+CO3 / CL+SO4	(EPM)		1.261							
SO4 / CL	(EPM)		4.027			115.359			379.485	

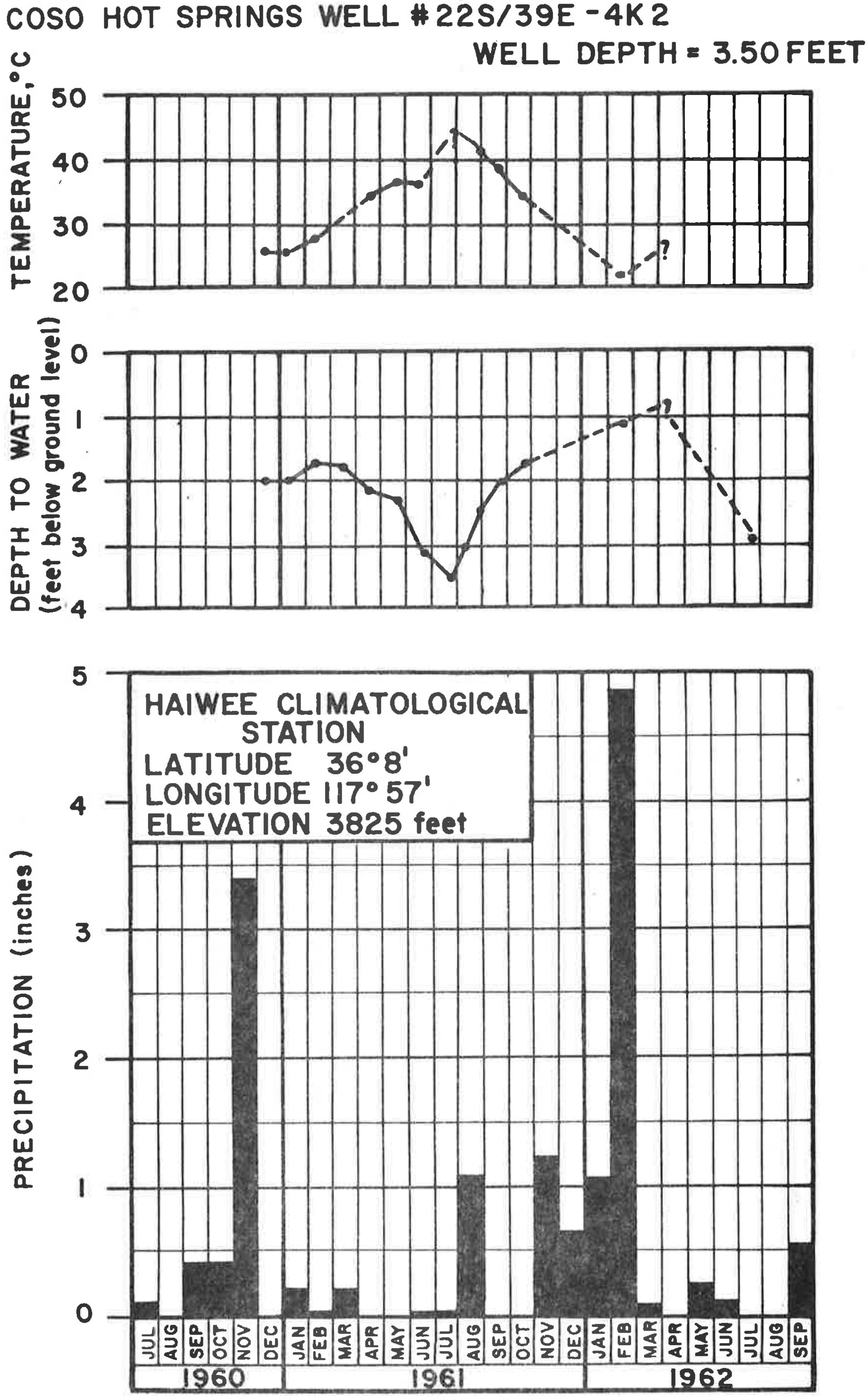
SUMMARY OF WATER ANALYSDS REPORT DATE 01/16/78

SAMPLE POINT			COSO POND			WELL K-1				
LOCATION DATA			T22S R39E 4/KS1			T22S R39E 4/K1				
SAMPLE NUMBER			CS-7			CS-8				
COLLECTION DATE, TIME			12/02/77			12/02/77				
TEMPERATURE (C)			49.50			91.20				
PH (F=FIELD, L=LAB)			2.24L			6.92L				
TDS (SUM OF GROSS PPM)			1451.80			184.65				
TDS (BY EVAPORATION)										
TDS (BY CALCULATION)			1451.80			178.55				
TDS (SUM LESS SIO2)			1169.80			142.65				
SP. COND. (U-MS/CM @ 25C)			3800.00L			240.00L				
GROSS ANALYSIS		PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO	PPM	EPM	IONIC RATIO
HCO3-					12.00	.197	.099			
CO3=										
CL-		2.60	.073	.003	1.70	.048	.024			
SO4=		1060.00	22.069	.996	83.00	1.728	.867			
F-		.20	.011	.000	.40	.021	.011			
NO3-										
PO4---										
TOTAL ANIONS		1062.80	22.153		97.10	1.994				
NA+		32.00	1.392	.252	33.00	1.436	.745			
K+		4.40	.113	.020	5.90	.151	.078			
CA++		55.00	2.745	.496	6.40	.319	.166			
MG++		15.60	1.283	.232	.25	.021	.011			
TOTAL CATIONS		107.00	5.532		45.55	1.926				
SIO2	(PPM)		282.00			42.00				
TOTAL EPM	(EPM)		27.685			3.920				
ANIONS / CATIONS	(EPM)		4.005			1.035				
AG	(PPM)									
AS	(PPM)									
B	(PPM)									
BA	(PPM)									
CD	(PPM)									
CN	(PPM)									
CO	(PPM)									
CR	(PPM)									
CU	(PPM)									
FE	(PPM)									
HG	(PPM)									
MN	(PPM)									
MO	(PPM)									
NI	(PPM)									
PB	(PPM)									
SE	(PPM)									
V	(PPM)									
ZN	(PPM)									
GROSS ALPHA	(PCI/L)									
RADIUM-226	(PCI/L)									
NATURAL URANIUM	(PCI/L)									
CA / MG	(EPM)		2.139			15.533				
NA / CA	(EPM)		.507			4.495				
CA+MG / NA+K	(EPM)		2.677			.214				
HCO3+CO3 / CL+SO4	(EPM)					.111				
SO4 / CL	(EPM)		300.998			36.046				


NORTH
WEST
EAST
horizontal lines are flow lines prior to development.
PLANNED GEOTHERMAL DEVELOPMENT
STAGNATION POINT
COSO HOT SPRINGS
SCALE
0 1 2 4 6 Miles
1 inch = 2.54 miles


NORTH
WEST
EAST
horizontal lines are flow lines prior to development.
PLANNED GEOTHERMAL DEVELOPMENT
STAGNATION POINT
COSO HOT SPRINGS
SCALE
0 1 2 4 6 Miles
1 inch = 2.54 miles


elevation - precipitation relationships
adapted from Rush, 1968
Panamint City
Haiwee
Randsburg
Wildrose RS
(5.2 inches)
Coso Hot Springs
Goldstone Echo 2
Inyokern
Las Vegas WB
Barstow
Trona
Death Valley
Long-Term Average Precipitation, Inches
2
4
6
8
10
12
14
16
Elevation Above Mean Sea Level, feet x 10³
0
2
4
6
8
10


COSO HOT SPRINGS WELL #22S/39E -4K2
WELL DEPTH = 3.50 FEET
TEMPERATURE, °C
50
40
30
20
?
DEPTH TO WATER (feet below ground level)
0
1
2
3
4
PRECIPITATION (inches)
5
4
3
2
1
0
HAIWEE CLIMATOLOGICAL STATION
LATITUDE 36°8'
LONGITUDE 117°57'
ELEVATION 3825 feet
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
1960
1961
1962

INITIAL DISTRIBUTION

1 Director of Navy Laboratories
4 Naval Air Systems Command
    AIR-30212 (2)
    AIR-954 (2)
7 Chief of Naval Operations
    OP-03E6 (2)
    OP-05 (1)
    OP-098 (1)
    OP-41
        Cdr. R. D. Furiga (1)
        LCdr. R. Owens (1)
    OP-986, Capt. Fulk (1)
4 Chief of Naval Material
    MAT-08 (2)
    MAT-08T (1)
    MAT-08T3, Capt. Thomas F. Stallman (1)
11 Naval Facilities Engineering Command
    FAC-03, Cdr. R. P. Cope (1)
    FAC-032F, Walter Adams (1)
    FAC-04 (1)
    FAC-044, F. C. Hildebrand (1)
    FAC-0441, L. V. Irvin, Jr. (1)
    FAC-0442, S. Z. Bryson III (1)
    FAC-09B, Capt. C. Courtright (1)
    FAC-102, Cdr. E. J. Peltier, Jr. (1)
    FAC-1023, M. E. Carr (1)
    FAC-203, LCdr. T. A. Dames (1)
    PC-3, Capt. W. Daniel (1)
1 Naval Facilities Engineering Command, Pacific Division (Utilities Division)
1 Naval Facilities Engineering Command, Western Division, San Bruno (Utilities Division)
5 Naval Sea Systems Command
    SEA-033 (3)
    SEA-09G32 (2)
2 Chief of Naval Research, Arlington
    ONR-102 (1)
    ONR-473 (1)
2 Assistant Secretary of the Navy (Research and Development)
    Dr. P. Waterman, Special Assistant (Energy) (1)
1 Commandant of the Marine Corps

2 Civil Engineering Laboratory, Port Hueneme
Technical Library (1)
Mike Slamanski (1)
2 Naval Academy, Annapolis
Library (1)
Mechanical Engineering Department, Professor Chin Wu (1)
2 Naval Post Graduate School, Monterey
1 Naval Research Laboratory
1 Office of Naval Research Branch Office, Boston
1 Office of Naval Research Branch Office, Chicago
1 Office of Naval Research Branch Office, New York
1 Office of Naval Research Branch Office, Pasadena
1 Office of Naval Research Branch Office, San Francisco
1 Headquarters, U.S. Army
1 Headquarters, U.S. Air Force
1 Air Force Academy (Library)
1 Air University Library, Maxwell Air Force Base
1 Assistant Secretary of Defense (Dr. W. C. Christensen)
12 Defense Documentation Center
1 Assistant Commissioner for Minerals, Anchorage, AK
1 Bureau of Mines, El Centro, CA (Don H. Baker, Jr.)
1 Bureau of Reclamation, Boulder City, NV
1 California Assembly Office of Research, Sacramento, CA
1 California Department of Conservation, Sacramento, CA
1 California Department of Water Resources, Sacramento, CA
1 California Division of Mines and Geology, Sacramento, CA
1 California Energy Resources Conservation and Development Commission, Sacramento, CA
1 California State Land Division, Sacramento, CA
6 Energy Research and Development Administration
Division of Geothermal Energy (1)
Larry Ball (1)
Bennie G. DiBona (1)
Arthur G. Follet (1)
Ronald R. Loose (1)
Randall C. Stephens (1)
1 Energy Research and Development Administration, Division of Geothermal Energy, Idaho Operations, Idaho Falls, ID
1 Energy Research and Development Administration, Division of Geothermal Energy, Nevada Operations, Las Vegas, NV
1 Idaho Bureau of Mines and Geology, Moscow, ID
1 National Academy of Engineering, Alexandria, VA (W. F. Searle, Jr.)
1 National Academy of Sciences (Dr. Robert S. Shane, National Materials Advisory Board)
2 Applied Physics Laboratory, Johns Hopkins University, Laurel, MD

4 United States Geological Survey, Menlo Park
   Dr. Bacon (1)
   Dr. Christianson (1)
   Dr. Duffield (1)
   Reid Stone (1)
1 Associated Universities, Inc., Upton, NY (Brookhaven National Laboratory)
1 Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA
1 Case Western Reserve University, Cleveland, OH (Department of Metallurgy and Materials Science)
1 Colorado Energy Research Institute, Golden, CO
1 EG&G Idaho, Inc., Idaho Falls, ID
1 Electric Power Research Institute, Menlo Park, CA
1 Franklin Institute, Philadelphia, PA (Library, Miriam Padusis)
1 Geothermal Energy Institute, New York, NY
1 IIT Research Institute, Chicago IL (Document Librarian)
1 Jet Propulsion Laboratory, CIT, Pasadena, CA
1 Lawrence Berkeley Laboratory, Berkeley, CA
2 Los Alamos Scientific Laboratory, Los Alamos, NM
   Jacobo R. Archuleta (1)
   Reports Library (1)
1 Massachusetts Institute of Technology, Cambridge, MA (Michael Batzle)
1 Oak Ridge National Laboratory, Oak Ridge, TN
1 Ohio State University, Columbus, OH (Department of Metallurgical Engineering)
1 Oregon State University, Corvallis, OR (Department of Mechanical Engineering)
1 Pennsylvania State University, State College, PA (Department of Geosciences)
1 Princeton University, Forrestal Campus Library, Princeton, NJ
1 Purdue University, West Lafayette, IN (Library)
1 Sandia Corporation, Albuquerque, NM (Leonard E. Baker)
1 Stanford Corporation, Santa Monica, CA (Technical Library)
1 SRI International, Menlo Park, CA (Robert W. Bartlett)
1 Tetra Technology, Inc., Pasadena, CA (J. J. Reed)
1 University of California, Lawrence Radiation Laboratory, Livermore, CA (Metallurgy Division)
1 University of California at Los Angeles, Los Angeles, CA (Prof. Kenneth L. Lee)
1 University of Denver, Denver Research Institute, Denver, CO
1 University of Hawaii, Honolulu, HI
1 University of South Dakota, Vermillion, SD (South Dakota Geological Survey Science Center)

2 University of Southern California Law Center, Los Angeles, CA
John J. McNamara (1)
Professor Christopher D. Stone (1)
2 University of Utah, Salt Lake City, UT
College of Engineering (1)
Geology and Geophysics Library (1)
1 University of Utah, Research Institute, Salt Lake City, UT
1 University of Utah, Research Institute Earth Sciences Group, Salt Lake City, UT