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BULLETIN No. 143-7

GEOTHERMAL WASTES AND THE WATER RESOURCES OF THE SALTON SEA AREA

FEBRUARY 1970

NORMAN B. LIVERMORE, JR.
Secretary for Resources
The Resources Agency

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

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GEOTHERMAL PILOT PLANT of Imperial Thermal Products, Inc. near Niland. Steam is being produced from a geothermal well as the chemically-rich brine collects in evaporation ponds. Red Island, partially inundated by the Salton Sea, is seen in the background (Photo courtesy of Morton International, Inc., 1965).

STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

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GEOTHERMAL WASTES AND THE WATER RESOURCES OF THE SALTON SEA AREA

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FOREWORD

As part of the Water Quality Investigation Program, a study was made of the geothermal wastes and water resources of the Salton Sea Area. This study included determining the nature, extent, and character of its water resources; describing its water quality conditions; and identifying and evaluating possible water quality problems arising from potential geothermal development.

The Department of Water Resources has undertaken this investigation as part of its continuing evaluation of surface and ground water quality problems as authorized in Section 229, Chapter 2, Division 1, of the California Water Code.

William R. Gianelli

William R. Gianelli, Director
Department of Water Resources
The Resources Agency
State of California
December 26, 1969

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*Photo courtesy of NASA.

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DEPARTMENT OF WATER RESOURCES

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ABSTRACT

The Salton Sea Area is part of the intensely faulted structural Salton Trough. / Geophysical surveys indicate several structural discontinuities along the sea bottom, roughly parallel to the San Andreas fault zone. / Fifteen wells have been drilled for geothermal resources. / With an evaporation rate of 5.9 feet, the Sea loses about 1.3 million acre-feet annually. / In 1967, the Sea was replenished with about 1.2 million acre-feet of surface inflow, principally irrigation return from applied Colorado River water. / The Sea is sodium chloride in character, contains over 300 million tons of salt, and has a concentration of 36,000 parts per million total dissolved solids. / Brines from geothermal wells have caused operational difficulties and a waste problem due to lack of disposal sites. / Separated by some 50 miles, effluents from the Buttes thermal area and Cerro Prieto geothermal field are chemically similar, though concentrations of their constituents are unequal. / Ground water and geothermal effluent are meteoric in origin, derived from local runoff and the historic Colorado River delta system. / In the Buttes geothermal field, a major well producing a postflash brine with a total dissolved solids of over 300,000 parts per million could annually produce approximately 400,000 to 500,000 tons of salt. This is nearly equivalent to 1/10 of the annual salt load entering the Salton Sea. / Conditions favorable for the occurrence of geothermal resources may be present in other parts of the Salton Sea Area and Imperial Valley.

CHAPTER I. INTRODUCTION

This report evaluates the surface and ground water resources and geothermal wastes of the Salton Sea Area. It also presents a preliminary appraisal of the water quality conditions and problems that may arise from geothermal wastes were the area's geothermal resources to be developed extensively.

As a source of power and mineral wealth, California's geothermal resources offer a valuable potential for future economic development. Moreover, their potential has thus far been but slightly realized. In California, these resources have been developed only in Sonoma County (The Geysers) and southeast of the Salton Sea in Imperial County.

To date, the development of the geothermal resources in the Salton Sea Area has been centered in the Buttes thermal area, southeast of the Salton Sea, near Obsidian Butte and Mullet Island (Plate 1). Essentially, however, this has been only a pilot operation, involving the drilling of 15 geothermal wells.

Three major operators have produced brine from these wells in their pilot operations and filled large temporary holding ponds where enrichment of the effluent and crystallization of salts from the brine have been principally through solar evaporation. However, development of geothermal resources in the Salton Sea Area has been hindered considerably by the lack of available disposal sites for brine, bittern wastes, and accumulated salt deposits. Moreover, the highly saline brine has caused operational problems. One of the principal developers claims that the cost of recovering products from these brines commercially is higher than that from other sources, such as salt beds.

Recently, there has been renewed interest in the geothermal resources, whose potential for power and minerals is considerable. The U. S. Geological Survey (USGS Circular 519, 1965) estimated the heat content of the Salton Sea geothermal reservoir (Buttes thermal area) at a minimum of 2×10^{19} calories. That estimate was based on an underlying geothermal reservoir which was assumed to be equivalent to a cylinder 7 km in diameter, 3 km in thickness, having an average temperature of 250°C, and an average volumetric specific heat of 0.7 cal/cm^3.

More recent studies by White (June-July 1968) in the Buttes thermal area indicate that an oval-shaped area, approximately 50 km^2 (about 20 mi^2) by 1 km (roughly, the interval between 3,000 to 6,000 feet deep), with a porosity of 10 percent,

contains 5 km^3 (about 40 million acre-feet) of interstitial brine.

Studies by Rex (October 1968) at the University of California at Riverside indicate that the Imperial Valley and its southern extension into Mexico form one large geothermal province with an average heat flow of two to three times the continental average. In California, this geothermal area is estimated to cover at least 2 million acres (about 3,100 square miles) and to be underlain by about 20,000 feet of sediment. Rex estimates that about 3 billion acre-feet of geothermal reserves occur in this vast area, assuming that the lower 15,000 feet of sediments are filled with hot brine and the sediments have an effective average porosity of 10 percent.

Large-scale development of geothermal resources poses a threat to water resources, if the disposal of brines, evaporites, and residual bitterns is not properly managed.

A USGS news release on May 11, 1967 warned:

> "Disposal of waste products is another of the more serious problems encountered in the development of geothermal resources. This is an acute problem in the Salton Sea area of California where the mineral content of the steam (postflash brine) according to a representative analysis, is 334,987 parts per million. It may be possible to recover some of the mineral content as a by-product of the production of energy, but the waste disposal problem will have to be resolved before the area can be commercially developed."

The Salton Sea is the largest body of water in California. According to Table 11 of the report, "Economic Benefits Derived From the Waters of and Lands Surrounding the Salton Sea" (Development Research Associates, February 1969), the total value of physical investments related to the Sea is in the order of $900 million. The Sea's salinity is about 36,000 parts per million (ppm)--slightly more saline than the oceans--and it is increasing; and this increase could be accelerated by the discharge of the still saltier geothermal wastes. Such an increase could have a disastrous effect on the Sea's fishery and a damaging effect on the region's entire economy.

Although the Salton Sea Area has substantial economic value, largely agricultural and recreational, the quality of most of the surrounding area's ground water is now unsuitable

EXTENSIVE AGRICULTURAL DEVELOPMENT along the northern and southern shores of the Salton Sea is irrigated with Colorado River water (Photo by Pacific Air Industries, Inc., June 4, 1952).

for most purposes without upgrading. Generally, except in the Coachella Valley, it is not potable and has limited local use. Nevertheless, protection of the quality of the ground water, the Sea, and its tributary surface waters for future uses should be considered in the light of technological advances before permitting further salinization by highly concentrated geothermal wastes.

The development of California's geothermal resources is still in its infancy. It suffers from technical, economic, and legal problems that must be resolved before it can reach its full potential without inflicting damage on other valuable resources. This, therefore, makes it necessary to continue effective control measures if the quality of California's water is to be protected. These measures should be based on cultural and economic factors, as well as on scientific and engineering knowledge.

As a result of increased interest in the development of California's geothermal resources, the Legislature enacted State Senate Bill No. 169 (Statutes 1967, Chapter 1398), setting up a Geothermal Resources Board in the State Department of Conservation. The Board's functions and jurisdiction encompass the exploration and development of geothermal resources. At the same time, the bill also amended and reaffirmed the section of the Public Resources Code authorizing the Division of Oil and Gas to supervise the drilling, operation, and abandonment of wells drilled for developing geothermal resources. The Department has authority to investigate the causes of possible damage to the water resources of the State. The Regional Water Quality Control Boards have the responsibility to regulate waste discharges to waters of the State. To date, as stated in its Resolution No. 63-14, the Colorado River Basin Regional Water Quality Control Board (No. 7) has prohibited discharging geothermal wastes into the Salton Sea and its tributaries.

OBJECTIVES OF THE INVESTIGATION

The objectives of this investigation were to:

1. Determine the nature, extent, and chemical quality of the water resources of the Salton Sea Area.

2. Evaluate potential quantity and quality of wastes from geothermal development.

3. Identify possible water quality problems arising from geothermal development requiring further study.

SCOPE AND CONDUCT OF THE INVESTIGATION

Geologic, geophysical, hydrologic, and water quality data for the study area were collected and evaluated. These were derived from previous studies and from investigations in the field.

Samples of water from wells, springs, and surface waters were collected and analyzed, mostly between March and July 1967. These data, plus other relevant data collected prior to that period, have been reviewed and assessed. The Department of Water Resources (DWR) analyzed the samples for chemical constituents and Gordon Bradford of the University of California at Riverside determined trace elements. A brief inspection of the Salton Sea Area was conducted to obtain an up-to-date overall view of its land and water use. Data were also obtained from the Imperial Irrigation District (IID), the Imperial County Health Department, the U. S. Department of Agriculture Soil Conservation Service, USGS, and the Coachella Valley County Water District (CVCWD).

AREA OF THE INVESTIGATION

The Salton Sea Area comprises those lands peripheral to the Sea and lying within Imperial and Riverside Counties (Plate 1). The lowlands along the southeastern shore of the Sea, near Mullet Island (11S/13E-10) and Obsidian Butte (11S/13E-32) merit particular attention because of the area's thermal activity (see Appendix A for site identification).

This lowland area of thermal activity, which has been recently investigated for its geothermal resources, has been variously known as the Salton Sea thermal area, Salton Sea geothermal area, Salton Sea geothermal field, geothermal field at Niland, Salton Sea field, Buttes area, etc. For the purpose of this report, however, and to be more concise (Rex, October 1968), this region is herein termed the Buttes thermal area. It forms part of a much larger geothermal province, extending from north of the Salton Sea and south through Imperial Valley into Baja California, Mexico. Those areas, adjacent to the Buttes thermal area, are discussed here to place the small current development in the Buttes area in proper perspective to potential large-scale developments of the Imperial Valley.

FINDINGS

1. The total value of physical investments related to the Salton Sea is in the order of $900 million. The

investments are supported principally by imported Colorado River water.

2. In 1967, the Salton Sea, the principal feature of the region, had an elevation of 232 feet below sea level, a surface area of about 230,000 acres, and a volume of approximately 6 million acre-feet.

3. Precipitation ranges from an annual average of less than 2 inches in the vicinity of the Salton Sea to about 10 inches in the Santa Rosa Mountains.

4. In 1967, surface inflow to the Sea was about 1.2 million acre-feet with less than 4,000 ppm Total Dissolved Solids (TDS), principally via the Alamo, New, and Whitewater Rivers; about 1 million acre-feet of this inflow was return irrigation water.

5. The Sea has a TDS content of about 36,000 ppm and contains about 300 million tons of salt in solution. Its only outflow is by evaporation, which amounted to about 1.3 million acre-feet in 1967.

6. Ground water with varying quality occurs in the sediments which have accumulated in the Salton Trough.

7. Most ground water contains mineral concentrations exceeding U. S. Public Health Service (USPHS) Drinking Water Standards and is Class 3 for irrigation. In the Salton Sea Area, TDS in ground water ranges from the less than 500 ppm in artesian wells near Mecca to about 50,000 ppm in the bubbling mud volcanos northwest of Niland.

8. Excluding geothermal brines, the temperature of ground water ranges from about 70° to 180°F.

9. The Sea, a part of the intensely faulted structural Salton trough is traversed by several structural discontinuities parallel to the San Andreas fault zone.

10. The region is seismically active; over periods of severe earthquakes, emanation of gases and liquids is greatly accelerated from the mud volcanos and related features along the San Andreas fault zone in the vicinity of the Buttes thermal area.

11. The Buttes thermal area, some 20 square miles, is part of a much larger geothermal province extending from north of the Salton Sea and south through Imperial Valley into Baja California, Mexico. Geothermal resources may underlie some 3,100 square miles of the Imperial Valley.

12. Though separated by some 50 miles, geothermal effluents from the wells near the Buttes thermal area and Cerro Prieto,

STEAM AND GAS EMISSIONS from partially submerged mud volcanos along the San Andreas fault zone near Mullet Island in the Buttes thermal area (© Norman A. Moore, 1949).

MUD VOLCANO AREA near Mullet Island showing mud volcano cones, which rise up to seven feet in height and are formed of viscous muds carried upward by rising waters and gases. In contrast, two mud pots, which are depressions, can be seen in the foreground (© Norman A. Moore, 1949).

Baja California, Mexico, have similar chemical characters, but Cerro Prieto's TDS is less than 10 percent of that from the Buttes thermal area.

13. About 40 million acre-feet of interstitial brine underlie the Buttes thermal area and about 3 billion acre-feet underlie the Imperial Valley.

14. In the Buttes thermal area, postflash brine from a typical geothermal well having over 300,000 ppm TDS and flowing at about 1 million gallons per day (gpd) can produce about 2.5 million pounds of solids per day, or nearly 500,000 tons annually.

15. In the Buttes thermal area, developers have extracted sodium chloride-rich geothermal brines from Pliocene formations at depths of about 5,000 feet. These deposits are capped by relatively impermeable sediments that restrict the upward movement of the superheated fluids.

16. In a 1962 pilot operation, mixing of geothermal wastes and diversions of Alamo River water in a ratio of about 1 to 12 produced an effluent with about 24,000 ppm TDS.

17. To preclude the threat of pollution, the Colorado River Basin Regional Water Quality Control Board (No. 7) prescribed discharge requirements prohibiting direct waste discharges from the geothermal wells in the Buttes thermal area to the Salton Sea and its tributaries.

CONCLUSIONS

1. The Salton Sea is in a state of adverse salt balance, due to the inflow of mineral-laden drainage waters, solution of salts from its bottom muds, and its having no outflow of minerals.

2. The Sea is valuable as a repository for irrigation drainage and for recreation and fish and wildlife.

3. Gases and liquids will continue to emanate along the San Andreas fault zone in the Buttes thermal area. Also, similar emanations may occur along other fault systems.

4. Isotope and water quality studies indicate that geothermal and ground waters, including geothermal water from Cerro Prieto, are meteoric in origin and have been derived from the Colorado River delta system and local runoff.

5. Geothermal resources may exist in other parts of the Salton Sea Area and Imperial Valley, and their

development may spread northward from the facilities at Cerro Prieto.

6. The indiscriminate discharge of highly saline geothermal brines to the Sea, its tributaries, and ground water could cause degradation of the quality of the water resources and thus constitute a threat of pollution; this, in turn, would be a threat to the present and future economic development of the Salton Sea Area.

7. If geothermal resources in the Salton Sea Area are to be developed to a practical economic level, the developers must concurrently investigate the means and provide plans for producing these resources, and for disposing the resultant wastes in light of their effects on the environment and its related beneficial uses. Surface and ground water resources are important environmental considerations.

8. Continued regulation by the Colorado River Basin Water Quality Control Board (No. 7) is essential for the proper containment of the geothermal resource under production and for disposal of geothermal wastes.

HIGH WATER MARK of ancient Lake Coahuila, coinciding with travertine deposits (arrow) along base of Santa Rosa Mountains near Travertine Rock (DWR Photo 1968)

TRAVERTINE ROCK, a prominent physiographic feature near the northwestern shore of the Salton Sea (DWR Photo 1968)

CHAPTER II. GEOLOGY AND HYDROLOGY

The nature and origin of the geologic formations, the presence of volcanic hills and mud volcanos, and the intensive faulting of the seismically active region are all indicative of the geothermal potential of the Salton Sea Area. A knowledge of the interrelationships of these geologic factors is essential for an understanding of the potential magnitude of geothermal wastes in the area, and its possible effect on the quality of the water resources of the area.

GEOLOGY

The low point of the Salton Trough, a major topographic and structural depression extending southeasterly from San Gorgonio Pass to the Gulf of California, is occupied by the Salton Sea. Centuries ago the Trough was filled by the waters of Lake Coahuila to an elevation of about 40 feet above sea level; today, the surface of the Sea is about 232 feet below sea level. The Colorado River delta forms a natural barrier which prevents inundation from the Gulf of California.

In the vicinity of the Sea, the Trough is bounded on the west by the Santa Rosa Mountains (Plate 1), which consist primarily of pre-Cenozoic meta-igneous rocks; and on the east by the Chocolate and Orocopia Mountains, largely a complex of pre-Cenozoic meta-igneous and Tertiary intrusive and volcanic rocks (Figures 1 and 2). The low hills bordering the Sea on the west are composed largely of nonmarine Pliocene sediments.

The Salton Trough has been filled with clastic sediments from the Colorado River drainage delta, its major source, and from the largely meta-igneous complex of the adjacent mountain areas (Dibblee, 1954, and Muffler and Doe, 1968). These sediments are principally continental deposits, consisting of fanglomerates, conglomerates, and lacustrine sandstones or claystones (Figures 1 and 2) and represent essentially continuous deposition since Miocene time. However, the older sediments are marine (Figure 2), and minor marine incursions of the Gulf of California also occurred throughout the deposition of the younger formations (Muffler and Doe, 1968).

An evaluation of the major rock units in the Salton Sea Area indicates that sedimentary rocks having the capacity for ground water storage underlie most of the area and extend as far south as the Gulf of California. Except for the northwest shore, along the periphery of the Salton Sea, the high salinity of the ground water in these sedimentary rocks makes the water generally unsuitable for most uses. The nonmarine sediments (Qc) and alluvial deposits (Qa) are unconsolidated and their general coarse-grained nature indicates they have a high capacity for

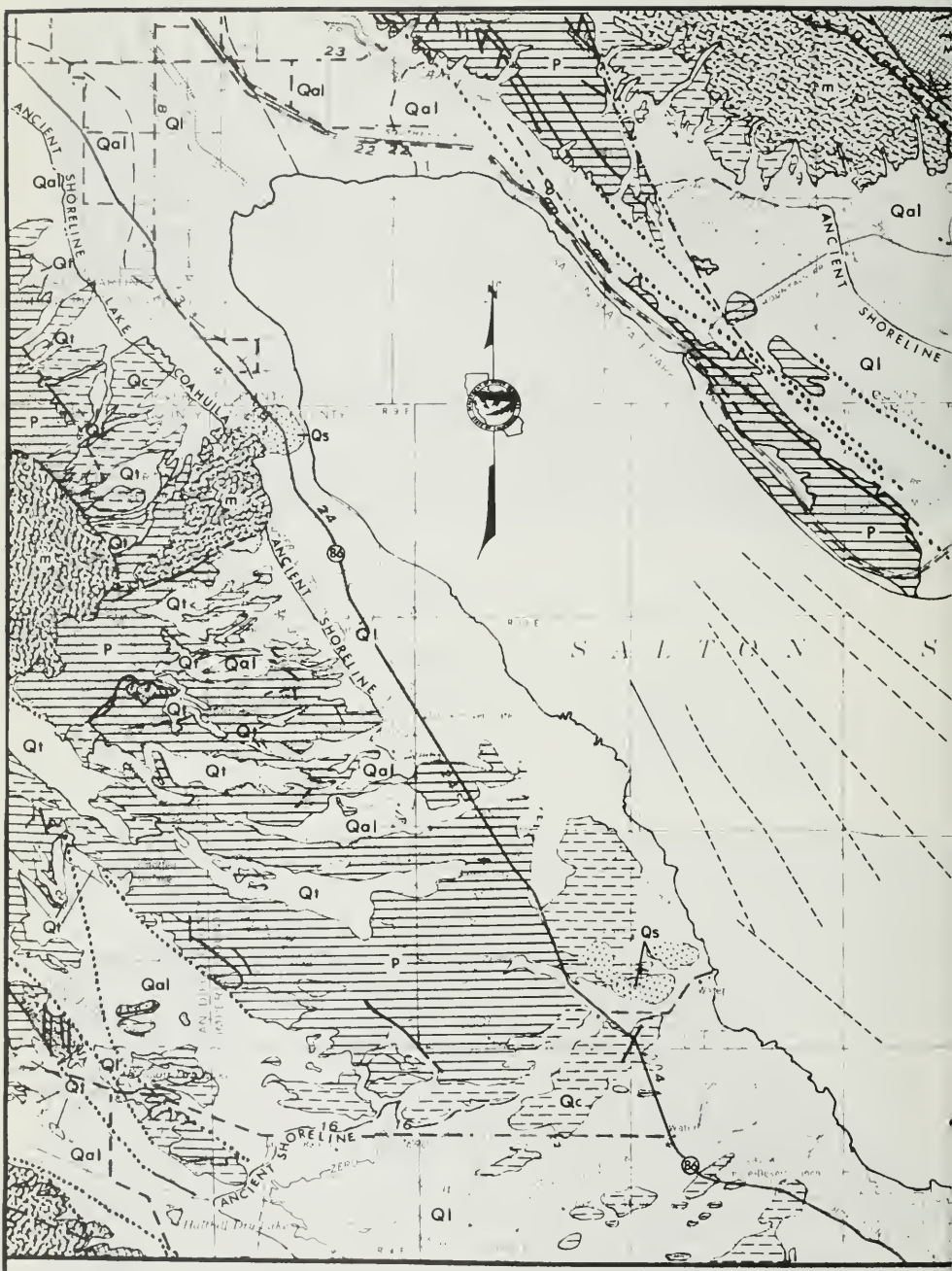


Figure 1 — AREA

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

LOCATION MAP

LEGEND

Qs	DUNE SAND	QUATERNARY
Qal	ALLUVIAL DEPOSITS	QUATERNARY
Ql, Qt	LAKE DEPOSITS, TERRACE DEPOSITS	QUATERNARY
Qc	NONMARINE SEDIMENTS	QUATERNARY
V	VOLCANIC ROCKS	TERTIARY
P	PLIOCENE FORMATIONS	TERTIARY
M	MIOCENE – EOCENE FORMATIONS	TERTIARY
m	GRANITIC, META - MORPHIC ROCKS	PRE – CENOZOIC

FAULT*

x MUD VOLCANO

o GEOTHERMAL WELL

*SEE APPENDIX G – GEOPHYSICAL SURVEY

Scale 1:250,000

5 0 5 Miles

GEOLOGY ADAPTED FROM THE CALIFORNIA DIVISION OF MINES AND GEOLOGY: SANTA ANA GEOLOGIC MAP SHEET, 1966 AND SALTON SEA GEOLOGIC MAP SHEET, 1967

EOLOGY

Geologic Age	Stratigraphic column	Map unit and symbol (See Figure 1)	Stratigraphic nomenclature*	Maximum thickness (feet)
QUATERNARY	Qs, Qt, Qal, Ql, Qt, Qc	Dune Sand (Qs)	Recent Dune Sand	300
		Alluvial Deposits (Qal)	Recent Alluvium	
		Volcanic Rocks (V)	Recent Volcanic Rocks	
		Lake Deposits (Ql)	Lake Coahuila (*Cahuilla*) Deposits	
		Terrace Deposits (Qt)	Quaternary Nonmarine Terrace Deposits	
		UNCONFORMITY		
		Nonmarine Sediments (Qc)	Brawley Formation	2,000
			Ocotillo Conglomerate	2,500
		Volcanic Rocks (V)	Pleistocene Volcanic Rocks	--
TERTIARY	P	Pliocene Formations (P)	Unnamed Pliocene-Pleistocene Nonmarine Sedimentary Deposits	--
			Canebrake Conglomerate	9,000
			Palm Spring Formation	7,000
			Borrego Formation	6,000
			Mecca Formation	1,000
			Imperial Formation	4,000
	V, M	Miocene–Eocene Formations (M)	Split Mountain Formation	2,700
			Unnamed Oligocene Nonmarine Sedimentary Rocks	--
			Maniobra Formation	--
		Volcanic Rocks (V)	Undifferentiated Tertiary Volcanic and Intrusive Rocks	--
		UNCONFORMITY		
PRE-TERTIARY	m	Granitic and Metamorphic Rocks (m)	Undifferentiated Mesozoic Granitic Rocks	--
			Orocopia Schist	--
			Other Pre-Cenozoic Granitic and Metamorphic Rocks	--

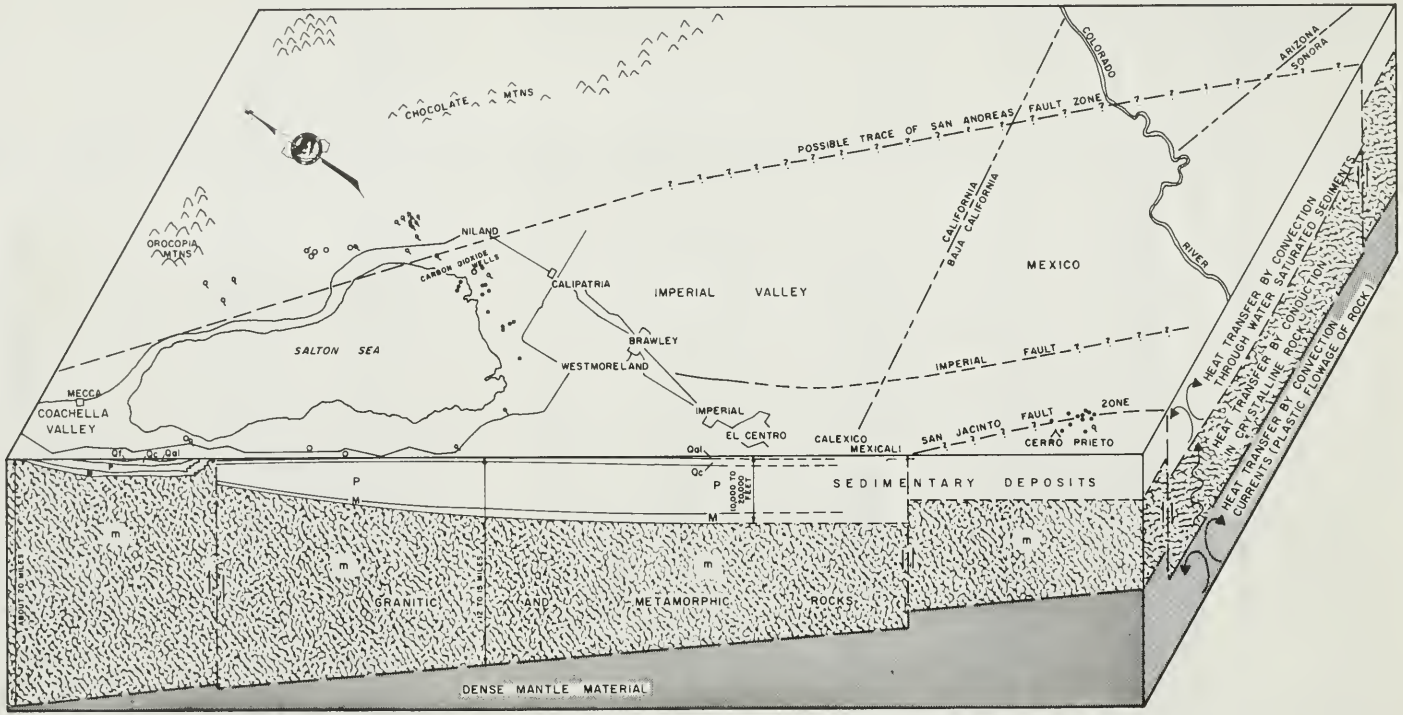
20,000

*After California Division of Mines and Geology Salton Sea (1967) and Santa Ana (1966) Geologic Map Sheets

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

DESCRIPTION
Wind-blown sand, local dunes. Locally distributed around Salton Sea. Gravel, sand, silt, and clay. Occurs along river channels and at foothills above the ancient shoreline of Lake Coahuila. Obsidian, rhyolite, and pumice composing volcanic domes on the southeast shore of Salton Sea. Locally interbedded obsidian flows and lake deposits. Clay, silt, sand, beach gravel, and evaporite deposits of the former extensive lake. Includes older lake beds above ancient shoreline of Lake Coahuila and locally undifferentiated alluvial deposits. Extensively dissected and locally folded stream terrace deposits of fanglomerate, gravel, and sand, in Borrego Valley.
Red-grey claystone, siltstone, sandstone, and pebbly gravel deposits. Grey, poorly consolidated boulder conglomerate, grading basinward into pink sandstone and claystone. Distributed generally in forebay areas along foothills. Quaternary rhyolite plugs along Salton Creek.
Moderately deformed fanglomerate in the northern Chocolate Mountains, consisting of unsorted, poorly consolidated, pale grey-yellow sediments containing mostly angular volcanic clasts. Grey conglomerate and fanglomerate of granitic and metamorphic debris. Unsorted and poorly consolidated. Continental origin. Light-grey arkosic sandstone and reddish claystone, grading into Canebrake conglomerate. Continental origin. Contains Pliocene and/or Pleistocene vertebrate fossils west of Salton Sea. Light-grey claystone and minor amounts of buff sandstone of lacustrine origin: contains a lacustrine fauna of minute mollusks, ostracods and rare foraminifera; grades laterally into Palm Spring formation. Greyish-red to yellowish-brown basal conglomerate, overlain by arkose and arkosic conglomerate of granitic and metamorphic debris. Continental origin. Light-grey claystone and lessor interbedded arkosic sandstone with calcerous oyster-shell "*reefs*." Shallow-water, marine in origin.
Red or grey cemented basal conglomerate or fanglomerate and sandstone of granitic and metamorphic debris. Overlain locally by gypsum and anhydrite beds (Fish Creek Gypsum member). The upper member is marine, while the middle and lower members are nonmarine in origin. Conglomerate, sandstone, breccia, mudstone, and evaporite rocks (Orocopia Mountains). Marine Eocene, siltstone, sandstone, conglomerate, and breccia with some sandy limestone (Orocopia Mountains). Local lava flows and tuffs. Flows are andesitic, rhyolitic, or basaltic rocks of various ages. Also includes intrusive acidic rocks and related diabasic dikes. Alverson andesite dated as Miocene
Granitic rocks. Pre-Cretaceous schist. Gneiss, limestone, schist, and granitic rocks, ranging in age from Mesozoic to Precambrian.

FIGURE 2– STRATIGRAPHIC SECTION



MODIFIED FROM CALIFORNIA DIVISION OF MINES AND GEOLOGY MINERAL INFORMATION SERVICE, JULY 1967 AND "GEOLOGY OF SOUTHERN CALIFORNIA," BULLETIN 170, CHAPTER II, PLATE 2, 1954

LEGEND

SEE PLATE 2 AND FIGURE 1 FOR EXPLANATION OF GEOLOGIC SYMBOLS

● GEOTHERMAL WELL

○ HOT MINERAL WELL

Q SPRING OR MUD VOLCANO

APPROXIMATE HORIZONTAL SCALE 1 INCH ≅ 7.5 MILES

NOTE HEAT RISING FROM DENSE MANTLE MATERIAL IS THOUGHT TO BE THE THERMAL SOURCE FOR GEOTHERMAL WATERS

Figure 3 - SCHEMATIC BLOCK DIAGRAM ALONG THE SALTON TROUGH

ground water storage. The coarser sand and gravel member of the upper Pliocene formations (P), although not as permeable as the Qa and Qc sediments, may function as storage and transmission conduits within the ground water reservoir.

The less permeable sedimentary rocks are the lake deposits (Ql) and the fine claystone members of the nonmarine sediments (Qc) and Pliocene formations (P). Evaporites in the lake deposits have been a significant contributor of salt to the Salton Sea. Rocks of the Miocene-Eocene (M) and lower Pliocene formations (P), Volcanic rocks (V), and granitic and metamorphic rocks (m) have the least potential for ground water storage. Sediment thickness is known to exceed 13,000 feet, according to well logs; and geophysical studies suggest it may exceed 20,000 feet (Biehler, 1964).

GEOTHERMAL ACTIVITY

Locally, the much higher than normal geothermal gradient in test holes and ground water extracted from wells are indicative of the region's geothermal resources. In general, temperatures within the earth increase with depth; in relatively "stable areas", the "normal" geothermal gradient is on the order of 1° F per 100 feet of depth. Thus the temperature of artesian water in some areas may indicate the approximate depth from which the water rises. Where geothermal resources occur, the gradient is much greater, generally at least two times the "normal" rate.

Geothermal resources are"...the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances".* A geothermal well is "...any well for the discovery of geothermal resources or any well on land producing geothermal resources or reasonably presumed to contain geothermal resources, or any special well, converted producing well or reactivated or converted abandoned well employed for reinjecting geothermal resources or the residue thereof".**

Several significant geologic factors in the Buttes thermal area give rise to a potential geothermal development. The hot dense mantle material of the earth's crust is nearer the sedimentary materials in this area due to a comparatively thin crystalline layer of granitic and metamorphic cap rock over the mantle material (Figure 3). Intensive faulting in the area allows the heat stored in the dense mantle to rise through broken and fractured

*California Public Resources Code, Chapter 1398, Section 6903.
**Ibid, Section 3703.

crystalline cap rock to escape into the overlying sedimentary rocks where it is confined over most of the area by impermeable sediments. In areas where faulting has ruptured the confining impermeable beds, the heat escapes through the ground by means of hot springs, carbon dioxide seeps, and mud volcanos.

Along the southeastern shore of the Salton Sea there is an impressive series of five volcanic domes, rising abruptly 100 feet above the flat valley floor. These domes -- Mullet Island, Red Island (two coalesced domes), Rock Hill and Obsidian Butte -- are composed chiefly of rhyolitic lavas, pumice beds, obsidian flows, and loose volcanic ejecta. This region, the Buttes thermal area, has been surrounded by active hot springs, carbon dioxide seeps, and mud volcanos. These phenomena, which are probably related to deep geothermal waters, find surface expression along fault zones.

Intensive faulting is evidenced by the trace of the San Andreas fault zone (Figure 1); and faulting in the southwestern part of the region no doubt is an extension of the San Jacinto fault system (Figure 3).

A geophysical survey of the Sea by DWR (Appendix G) revealed several faults and structural discontinuities along the Sea bottom that are believed to be related to the San Andreas fault zone (Figure 1). In addition, numerous earthquake epicenters indicate that the region is seismically active (Figure 4). The relationship of this seismicity to thermal eruptions was observed near Cerro Prieto in Baja California during the Fort Yuma earthquake of 1852. During the 1906 San Francisco earthquake, gas and steam emissions from mud volcanos increased markedly in the Buttes thermal area (California Division of Oil and Gas, 1942). Consequently, during periods of severe seismicity, it may not be unreasonable to assume that gaseous and liquid emanations could also escape to the land surface along the extensive fault systems under the Salton Sea.

Magnetic and gravity surveys of the region disclose positive anomalies which coincide with a thermal anomaly near the five volcanic domes (California Division of Mines and Geology, Special Report 75). Locally, the anomalies from these and other geophysical surveys are caused by the volcanic domes and their dense intrusive source. Regionally, however, they may be due to the dense mantle material being relatively close to the surface because of the thinning of the overlying granitic and metamorphic basement (Figure 3). Heat transfer by convection currents from the dense material through the overlying granitic and metamorphic rocks is thought to be the source of heat for the geothermal water confined deep within the sedimentary deposits (Figure 3). Temperatures in geothermal wells near the center of the Buttes thermal area are about 580° F at a depth of about 3,000 feet and 680° F at 7,000 feet.

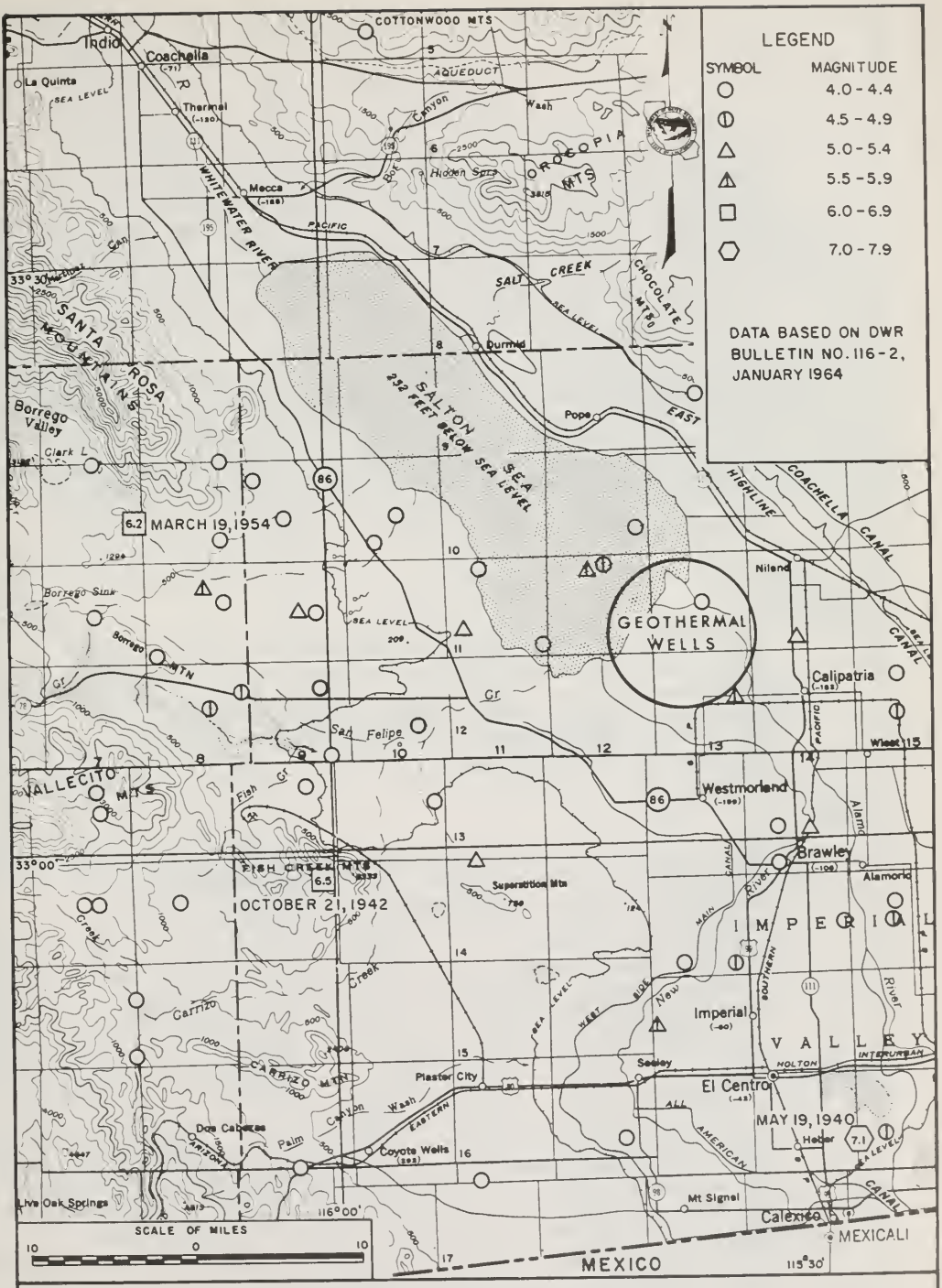


Figure 4 - LOCATION OF MAJOR EARTHQUAKE EPICENTERS, 1934-1961

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

Pliocene formations, mainly sands of the Borrego and Palm Springs formations, are the underground reservoirs from which geothermal brines in the Buttes thermal area are extracted. Relatively impermeable overlying sedimentary deposits form an insulating cap which restricts the upward movement of the superheated fluids. Where the cap rock is broken by fracture zones, springs and mud volcanos emit gases and heated waters. Thermal water from springs and wells is also found in other areas bordering the Salton Sea.

Both the Buttes and Cerro Prieto thermal areas are associated with zones of major faulting, Quaternary volcanism, mud volcanos, and above-normal geothermal gradients (Figure 3). Consequently, where similar conditions exist, either at the surface or in depth, they may indicate the occurrence of geothermal resources. A comprehensive summary of these two fields is presented in a paper by J. B. Koenig of the California Division of Mines and Geology (Mineral Information Service, July 1967).

HYDROLOGY

The following section deals with the hydrologic aspects of the study area. It includes a description and evaluation of these significant factors: climatology; the Salton Sea, its major inflow and tributary creeks; imported water; and ground water. All of these influence the region's hydrologic regimen and therefore its water quality.

Climate

The Salton Sea Area has a typical desert climate, with cloudbursts and, on rare occasions during the winter months, snow. Precipitation ranges from an average of less than 2 inches annually on the valley floor to over 10 inches annually in the Santa Rosa Mountains. U. S. Weather Bureau precipitation data from four communities and records from three Salton Sea stations (Figure 5) maintained by IID are listed in Table 1. During the period 1908-1962, rainfall in the Sea averaged 2.5 inches annually, equivalent to an annual average volume of about 42,000 acre-feet added directly to the Sea (USGS Atlas HA-222, 1966).

Evaporation, at a rate of about 5.8 feet per year (USGS Professional Paper 486-C), is the only outflow from the Salton Sea and is the partial cause of its salinity. All inflow to the Sea adds salts, while evaporation increases the salt concentration. Table 2 lists the estimated volumes of water that have evaporated from 1908 through 1967 (USGS Professional Paper 486-C). Evaporation losses amounted to about 1.3 million acre-feet in 1967.

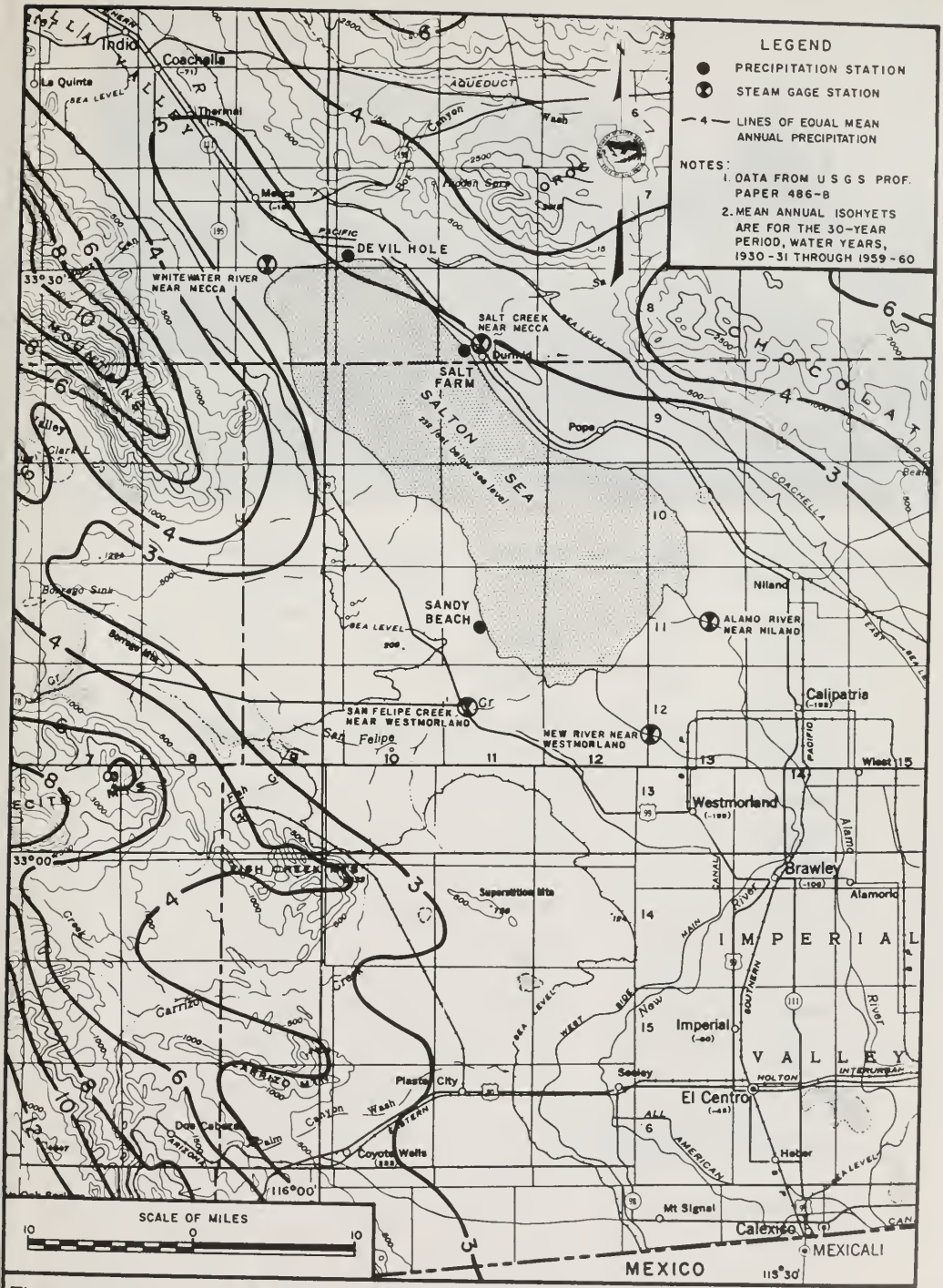


Figure 5 - ISOHYETS OF MEAN ANNUAL PRECIPITATION, SALTON SEA AREA

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

VOLCANIC ROCKS of Obsidian Butte, one of a series of five prominent hills along southeastern shore of Salton Sea (DWR Photo, 1967).

TABLE 1

PRECIPITATION FOR SELECTED STATIONS
In inches

Month	Brawley [a]	El Centro [a]	Indio [a]	Niland [b]	Devils Hole [c]	Salt Farm [c]	Sandy Beach [c]
October	.24	.25	.23	.18	.19	.19	.16
November	.10	.09	.30	.17	.23	.19	.13
December	.42	.45	.68	.39	.26	.22	.26
January	.33	.39	.50	.35	.31	.32	.32
February	.35	.41	.42	.24	.12	.13	.12
March	.13	.20	.25	.13	.07	.08	.06
April	.08	.12	.10	.04	.02	.06	.04
May	.01	0	.01	TR	0	.01	0
June	.01	.01	.01	TR	0	0	0
July	.02	.10	.12	.01	.03	.02	.04
August	.32	.37	.33	.27	.14	.15	.27
September	.29	.26	.43	.10	.16	.17	.17
TOTAL	2.30	2.65	3.38	1.88	1.53	1.54	1.57

a. 30-year period, 1930–31 through 1959–60
b. 19-year period, 1941–42 through 1959–60
c. 19-year period, 1948–49 through 1966–67

From U. S. Weather Bureau and Imperial Irrigation District climatological records.

TABLE 2

ESTIMATED ANNUAL EVAPORATION FROM THE SALTON SEA*

In acre–feet

Year	Evaporation	Year	Evaporation	Year	Evaporation
1908	1,800,000	1928	970,000	1948	1,150,000
09	1,730,000	29	980,000	49	1,110,000
10	1,660,000	30	1,010,000	50	1,090,000
11	1,570,000	31	1,030,000	51	1,160,000
12	1,520,000	32	1,020,000	52	1,140,000
1913	1,460,000	1933	1,020,000	1953	1,260,000
14	1,400,000	34	980,000	54	1,170,000
15	1,340,000	35	930,000	55	1,290,000
16	1,250,000	36	930,000	56	1,330,000
17	1,140,000	37	950,000	57	1,210,000
1918	1,050,000	1938	980,000	1958	1,230,000
19	960,000	39	1,020,000	59	1,280,000
20	940,000	40	1,060,000	60	1,310,000
21	910,000	41	1,070,000	61	1,360,000
22	900,000	42	1,090,000	62	1,330,000
1923	890,000	1943	1,090,000	1963	1,380,000
24	900,000	44	1,100,000	64	1,360,000
25	880,000	45	1,100,000	65	1,260,000
26	910,000	46	1,100,000	66	1,310,000
27	950,000	47	1,110,000	67	1,340,000

*After U S G S Prof. Paper 486–C, 1966

Table 3 illustrates the region's temperature, which ranges from 13° F, to 125° F with an annual average of about 73° F. Summers are hot and dry, while winters have mild days and cold nights. The prevailing winds blow from the southeast.

Salton Sea

The Sea occupies the deepest part of the Salton Trough, whose lowest point is nearly 280 feet below sea level. In 1967, it received drainage of over 1.2 million acre-feet (Table 4) from an area of about 8,400 square miles, including the Coachella Valley to the north and the Imperial and Mexicali Valleys to the south.

In 1907, the Salton Sea stood at 195 feet below sea level, after the Colorado River had run uncontrolled into the Salton Sink for over two years. As evaporation exceeded inflow, the Sea declined until the 1920's when inflow began to equal or exceed evaporation and the surface of the Sea rose. In 1967, the Sea's surface reached its present elevation of about 232 feet below sea level, with an area of about 230,000 acres and a volume of over 6 million acre-feet (Figures 6 and 7).

Major Inflow

Surface flow -- principally return irrigation water (annually about 1,000,000 acre-feet) plus some domestic waste water, seepage, and runoff -- are the major sources of the Sea's replenishment. This flow is derived mainly from applied imported Colorado River water and is a perennial flow to the Sea via three major rivers (Figure 5) and numerous drains and ditches. Generally, more than 90 percent of the surface inflow to the Sea comes from the Imperial Valley and about 10 percent from the Coachella Valley and other areas (USGS Professional Paper 486-C).

The Alamo and New Rivers have average annual flows of over and less than 500,000 acre-feet, respectively. They drain the Mexicali Valley in Mexico and cross the International Boundary, passing through the Imperial Valley to the Sea (Table 5). Some 120,000 acre-feet of this flow originates in Mexico. The Whitewater River rises in the San Bernardino Mountains, northeast of the City of Banning, travels the length of the Coachella Valley, and empties into the Sea. It is ephemeral and occasionally occurs as rising water along its length. Sections of the Whitewater River have been improved and are known as the Coachella Valley Storm Drain. Annually, less than 100,000 acre-feet of flow from this source enters the Sea (Table 5).

The major portion of the flow in the New, Alamo, and Whitewater Rivers is irrigation return water and seepage, with lesser amounts

TABLE 3
TEMPERATURE CHARACTERISTICS IN THE VICINITY OF THE SALTON SEA
In degrees Fahrenheit

Month	Imperial					Indio				
	Monthly			Extremes		Monthly			Extremes	
	Normal	Mean high	Mean low	High	Low	Normal	Mean high	Mean low	High	Low
January	54.1	69.0	39.1	96	16	54.1	70.0	38.1	94	13
February	58.0	73.2	43.1	94	22	58.1	74.3	43.3	97	20
March	63.6	79.3	48.0	104	30	64.5	80.0	49.1	104	27
April	70.9	86.6	54.9	107	35	72.3	86.9	56.9	110	33
May	77.8	94.0	61.3	118	44	79.1	93.4	63.8	121	33
June	85.1	101.9	68.1	121	50	86.4	101.9	71.2	121	52
July	91.8	106.9	76.3	124	60	92.1	106.9	77.3	125	59
August	90.8	105.0	76.2	124	60	90.6	105.4	76.0	121	48
September	86.0	101.4	69.6	118	49	86.1	101.6	69.6	122	46
October	74.8	90.6	58.4	111	36	75.5	91.6	58.2	113	36
November	62.3	78.4	46.4	98	28	62.9	80.6	45.6	101	23
December	55.9	70.4	40.7	90	22	55.8	71.7	38.9	96	17
Annual	72.6	88.1	56.8	124	16	73.1	88.7	57.3	125	13
Years of record	30	35	35	40	40	30	55	55	64	63

From U. S. Weather Bureau climatological records.

TABLE 4

ESTIMATED ANNUAL SURFACE INFLOW TO THE SALTON SEA*

In acre–feet

Calendar year	Imperial Valley	Coachella Valley	Other areas	Total
1944	1,090,000	––	10,000	1,100,000
45	1,070,000	––	10,000	1,080,000
1946	1,120,000	––	10,000	1,130,000
47	1,070,000	––	10,000	1,080,000
48	1,050,000	20,000	10,000	1,080,000
49	1,130,000	36,000	10,000	1,176,000
50	1,140,000	65,000	10,000	1,215,000
1951	1,210,000	108,000	10,000	1,328,000
52	1,300,000	86,000	10,000	1,396,000
53	1,380,000	63,000	10,000	1,453,000
54	1,300,000	72,000	10,000	1,382,000
55	1,120,000	85,000	10,000	1,215,000
1956	1,170,000	71,000	10,000	1,251,000
57	1,080,000	53,000	10,000	1,143,000
58	1,080,000	56,000	10,000	1,146,000
59	1,140,000	57,000	10,000	1,207,000
60	1,180,000	70,000	10,000	1,260,000
1961	1,242,000	84,000	10,000	1,336,000
62	1,280,000	113,000	10,000	1,403,000
63	1,338,000	133,000	10,000	1,481,000
64	1,026,000	121,000	10,000	1,157,000
65	977,000	137,000	10,000	1,124,000
1966	1,092,000	131,000	10,000	1,233,000
67	1,112,000	129,000	10,000	1,251,000

*After USGS Prof. Paper 486–C, 1966

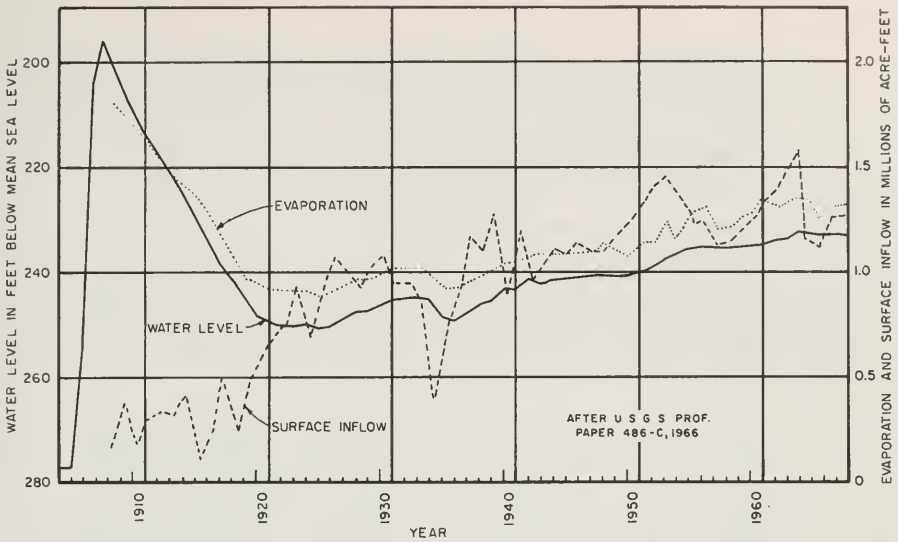


Figure 6- HISTORIC SALTON SEA-WATER LEVELS, EVAPORATION AND SURFACE INFLOW

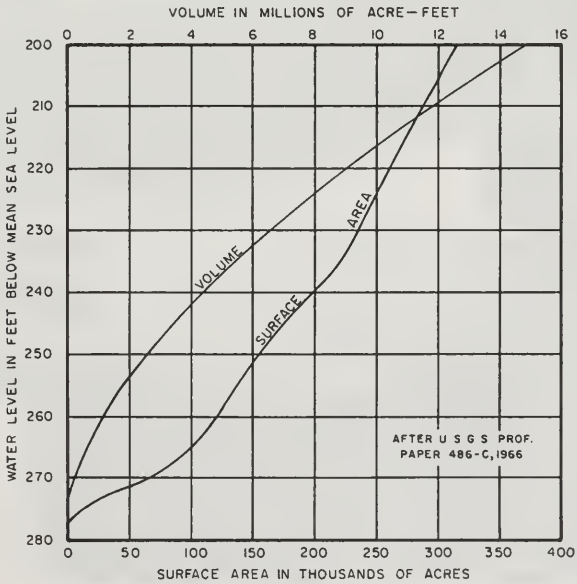


Figure 7- ELEVATION-AREA-VOLUME RELATIONSHIPS OF THE SALTON SEA

of storm flow. Decrease in flows of the Alamo and New Rivers in 1964 and 1965 (Table 5) at first were the result of IID and CVCWD complying with the Secretary of the Interior's 10 percent reduction in Colorado River water use and, later, the result of measures by IID and CVCWD for efficient water delivery and use.

In addition to these three rivers, more than 30 drains from the Imperial Valley and 18 ditches from the Coachella Valley empty into the Salton Sea. This drainage system is needed to maintain a favorable salt balance in the irrigated lands by carrying away its salt-laden agricultural drainage water to the Sea; it is also needed to prevent waterlogging of the land, which it does by controlling the water table.

An extensive system of subsurface tile drains collects and conveys irrigation return water to these surface drains and ditches. The tile drains are generally laid at a depth of about 6 feet. Where inverts of these surface channels lie at higher elevations than their tributary tile drains, the irrigation return water first flows into sumps and then is pumped up to the surface drains and ditches for discharge to the Sea.

PUMICE (DRAIN ALTERNATE) BYPASS CANAL near Rock Hill carries return irrigation water to the Salton Sea (DWR Photo, 1968).

TABLE 5

ANNUAL RUNOFF AT GAGING STATIONS ADJACENT TO THE SALTON SEA

In acre-feet

Calendar year	Alamo River near Calipatria	New River near Westmorland	Whitewater River near Mecca	Salt Creek near Mecca	San Felipe Creek near Westmorland
1943	491,350	490,030	--	--	--
44	505,850	504,520	--	--	--
45	519,480	485,220	--	--	--
1946	578,390	475,750	--	--	--
47	564,340	442,530	--	--	--
48	539,240	441,360	--	--	--
49	610,020	450,240	--	--	--
50	606,810	460,650	--	--	--
1951	641,960	490,040	--	--	--
52	697,410	524,060	--	--	--
53	756,990	540,550	--	--	--
54	732,680	492,770	--	--	--
55	654,450	395,850	--	--	--
1956	684,060	429,640	--	--	--
57	622,830	402,560	--	--	--
58	614,400	405,200	--	--	--
59	651,680	434,230	--	--	--
60	682,400	445,000	--	--	--
1961	675,500	437,000	53,390	3,500	1,130
62	681,300	455,300	69,600	4,420	370
63	723,700	477,500	75,740	5,310	8,700
64	563,500	365,900	75,330	4,080	100
65	535,100	357,800	88.070	4,630	830
1966	610,700	383,500	79,190	3,740	2,510
67	620,100	383,300	79,160	3,640	9,080

SUMP PUMP No. 15 discharging return irrigation water into drain along Gentry Road, near Niland (DWR Photo 1968).

Tributary Creeks

The Salton Sea is also fed by many minor streams that discharge directly into it. Of these, Salt Creek, entering from the east, and San Felipe Creek, from the west, contribute about one-half the minor inflow (Table 5). The inflow from areas other than the irrigated and developed sectors of Imperial and Coachella Valleys has been estimated as about 10,000 acre-feet per year. Seepage from the Coachella Canal contributes to flow in Salt Creek. San Felipe Creek maintains a small base flow during some of the winter months, but over 90 percent of its gaged flow is storm runoff.

Imported Water

Because much of the region lacks a suitable local water supply, IID and CVCWD annually import about 3 million acre-feet of Colorado River water via their major canals for irrigation and municipal purposes.

Ground Water

Ground water is used in the northwesternmost part of the study area near Mecca. Some is extracted for domestic purposes from

wells north of Travertine Rock (Plate 1) and about 1,500 acre-feet per year is exported as far south as Salton City via a pipeline along the southwest edge of the Sea. About 300 acre-feet per year are also exported via another pipeline which extends south toward Bombay Beach along the northeast edge of the Sea.

In the Dos Palmas Springs area (Plate 1), northeast of the Sea, ground water is used for irrigation. Locally, where no potable supply is available, water is imported by tank trucks, probably less than 50 acre-feet per year (Department of Water Resources Bulletin No. 108, 1964). Also, less than 2,000 acre-feet per year of ground water is extracted locally for non-potable use.

Average subsurface flow into the Salton Sea has been estimated at 50,000 acre-feet per year. Of this amount, about 30,000 acre-feet, including 2,400 acre-feet of unchecked flow from 500- to 1,500-foot-deep wells (Department of Water Resources Bulletin No. 108, 1964), enters from the Coachella Valley; about 10,000 acre-feet from the vicinity of San Felipe Creek; about 2,000 acre-feet from the Imperial Valley; and about 8,000 acre-feet from other peripheral areas (USGS HA-222, 1966).

In the Salton Sea Area, water of higher than normal temperature, but not as high as the superheated geothermal water, issues from numerous springs and wells. These springs and wells are identified in the monitoring network of Plate 1 and, where available, temperatures of water from these sources are shown on Plate 1 and in Appendix D, Selected Chemical Analyses. According to USGS Professional Paper 492 (1965), any spring or well water whose average temperature is at least 15° F above the mean annual temperature of air at the same locality may be classed as thermal (air temperature for the Salton Sea Area is about 73° F) (Table 3).

Although most of the descriptive terms for thermal water apply to springs, for the purpose of this report these terms will also be applied to ground water from wells. Meinzer, in USGS Water Supply Paper 494 (1923), divided thermal springs into hot and warm springs. Water from hot springs has a temperature higher than that of the human body, generally above 98° F, while water from warm springs has a temperature lower than that of the human body. Therefore, in this study, thermal waters are generally higher than 88° F (73° + 15°); hot water (excluding geothermal) higher than 98° F; and warm water, higher than 88° F, but less than 98° F.

Along the foothills northeast of the Sea, several spas, developed by drilling wells near springs, produce artesian ground water ranging from 140° F (9S/13E-7M1) to 180° F (8S/12E-36P1).

Similar hot water has been obtained from the Holly Corporation's hot mineral well (11S/9E-2B1), several miles southwest of Salton City (Plate 1). Hot water on the order of 100° F is produced from wells along the western shore of the Sea near Travertine Rock (9S/9E-4K1), at Truckhaven (10S/10E-18N1), and southeast of the Sea near Mullet Island (11S/13E-13D2).

Warm ground water of about 90° F is produced from wells near Oasis (8S/8E-13Q1) and Mecca (7S/9E-18M1), as well as from wells east of the Sea near Hunters Spring (8S/11E-12P2) and Frink Spring (9S/13E-20E1). Around the northern half of the Sea, numerous wells produce ground water with temperatures of about 80° F.

Prior to their recent inundation in the 1950's, numerous mud pots and mud volcanos near Mullet Island (Plate 1) produced boiling pools of mud and water that emitted steam and gases. However, although not as active and at much lower temperatures, similar features are found near the geothermal wells (11S/13E-24ES1) and northwest of Niland (10S/13E-27BS1).

East of the Salton Sea, in a zone roughly parallel to the San Andreas fault system, the flow of several prominent springs generally falls within a temperature range of 75° F to 85° F. Their rate of flow varies from about 0.01 cfs (5 gpm), as in Hunters Spring (8S/11E-12PS1) to about 2 cfs in the several Dos Palmas Springs (8S/11E-3CS). Locally, flow from other springs, such as Kane Spring (12S/11E-21MS1), has a temperature of about 70° F.

Since the turn of the century, the natural springs have been used locally for domestic and agricultural purposes. It is estimated that the total annual flow and production of water (excluding geothermal production) from both springs and wells on land peripheral to the Sea is on the order of less than 5,000 acre-feet per year.

Upon completion of the Coachella Canal in 1948, seepage of imported Colorado River water from the unlined Coachella Canal also contributed to the flow of natural springs. This seepage is indicated by changes in the water quality of historic springs and locally by rising water levels and the formation of new springs. Some domestic wells less than 25 feet deep along the Coachella Canal produce ground water which shows the influence of the seepage of Colorado River water. In a move designed to reduce seepage, IID is installing buried drain lines parallel to the East Highline Canal to intercept the percolating waters, which flow by gravity to collecting wells and are then pumped back into the canal system. IID is also helping farmers to line their ditch bank laterals with concrete to reduce percolation.

CHAPTER III. WATER QUALITY

The chemical quality of the receiving and geothermal waters of the Salton Sea Area is related to the geohydrologic environment, as well as to man's activities. The water resources of the region--the Sea itself, its tributaries, and the ground water in the area surrounding it--have a wide variation in the concentration of various chemical constituents because of the diversity of environments and sources and because of the effects of man's activities.

SALTON SEA

The Sea's volume is over 6 million acre-feet. Its salinity is slightly higher than that of the ocean, but concentrations of individual constituents differ. Based on samples from various locations (Plate 1), its composition, though somewhat variable (Appendix D), is sodium chloride in character and has a TDS concentration of approximately 36,000 ppm (June 1967). Sulfate, the third most dominant ion, is indicative of the Sea's origin--overflow from the Colorado River--and its subsequent replenishment by irrigation return water. Diagrams of chemical analyses of the Salton Sea (Plate 1) show the influence of return irrigation waters (11S/13E-28L).

The Sea has undergone marked chemical quality changes since the turn of the century. During the flooding of the Salton Sink (November 1904 - June 1907), the TDS of the inflow was probably less than 300 ppm (USDA Bulletin No. 235, 1911). By June 1907, when some 16 million acre-feet of Colorado River water had flowed into the Sink, the Sea was sodium chloride in character and contained about 3,600 ppm TDS (USGS Professional Paper 486-C, 1966).

This radical change in quality resulted from the solution of surficial salt deposits that had accumulated from previous flood flows into the Sink during late Quaternary time. These deposits were of such an extent--covering more than 1,000 acres--that sodium chloride was extracted commercially before they were flooded in 1904. However, much of the sulfate, unlike sodium chloride, did not redissolve because it had precipitated with calcium to form relatively insoluble calcium sulfate deposits.

From 1907 through 1916, the TDS of the Salton Sea increased from about 3,600 to about 16,000 ppm, as the surficial salt deposits continued to redissolve. Since the early 1920's, the TDS has ranged from about 32,000 to 43,000 ppm (USGS Professional Paper 486-C, 1966).

Because there is no outflow from the Sea--other than evaporation--salts remain in the Sea. Consequently, about 5.6 million tons of salts accumulate each year (Federal-State Technical Group, Salton Sea Investigations, 1969); the Sea now contains some 300 million tons. About 113 of the 300 million tons were redissolved from salts deposited on the floor of the Sink prior to the 1904 flooding (Arnal, 1961) and the rest was concentrated by evaporation from subsequent inflow. According to Pomeroy (1965), diffusion of chloride to the Sea from the bottom muds is still continuing and the source is virtually inexhaustible.

Based on an average evaporation rate of 5.8 feet per year and the Sea's elevation of about minus 232 feet (USGS HA-222, 1966), average evaporation losses amount to approximately 1.34 million acre-feet per year. This is offset by an estimated annual inflow of about 1.25 million acre-feet, principally of return irrigation water and other runoff, 50,000 acre-feet of subsurface inflow, and some 40,000 acre-feet of precipitation.

Major Inflow

Irrigation return water from applied Colorado River water constitutes the Sea's major source of replenishment, largely via the Alamo and New Rivers and to a lesser degree by the Whitewater River (Plate 1). Smaller quantities are also contributed by the various drains and ditches which empty into the Sea. The quality of these waters is also affected by domestic and industrial wastes.

The Alamo River near Calipatria (11S/13E-22H), with an annual flow of over 500,000 acre-feet (Table 5), has a TDS of about 2,500 ppm, a sodium chloride-sulfate character, and a fluoride concentration of about 1 ppm.

The New River near Westmorland (12S/13E-19N), containing approximately 3,500 ppm TDS, is sodium chloride in character, with nearly 1 ppm fluoride; it has an annual flow of less than 500,000 acre-feet (Table 5).

The TDS of the Whitewater River at Mecca (7S/9E-30R), with an annual flow of less than 100,000 acre-feet (Table 5), is approximately 2,500 ppm. This water has a relatively high fluoride concentration of about 3.5 ppm and a sodium sulfate-chloride character (Appendix D).

One of the drains emptying into the Salton Sea is the Pumice (Drain Alternate) By-Pass-Canal (11S/13E-28L) near Rock Hill (Plate 1) which, based on a February 8, 1968 measurement,

may discharge on the order of 15,000 acre-feet per year of irrigation return water. This water has a TDS of about 3,000 ppm and is sodium sulfate-chloride in character.

Tributary Creeks

Inflow to the Salton Sea from San Felipe Creek at State Highway 86 (12S/11E-17M) occurs largely as flood runoff. Consequently, it is variable, ranging from about 100 to 8,700 acre-feet per year (Table 5), as compared to the relatively constant flow from Salt Creek near State Highway 111 (8S/10E-2P). From 1955 to 1957 (Appendix D), flow in San Felipe Creek ranged from about 7,000 to 9,000 ppm TDS and was sodium chloride in character, with significant sulfate concentrations. Flow in Salt Creek is sodium chloride in character, has a high fluoride concentration, and contains nearly 4,500 ppm TDS. It includes seepage losses from the Coachella Canal.

IMPORTED WATER

Annually, about 3 million acre-feet of Colorado River water is imported by IID and CVCWD via their major canals. The TDS of this water, as indicated by flow in the Coachella Canal (8S/12E-6J), is generally less than 1,000 ppm. Although somewhat variable, its typical character is sodium-calcium sulfate.

GROUND WATER

The chemical quality of ground water in the Salton Sea Area has been largely influenced by the structural development of the region. Because the area occupied by the Sea is the topographic low of the landward extension of the Salton Trough, it has been subjected to frequent periods of flooding and sedimentation in a subsiding basin. As the waters evaporated, extensive salt deposits formed which were covered during subsequent periods of sedimentation. Because of saline deposits trapped in the sediments of the basin, ground water in general, for a given depth, becomes more saline toward the Sea. However, northwest of the Sea, the influence of the saline deposits on the ground water has been minimized by the subsurface recharge of the Whitewater River drainage system.

Ground water in the Salton Sea Area varies from the less than 500 ppm TDS artesian ground water near Mecca to the 50,000 ppm TDS water from mud volcanos northwest of Niland.

No.	Location	Description	Date	T-°F	pH	Character	TDS[a]	Cl	F	B	K/Na epm x 100
							ppm				
1.	7S/ 9E-18M1	Barnes' Well	8- 3-61	90	9.0	Na HCO_3	173	17	0.8	0.01	1.25
2.	7S/ 9E-30R	Whitewater River	5- 8-67	78	8.1	Na SO_4	2,195	442	3.6	0.85	1.02
3.	8S/ 9E-29H1	Newkirk's Well	12-18-59	—	8.2	Na SO_4	588	108	5.1	0.41	0.69
4.	9S/ 9E-4K1	Fish Spnngs Artesian Well	5-19-67	115	7.1	Na Cl	10,441	5,950	2.6	10.10	0.41
5.	10S/10E-18N1	Ballard's Truckhaven Well	5-19-67	104	8.2	Na Cl	3,716	1,600	1.6	5.90	0.48
6.	11S/ 9E-2B1	Holly Corp's Hot Mineral Well	5-19-67	136	8.1	Na Cl	2,182	960	3.4	6.60	0.40
7.	11S/11E-21P	Salton Sea at Navy Base Pier	6- 8-67	77	7.7	Na Cl	35,976	15,000	3.2	9.20	0.97
8.	12S/11E-21MS1	Kane Spring	5-12-67	67	8.0	Na Cl	3,096	1,130	2.8	5.70	0.21
9.	12S/11E-17M	San Felipe Creek at Highway 86	12-17-57	59	7.8	Na Cl	9,040	2,970	1.4	2.20	0.58
10.	12S/12E-29NS1	Poe Road Spring	5-12-67	70	6.8	Na HCO_3-Cl	4,320	1,150	0.6	5.00	1.91
11.	12S/11E-24X	Auger Hole No. 7, USDA, ARS	12- 7-64	72	7.5	Na SO_4	6,422	1,372	—	—	1.11
12.	8S/12E-6J	Coachella Canal N/O R.R.	5-10-67	70	8.2	Na-Ca SO_4	855	137	0.6	0.22	2.02
13.	12S/13E-19N	New River near Westmoreland	5- 8-67	75	7.6	Na Cl	3,229	1,144	0.7	0.28	1.88
14.	11S/13E-22H	Alamo River near Calipatria	5- 8-67	75	8.0	Na Cl-SO_4	2,350	639	0.9	0.26	1.72
15.	11S/13E-28L	Pumice-By-Pass Canal	2- 8-68	57	7.4	Na SO_4-Cl	2,891	747	0.6	0.60	1.50
16.	12S/13E-4Q2g	Western Geothermal, Sinclair 4	7- 5-67	> 212	5.3	Na Cl	255,700	154,590	14.	332.	15.00
17.	11S/13E-24ES1	Mud Volcano (Pot)	11-23-64	100	7.4	Na Cl	16,232	9,010	2.8	69.30	3.26
18.	10S/13E-27BS1	Mud Volcano (Pot), Etna	3-15-67	68	6.0	Na Cl	48,237	27,900	3.6	84.00	1.79
19.	11S/13E-13D2	Maisson's Well "Hot Mineral Spa"	2- 8-68	104	6.4	Na Cl	22,432	12,423	1.8	50.00	4.13
20.	9S/13E-20LS1	Frink Spring	10-29-64	75	8.1	Na Cl	3,605	1,720	2.8	4.00	2.24
21.	9S/13E-7M1	Fountain of Youth Hot Mineral Well	2-21-64	140	6.5	Na Cl	4,634	2,240	3.5	6.60	3.28
22.	9S/12E-1D1	Bashford's New Well No. 1	7- 6-63	—	8.1	Na-Ca SO_4	835	122	1.8	—	4.33
23.	8S/12E-36P1	New Pilger Hot Mineral Well	5-11-67	180	7.4	Na Cl	2,763	1,370	5.0	4.10	2.19
24.	8S/11E-12P2	"Hunter's Spring" New Well	10-27-64	90	7.8	Na Cl	2,125	1,046	3.0	0.08	0.31
25.	8S/11E-28R	Salt Creek above Hwy. 111 Bridge	5-11-67	62	8.0	Na Cl	4,340	1,550	5.5	5.00	1.04
26.	8S/11E-3CS1	Dos Palmas Spnngs	11-11-17	80	—	Na Cl	1,609	688	—	—	—
27.	8S/11E-3CS1	Dos Palmas Spnngs	5-10-67	82	7.9	Na Cl	1,330	432	2.0	1.90	2.32
28.	8S/10E-1A	Pon's Well – Avenue 74	9-20-61	81	7.3	Na Cl	1,984	825	3.1	3.70	0.11
29.	7S/10E-30F1	Helman's Well	12-16-59	83	8.7	Na Cl	745	298	4.4	0.08	0.45
30.	M-10	Cerro Prieto Area, Mexico Geothermal Well	3-16-67	160	5.8	Na Cl	12,073	7,175	1.2	11.00	8.29

a. Computed

Figure 8 - TRILINEAR DIAGRAM

LEGEND

TDS CONCENTRATION, PPM

- ○ < 500
- □ 500 - 1,000
- △ 1,000 - 5,000
- ○ 5,000 - 10,000
- ○ 10,000 - 100,000
- ● > 100,000

WELL DEPTH FEET

- A < 100
- B 100 - 500
- C 500 - 1,000
- D 1,000 - 2,000
- E > 2,000

NOTES:

1. SIGN < = LESS THAN AND SIGN > = GREATER THAN VALUE SHOWN
2. SEE PLATE I FOR LOCATION AND APPENDIX D FOR CHEMICAL ANALYSES.
3. DISCUSSION IN APPENDIX F OF TRILINEAR DIAGRAM.

EMICAL ANALYSES OF SELECTED WATERS

Most ground water in the Salton Sea Area is sodium chloride in character (Figure 8 and Plate 1). Exceptions are the artesian sodium bicarbonate ground waters from wells northwest of the Sea (Figure 8, Location No. 1) and the sodium bicarbonate-chloride waters near Poe Road Spring (Figure 8, Location No. 10) on the southern shore of the Sea. The artesian sodium bicarbonate ground water northwest of the Sea also differs from the prevalent sodium chloride water (Plate 1) in its greater than 8 pH, its carbonate concentration of about 10 ppm, and its TDS concentration as low as 200 ppm.

Chemical analyses of ground water (7S/9E-18M1) from near Mecca show the influence of upstream recharge by the Whitewater River and its tributaries northwest of the study area. Near the community of Whitewater, flow in the River generally has less than 300 ppm TDS (Department of Water Resources Bulletin No. 130-67, 1968).

Hot mineralized ground water, generally above 100°F and containing about 2,000 to 5,000 ppm TDS, 1 to 5 ppm fluoride, and 4-7 ppm boron, is found along the San Andreas fault zone in the Fountain of Youth (9S/13E-7M1) and the New Pilger (8S/12E-36P1) hot mineral wells; and along the west side of the Salton Sea in the Holly Corporation's hot mineral well (11S/9E-2B1) and at the Truckhaven Well (10S/10E-18N1) (Appendix D). However, adjacent to the Sea at the Fish Springs' artesian well (9S/9E-4K1), the 115°F sodium chloride ground water has a TDS of about 10,000 ppm, its fluoride concentration is about 3 ppm, and its boron about 11 ppm.

In the vicinity of the Buttes thermal area, water rising from mud volcanos and flowing from the old carbon wells is sodium chloride in character. It contains about 50 ppm or more of boron, less than 5 ppm fluoride, and approximately 16,000 to 48,000 ppm TDS (Figure 8). Temperatures of over 100°F have been measured for ground water from the carbon dioxide wells (11S/13E-13D1) with values as low as 68°F recorded at the mud pots northwest of Niland (10S/13E-27BS1).

Warm ground water (about 90°F) produced from wells near Hunter and Frink Springs (8S/11E-12P2 and 9S/13E-20E1) along the Andreas fault zone has TDS of about 2,000 to 4,000 ppm, fluoride concentrations of 4 ppm, and boron concentrations of less than 1 to about 5 ppm (Appendix D). However, the springs, although of similar quality to the thermal water from the wells, generally fall within a temperature range on the order of 70 to 80°F. Similar quality water is found southwest of the Sea at Kane Spring (12S/11E-21MS1).

NEW PILGER WELL (8S/12E-36P1), a hot mineral well, producing 180°F water near the Hot Mineral Spa (DWR Photo, 1967).

The higher potassium:sodium ratio of sodium chloride ground water from east of the Sea distinguishes it from that west of the Sea (Figure 8).

Locally, wells less than 25 feet deep, such as 9S/12E-1D1, intercept seepage of Colorado River water from the Coachella Canal. Production from this well is sodium-calcium sulfate in character and contains about 1,000 ppm TDS; however, it differs significantly from Coachella Canal water in that there is a more than twofold increase in its fluoride concentration.

Analyses of water from auger holes less than 10 feet deep along the southern periphery of the Salton Sea (Plate 1) show the results of irrigating with imported Colorado River water. However, chemical quality varies according to how long the land has been free from inundation by the Sea and how long the area has been irrigated. Water from auger hole 11S/14E-8X, with over 25,000 ppm TDS and a sodium

MUD VOLCANO "ETNA", a spring (10S/13E-27BS1) producing gas and water. This feature is probably related to geothermal activity and San Andreas fault system (DWR Photo, 1967).

GAS BUBBLE collapses as second bubble forms in mud volcano near Mullet Island (© Norman A. Moore, 1949).

chloride character, indicates only a partially leached soil, whereas near San Felipe Creek the sodium-calcium sulfate-chloride water of auger hole 12S/11E-16S, having less than 2,500 ppm TDS, points to extensive leaching through irrigation or flushing by natural runoff.

A 650-foot-deep test well, near the intersection of San Felipe Creek and State Highways 78 and 86, produced large flows containing about 1,400 ppm TDS. However, at depths of less than 250 feet, the TDS concentration was approximately 8,000 ppm (Pomeroy, 1965).

Although absolute concentrations of the individual trace elements may vary in waters from one locale to the next, the relationship of these constituents to each other as a group is very similar (Plate 2). That is, the rosette-like patterns of the trace element diagrams disclose a high degree of similarity, especially those segments of the diagrams depicting lithium (Li), copper (Cu), iron (Fe), lead (Pb), and strontium (Sr). As shown on Plate 2, the pattern characteristic of these trace elements is common to nearly all water in the study area, including Colorado River water from the Coachella Canal (8S/12E-6J).

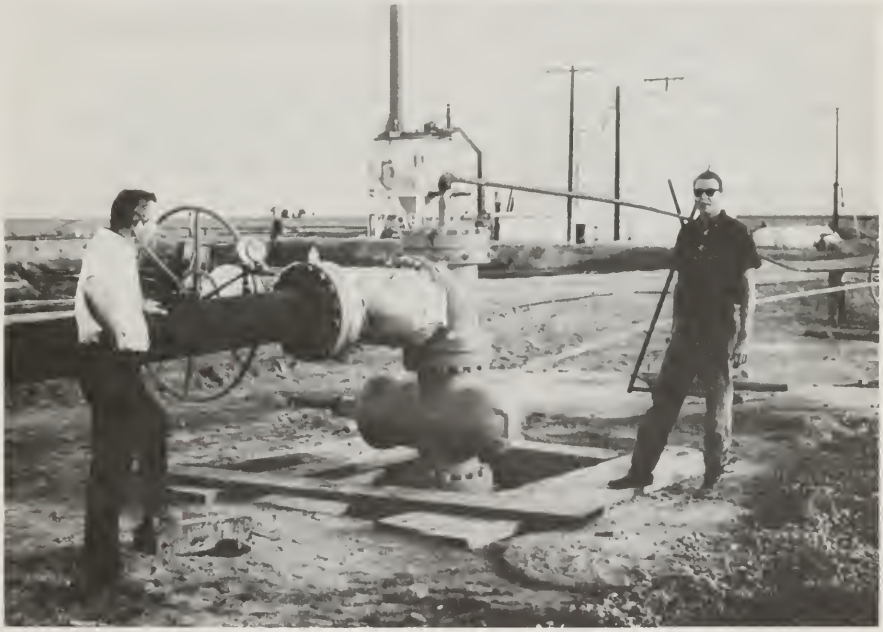
Among the trace elements--vanadium (Va), zinc (Zn), manganese (Mn), molybdenum (Mo), and barium (Ba)--there is a great variation in the trace element diagrams. Sr and Li generally reveal the highest concentrations, while Fe, Ba, Mn, and Zn may also occur in higher quantities than the trace elements--Cu, Mo, V, or Pb. Mo concentrations are relatively low in the thermal waters from the Buttes thermal area, but show higher concentrations elsewhere.

Ground water from the northwestern part of the study area (Plate 2) has a somewhat different trace element pattern. It has relatively higher Va and lower Ba and Sr concentrations than that found elsewhere in the study area.

GEOTHERMAL WATERS

Because the geothermal development in the Salton Sea Area is currently confined to the vicinity of the Buttes thermal area, the following discussion is largely concerned with the quality of the geothermal waters in that region. The quality of the geothermal water is related to the depth at which it is extracted.

Wells in the Buttes thermal area have been drilled to depths of more than 8,000 feet, although most of them are approximately 5,000 feet deep with a few being on the order



GEOTHERMAL WELL, SINCLAIR 4, near Niland. Above: well (12S/13E-4Q2$_g$) owned by Western Geothermal, Inc. produces geothermal brines for calcium chloride extraction. Upper left: pipe leading from well to surface pond just before well was brought into production (note salt encrustation on pipe and ground surface). Lower left: taken a few minutes later, shows steam and hot brine forced from well under tremendous pressure (DWR Photos, 1967 and 1968).

of 2,000 feet. The depth of wells drilled in that area, the dates drilled, and well identifications are presented in Table 6.

During a test in 1962 of IID 1 (11S/13E-23F1$_g$) a flow of 625,500 pounds per hour (consisting of 125,000 pounds of steam and 500,500 pounds of brine) was recorded at wellhead conditions of 200 pounds per square inch-gage and 405°F (California Department of Mines and Geology, Special Report 75, 1965). Production temperatures from other wells have ranged from 300°F to 600°F.

Largely sodium chloride in composition (Appendix D), the preflash geothermal waters from the deep wells (5,000 feet) are noted for their salinity--commonly over 250,000 ppm TDS--and for their relatively high concentrations of trace elements (Appendix E).

During production, as the superheated geothermal fluids rise in the deep wells and approach atmospheric conditions, some 15 to 20 percent by weight of the flow flashes to steam, leaving a hot saline solution, or postflash brine, with a TDS concentration of over 300,000 ppm. Flow from some geothermal wells in the Buttes thermal area has been reported to be about 1 million gpd (about 3 acre-feet per day).

The geothermal waters from the deep wells in the Buttes thermal area have a pH of about 5, a sulfate content of less than 100 ppm, and a boron concentration of more than 200 ppm (Appendix D). Other distinctive features are: (a) a specific gravity of from 1.2 to 1.3; (b) ammonium concentrations of about 400 ppm; (c) potassium:sodium ratios of about 15; and (d) high trace element concentrations, particularly the heavy metals barium, iron, and manganese (Appendix E).

Representative of production from the shallow geothermal wells is that from IID 3, 11S/13E-23D1$_a$, about 1,700 feet deep (used as a waste injection well subsequent to completion in 1965). This sodium chloride-rich water has a TDS of 35,600 ppm (Muffler and White, 1969), a pH of 7.5, a sulfate content of 621 ppm, and a boron concentration of 100 ppm (Appendix D).

Rex (October 1968) believes that the Buttes thermal area is underlain by two separate types of geothermal brines. The deeper brine is very hot and hypersaline (20-30 percent TDS), while a cooler, less saline, noncorrosive brine (approximately 1-3 percent TDS) lies above it. The contact between these two brines dips to the south. According to Rex, it is at approximately 2,000-2,500 feet at IID 1 (11S/13E-23F1$_g$) near

TABLE 6

GEOTHERMAL WELLS IN THE SALTON SEA AREA

DWR number	Name	Drilling started	Drilled depth in feet
11S/13E–10L1$_g$	Pioneer Development, No. 1	March 1927	727
–10L2$_g$	Pioneer Development, No. 2	—	1,263
–10L3$_g$	Pioneer Development, No. 3	—	1,473
–13K1$_j$	Earth Energy, Hudson Ranch 1	June 1964	6,141
–22J1$_g$	Imperial Thermal Products, IID 2	November 1963	5,826
–23C1$_j$	Imperial Thermal Products, IID 3	March 1965	1,695
–23F1$_g$	Imperial Thermal Products, IID 1	January 1962	5,232
–23G1$_g$	Joseph O'Neill, Sportsman 1	January 1961	4,729
–23P1$_g$	Imperial Thermal Products, Calif. 1	April 1964	4,861
–23D1$_g$	Earth Energy, River Ranch 1	October 1963	8,100
–27M1$_g$	Earth Energy, J. J. Elmore 1	March 1964	7,117
12S/13E– 4P1$_g$	Western Geothermal, Sinclair 2	February 1961	2,368
– 4C2$_g$	Western Geothermal, Sinclair 4	April 1964	5,306
–10D1$_g$	Western Geothermal, Sinclair 1	November 1957	4,720
–10D2$_g$	Western Geothermal, Sinclair 3	October 1962	6,922

j – Geothermal well used as an injection well

Red Hill; and at about 5,000-6,000 feet at Sinclair 3 (12S/13E-10D2$_g$) about four miles south. However, this brine contact was not found in Standard Oil Company's Wilson 1 (14S/15E-20) located just east of Imperial. Only about a 4 percent TDS brine was found in this well, and bottom hole rock temperatures reached 500°F (260°C). It was drilled in 1963 to a depth of 13,443 feet.

Although both the geothermal brines and other thermal waters are similar in composition--aside from their great differences in absolute concentrations--the configurations of the chemical analysis diagrams of the deep geothermal brines from the Buttes thermal area also differ from other ground waters in the study area in that the percentage of magnesium, sulfate, and bicarbonate concentrations in the brines is negligible, while that of calcium is quite considerable (Plate 1). Moreover, the trace element diagrams of the geothermal waters also differ from those of the other thermal waters (Plate 2) in that they have proportionally much higher concentrations of lead and zinc.

A radioactivity level (beta-gamma) of 550 picocuries per liter (pc/l) was measured in effluent from geothermal well 12S/13E-4Q2$_g$ as compared to a value of about 60 pc/l (Table 15, Appendix E) for a sample from the Truckhaven well 10S/10E-18N1. Another measurement of 1,464 pc/l was determined for geothermal well 12S/13E-4Q2$_g$ as compared to a value of 124 pc/l for the Massion well 11S/13E-13D2. The difference in values of the two geothermal radioactivity measurements is apparently due to methods of sample preparation and handling and laboratory testing procedures (see Table 15). The radioactivity of natural waters generally lies in the range of 1 to 1,000 pc/l (McKee and Wolf, 1963).

CHAPTER IV. GEOTHERMAL WASTES

Development of geothermal resources in the Buttes thermal area has consisted essentially of pilot operations, although with limited success due largely to operational difficulties, waste disposal problems, and economic constraints. However, about 50 miles south of the Buttes area (Figure 9), geothermal energy is now being developed commercially in the Cerro Prieto area. The great advantage of the Cerro Prieto over the Buttes geothermal field is the low salinity of its postflash geothermal effluent, less than 20,000 ppm as compared to that of the Buttes area, which is more than 300,000 ppm. Rex (October 1968) believes that geothermal waters similar to those from Cerro Prieto may also underlie the Imperial Valley and have a commercial potential.

The following section describes the existing developments and potential geothermal resources of the Salton Sea Area, including waste discharge problems. In addition, this section summarizes current studies of potential geothermal resources and plans for the beneficial uses of the Salton Sea.

EXISTING GEOTHERMAL DEVELOPMENT

The first attempt to find a natural source of steam to operate a power plant in the Buttes thermal area was undertaken by the Pioneer Development Company in 1927 (California Department of Conservation, Division of Oil and Gas, July - December 1942). Three wells (Table 6) were drilled near Mullet Island (Plate 1), but the project was abandoned because the pressure and volume of steam were insufficient for commercial purposes. In 1957, interest in the geothermal resources of the Buttes thermal area was renewed. Since then, some 15 geothermal wells have been drilled by various developers. The three principal operators are Western Geothermal, Inc. (Chloride Products), Imperial Thermal Products, Inc. (Morton International, Inc.), and Earth Energy Co. (Union-Pure Oil Co.).

Since 1966, Western Geothermal (General Earth Minerals Corp. acquired mineral leases and facilities in July 1969) has produced limited quantities of brine from its Sinclair No. 4 geothermal well ($12S/13E-4Q2_g$). After treatment, a calcium chloride product was marketed for industrial use.

In January 1965, Imperial Thermal Products assumed the operating function of its present facilities and began conducting pilot operations for electrical power generation and chemical recovery of mineral salts. During the spring

of 1965, a 3,000-kilowatt pilot steam generation plant was installed near geothermal well IID No. 1 (11S/13E-23F1$_g$). Several large solar evaporation ponds were constructed by Imperial Thermal for extracting chlorides of calcium, potassium, sodium, and other mineral salts from the geothermal brines.

Earth Energy set up similar operations on property adjacent to Imperial Thermal's development. In addition to Earth Energy's solar evaporation ponds, a pilot separation plant was constructed near its geothermal well, River Ranch No. 1 (11S/13E-23D1$_g$). This plant was operated for several months during 1964 and 1965, producing potassium chloride and other salts. At present, Thermal and Earth Energy are not marketing any products from their facilities.

GEOTHERMAL WASTES AND BY-PRODUCTS

There have been several types of waste products associated with the pilot operation in the Buttes thermal area, namely:

1. Geothermal brines.

2. Salt deposits crystallized from brines.

3. Waste liquors (bitterns) remaining after the crystallization of salt deposits.

Depending on the method and stage of treatment, these waste products may exist in various combinations.

Where the geothermal resource is developed for energy all mineral products from the wells constitute wastes. However, if it is developed for minerals, then excess salts, geothermal effluents (brines), and bitterns that remain after the minerals are extracted constitute wastes. In the Salton Sea Area, the objective has been both energy and minerals.

The maximum development of geothermal resources in the Buttes thermal area, as well as in other regions, needs the provision of adequate storage and disposal facilities to forestall the threat of pollution. The Colorado River Basin Regional Water Quality Control Board (No. 7) recognized the disposal of extremely saline effluent, bittern, and salts from existing geothermal developments in the Buttes thermal area as a possible pollution threat to the Salton Sea and other receiving waters. It has therefore played an active role in controlling their harmful disposal to surface and ground water. Since 1961, the Board and the Department have worked closely with developers to prevent geothermal wastes from damaging the quality of the Salton Sea Area's water resources.

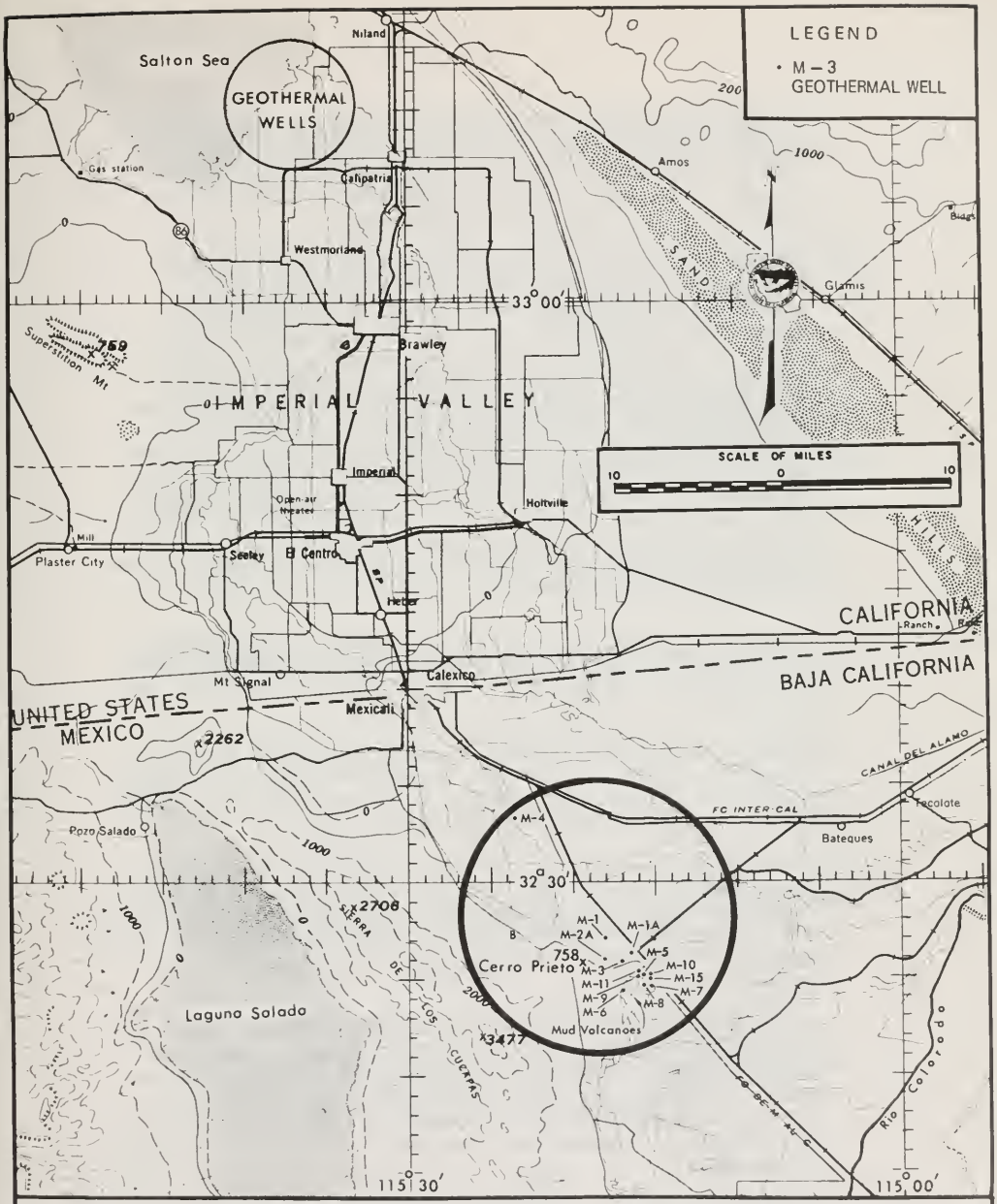


Figure 9 – LOCATION OF GEOTHERMAL WELLS: CERRO PRIETO AREA, BAJA CALIFORNIA, MEXICO

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

In Resolution No. 67-1 and prior resolutions, the Board prescribed requirements for storing and disposing effluent from the geothermal wells into temporary holding ponds in the Buttes thermal area. The ponds now cover an area of about 300 acres near the geothermal wells.

On March 22, 1962, the Board adopted Resolution No. 62-6 permitting a 90-day test of waste disposal from pilot operations of geothermal well IID No. 1 (11S/13E-23F1g). Commencing May 18, 1962, the quantity and quality of the effluent from the well was monitored continuously during the test. About 5 acre-feet of effluent was mixed daily with about 60 acre-feet of diversions from the Alamo River and the combined flow was discharged to the marshy areas adjacent to the Sea. Chemical analyses (Appendix D) of the resulting discharge (11S/13E-23F) showed a sodium chloride character, with nearly 24,000 ppm TDS--considerably higher than that of most surface inflow, which is less than 5,000 ppm. Temperatures of the effluent prior to dilution exceeded 210°F, but that of the combined flow varied from 88°F at night to 108°F by the day.

Thus, tests of waste discharges from these pilot operations indicated that the effluent produced from geothermal wells might adversely affect the Sea's temperature, salinity, and wildlife.

Based on a well discharge of 1 million gpd and a postflash brine of over 300,000 ppm TDS, a geothermal well could produce about 2.5 million pounds of sodium-chloride-rich solids daily, or 0.46 million tons annually.

The estimated annual salt production from only 3 wells thus could amount to more than 1 million tons per year, equivalent to approximately 1/5 of the total annual salt contribution to the Salton Sea from all sources. Consequently, indiscriminate waste discharges from geothermal wells could be sources of serious impairment.

To protect the beneficial use of the Alamo River, Salton Sea, and ponds of the Imperial Waterfowl Management Area, the Board prohibited any further discharge of geothermal wastes into any conveyance channel leading into the Salton Sea. This requirement was stated in Resolution No. 63-14 (December 12, 1963) and in subsequent resolutions concerning geothermal development.

The Earth Energy Co. and Imperial Thermal Products therefore experimented with injection wells as an alternative to surface disposal. By this method, the waste is injected back into the formation from which the brine is produced. In the fall of 1965, in compliance with Board Resolution No. 65-10,

Earth Energy injected surplus brines and bitterns from geothermal well River Ranch 1 (11S/13E-23D1$_g$) into its waste disposal injection well, Hudson Ranch 1 (11S/13E-13K1$_j$), below the 5,000-foot depth.

By December 1966, Imperial Thermal injected 100,000 gallons of wastes (about 0.3 acre-feet) into its disposal well IID 3 (11S/13E-23C1$_j$) at about the 1,700-foot depth. The average TDS content was approximately 40 percent by weight (400,000 ppm TDS).

According to the 1967 State Senate Permanent Fact Finding Committee's Fourth Progress Report to the California Legislature on geothermal resources, "One of the physical problems facing maximum exploration and development of this resource (geothermal) is the large volume of bittern brine that is associated with such development, as it is on land operation."

In the Committee's Report, possible methods suggested to minimize the threat of pollution from development of geothermal resources include:

1. Development of deposits found to have only dry steam;

2. Reinjection into the producing horizon;

3. Reinjection into contaminated horizons other than the producing zone;

4. Dilution, a principal, practical method on land where surface waters are abundant and the amount of effluent is not large;

5. Ponding, onshore geothermal fluids can be ponded for evaporation or for indefinite storage;

6. Saline water conversion;

7. A closed system using a heat exchanger;

8. Exporting waste from a region for disposal elsewhere;

9. Developing a market for all products.

POTENTIAL GEOTHERMAL DEVELOPMENT AND WASTES

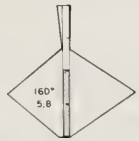
The areal extent of the potential geothermal resource has a direct bearing on the extent of possible disposal problems that could result from future geothermal development. The

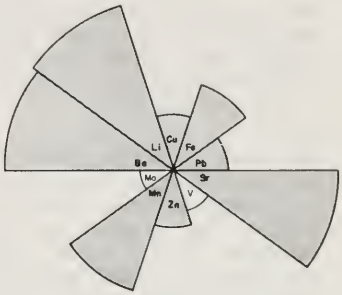
presence of geothermal water in the Buttes thermal area is well established, but it may also be present elsewhere in the Salton Sea Area, according to assessments by the Department and others. Geophysical investigations, petroleum explorations, and isotope studies furnish evidence of geohydrologic conditions favorable for the occurrence of geothermal waters in the Imperial Valley, as indicated by the studies of Craig (1969), Muffler and White (1969), Helgeson (1968), Skinner, et al (1967), Biehler (1964), Kovach, et al (1962), and others. Regionally, geothermal water may extend south from the northern end of the Imperial Valley into Baja California, at least as far as the Cerro Prieto geothermal field (Figure 9). In Cerro Prieto, geothermal energy is now being developed commercially; a 75,000-kilowatt capacity steam power plant will be completed by 1970, with an additional facility being planned for the future. According to Rex (October 1968), the Imperial Valley and its southern extension into Mexico form one large geothermal province with an average heat flow of two to three times the continential average, covering an area in California of at least 2 million acres (about 3,100 square miles) and underlain by about 20,000 feet of sediment.

He estimates there are about 3 billion acre-feet of geothermal water in this vast area, assuming the lower 15,000 feet of sediments are filled with hot brine and the sediments have an effective average porosity of 10 percent. The widespread occurrence of geothermal water makes it attractive to find regions where brines hotter than 550°F are within 5,000 feet of ground surface. If these resources should be developed, this could create a vast potential source of waste products which could, in turn, create a threat of pollution to the region's water resources.

Although the Cerro Prieto geothermal waters have a TDS of less than 10 percent of that from the deep wells (5,000 feet) in the Buttes thermal area, the relative concentration of their major constituents is similar. Their chemical constituents are shown on Plate 1 (12S/13E-4Q2$_g$) and in Figure 10 (M-10). Evidence of the common origin of the geothermal waters from Cerro Prieto, Colorado River water, and ground water from the Salton Sea Area is also indicated by the similar characteristic pattern formed by the Li, Cu, Fe, Pb, and Sr segments of their trace element diagrams. However, the trace element diagrams (Plate 2) of geothermal water (12S/13E-4Q2$_g$) from the Buttes thermal area point to a more complex origin than that of water from other areas.

Because mineral and trace element concentrations in water from various geothermal fields substantially differ, waste discharges from specific geothermal fields, and even





NOTES:

1 DATE SAMPLED - 3/16/67
2 SEE FIGURE 9 FOR WELL LOCATION
3 SEE PLATE 1 LEGEND FOR EXPLANATION OF MODIFIED STIFF DIAGRAM
4 SEE APPENDIX F FOR DISCUSSION ON DIAGRAM

NOTES:

1 DATE SAMPLED - 3/16/67
2 SEE FIGURE 9 FOR WELL LOCATION
3 SEE PLATE 2 LEGEND FOR EXPLANATION OF TRACE ELEMENT ROSE
4 SEE APPENDIX F FOR DISCUSSION ON TRACE ELEMENT ROSE

Figure 10 - GRAPHIC ANALYSES OF GEOTHERMAL WELL M-10, MEXICO

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

individual geothermal wells, must be individually evaluated as to quantity and quality. The collection of information during geothermal exploration would necessarily also include quality data of the area's water resources.

Before any major development is undertaken to utilize the potential geothermal resources of the Imperial Valley, plans would be necessary to protect the water resources for their full utilization.

CURRENT STUDIES

The U. S. Department of Interior, with the cooperation of other federal and state agencies, conducted a reconnaissance investigation of the Salton Sea. Its objective was to find ways to make best use of the Sea consistent with its primary function of storing agricultural drainage and seepage water. Its specific activities were to:

1. Formulate a plan, or alternate plans, to stabilize the level of the Sea, limit its salinity, and control its nutrient-related problems.

2. Evaluate the engineering and financial practicability and economic justification of alternate plans.

The results of the investigation are summarized in the Federal-State Technical Group's provisional report, "Salton Sea Project California, Reconnaissance Investigation", August 1969. This report recommends a project feasibility level investigation to confirm the results of the reconnaissance investigation.

Currently, Dr. Rex, with the assistance of Dr. Meidav, of the Institute of Geophysics, University of California at Riverside, is directing the Imperial Valley Project (IVP). This program was initiated to develop the geothermal resources of the Lower Colorado River delta, which includes the Imperial Valley and adjoining areas. The investigation is first concentrating on the Imperial Valley, but later field studies will embrace Arizona, Mexico, and perhaps Nevada to define the extent and quality of their geothermal resources.

Following a critical evaluation of the preliminary exploration phase, Rex (October 1968) proposes extensive field tests to provide data necessary for determining the economics of developing geothermal energy for power, desalination, and possibly mineral extraction.

If this preliminary phase proves successful, he intends to conduct a full-dress engineering and economic evaluation of the potentials of geothermal energy in the Lower Colorado Basin for desalination, power, and possibly mineral extraction.

Appendix A

IDENTIFICATION SYSTEMS AND CRITERIA USED IN REPORT

Appendix A

IDENTIFICATION SYSTEMS AND CRITERIA USED IN REPORT

This appendix contains explanations of the sampling point identification system, areal designation system, and water quality criteria used in the preparation of this study and report.

SAMPLING POINT IDENTIFICATION SYSTEM

For convenience in recording the wells, springs, and surface waters from which samples have been taken in this investigation, the following system has been used:

Water Wells

Wells from which samples of water or measurements of depth to ground water have been obtained are assigned state well numbers. For these, wells are referenced by use of the United States Public Land Survey System. The well number consists of the township, range, and section numbers, a letter to indicate the 40-acre lot in which the well is located, and a number to identify the particular well in the 40-acre lot.

Sections are subdivided into 40-acre lots, as shown in the figure. For example, well 7N/34W-13N3 denotes the third well to be assigned a number in Lot N of Section 13 of Township 7 North, Range 34 West.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Section lines have not generally been surveyed into areas included in the Spanish and Mexican land grants. So that the state well number system may be used in these areas, section lines have been projected across the ranchos on the standard United States Geological Survey quadrangle sheets. The projections of section lines used for well numbering in the Southern District are delineated on quadrangle sheets in the Los Angeles office of the Department of Water Resources. It is suggested that interested agencies and individuals desiring to project section lines for well numbering trace the projections from the Department's maps, so as to avoid conflicts and confusion in assigning well numbers.

The reader will occasionally notice a well which does not plot in the location indicated by its number. This occurs in instances where an erroneous number has been assigned and used for a relatively long time; generally, the erroneous number has been referred to in numerous reports. To avoid further confusion, the number has been continued in use.

Geothermal Wells

For the purpose of this report, geothermal wells are assigned state well numbers on the same basis as water wells, but the subscript letter "g" is inserted immediately after the complete well number to distinguish it from a standard water well, e.g., 12S/13E-4Q2$_g$. The subscript letter "j" on the other hand indicates that the geothermal well is used as an injection well, e.g., 11S/13E-13K1$_j$.

Springs

Springs are assigned state well numbers on the same basis as are water wells, but the letter "S" is inserted immediately after the lot identification. For example, 7N/34W-5NS1 is the first spring assigned a number in Lot N of Section 5 of Township 7 North, Range 34 West.

Surface Waters

The system used for identifying surface water monitoring points is similar to that used for wells or springs, except that identification applies only to the 40-acre lot; e.g., 7S/9E-30R.

WATER QUALITY CRITERIA

Many sets of guidelines by which the suitability of water may be judged have been suggested by authorities to codify the requirements for water quality for beneficial use. Included in these attempts at classification are several terms, some of which may appear strange or confusing to the reader; among them are standards, criteria, and objectives. This section attempts to define the jargon of the discipline as used in this report and to explain at least one of the many systems employed.

Definition of Terms

Before any discussion of water quality classification can be presented, it is necessary to explain several terms. These are:

Standards. Standards are those values established by some regulatory agency as obligatory limits on water quality. Perhaps the best-known of these are the United States Public Health Service Drinking Water Standards. Equally important to any discussion of water quality criteria in California are those standards established by the California Department of Public Health. The two sets of standards differ only slightly.

Criteria. As opposed to standards, criteria are guidelines for judging water for a particular use. They are more general than standards and are by no means obligatory. Criteria must be cited with reference to the use for which a particular water source is intended, as they can vary from place to place and with a given situation. The discussion here is only intended as a brief summary; for a more definitive work, the reader is referred to the excellent treatise by Dr. J. E. McKee and H. W. Wolfe, entitled "Water Quality Criteria", to mention only one of many books on the subject.

Objectives. Objectives refer to the level of water quality desired. They are used most often with respect to ground water in one basin or to surface water in a given stream, lake, bay, or area of the ocean. Generally, objectives are goals for water quality that are thought to be reasonable to maintain in a natural body of water, particularly one which receives some discharge of manmade waste. It might be noted that use of the term objectives usually implies that the objectives have been established by some regulatory agency. It should also be stressed that, for effective water quality control, objectives should only be established after due

deliberation and study, and they should be reexamined periodically. Objectives are dynamic and should be modified according to changes in environment.

Specific Uses

With the general terminology defined, the specific requirements for various uses can now be examined.

Domestic Use. Water used for drinking and culinary purposes should be clear, colorless, odorless, pleasant-tasting, and free from toxic salts. It should not contain excessive amounts of dissolved minerals and must be free from pathogenic organisms. In addition to these physical and bacteriological requirements, certain qualifications are generally placed on chemical quality, either as requirements by a regulatory agency or for comparative grading of different waters.

The 1962 Drinking Water Standards of the United States Public Health Service are legally applicable only to drinking water and water supply systems used by interstate carriers and others subject to Federal quarantine regulations. However, they have been adopted by the entire water works profession as minimum standards for control and are widely quoted.

The standards themselves, as promulgated, include discussions of bacteriological, physical, radiological, and chemical aspects. Only the chemical aspects will be discussed here. Table 7A presents the standards; the recommended values are those which should not be exceeded in a water supply if other more suitable supplies are or can be made available. The mandatory values are those which, if exceeded, constitute grounds for rejection of the supply.

The standards for fluoride are related to the annual average of maximum daily air temperatures (based on a minimum five-year record) and are presented in Table 7B. The average concentration should not exceed the appropriate upper limit in the table. The presence of fluoride in average concentrations greater than twice the optimum values in Table constitutes grounds for rejection of the supply. The standards further state that where fluoridation is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in Table 7B.

In California, the State Board of Public Health issues water supply permits in accordance with its "Interim Policy on Mineral Quality of Drinking Water", as adopted September 4, 1959, and in accordance with "Policy Statement and Resolutions by the State Board of Public Health with Respect to Fluoride

TABLE 7A

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS, 1962

Substance	Recommended limits of concentrations, in mg/l	Mandatory limits of concentrations, in mg/l
Metheylene blue active substance (MBAS) as ABS	0.5	--
Arsenic (As)	0.01	0.05
Barium (Ba)	--	1.0
Cadmium (Cd)	--	0.01
Carbon chloroform extract (CCE)	0.2	--
Chloride (Cl)	250	--
Chromium (hexavalent) (Cr^{+6})	--	0.05
Copper (Cu)	1.0	--
Cyanide (CN)	0.01	0.2
Fluoride (F)	**	**
Iron (Fe)	0.3	--
Lead (Pb)	--	0.05
Manganese (Mn)	0.05	--
Nitrate (NO_3)*	45	--
Phenols	0.001	--
Selenium (Se)	--	0.01
Silver (Ag)	--	0.05
Sulfate (SO_4)	250	--
Total dissolved solids (TDS)	500	--
Zinc (Zn)	5	--

*In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.
**See Table 7B. Standards in Tables 7A and 7B were adopted in 1962.

TABLE 7B

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS, 1962 -- FLUORIDE

Annual average of maximum daily air temperatures, in degrees Fahrenheit	Recommended control limits -- fluoride concentrations, in mg/l		
	Lower	Optimum	Upper
50.0 - 53.7	0.9	1.2	1.7
53.8 - 58.3	0.8	1.1	1.5
58.4 - 63.8	0.8	1.0	1.3
63.9 - 70.6	0.7	0.9	1.2
70.7 - 79.2	0.7	0.8	1.0
79.3 - 90.5	0.6	0.7	0.8

Ion Concentrations in Public Water Supplies", as approved August 22, 1958. The interim policy on mineral quality is presented as follows:

1. Water supply permits may be issued for drinking and culinary purposes only when the Public Health Service Drinking Water Standards of 1946[1] and the State Board of Public Health policy on fluorides are fully met.

2. In view of the wide variation in opinion in this field, the uncertainty as to the long-time health effects, the uncertainty of public attitude concerning various mineral levels, and the obvious need for further study, temporary permits may be issued for drinking water supplies failing to meet the Drinking Water Standards if the mineral constituents do not exceed those listed under the heading "Temporary Permit" in Table 8 .

TABLE 8*

UPPER LIMITS OF TOTAL SOLIDS AND SELECTED MINERALS IN DRINKING WATER AS DELIVERED TO THE CONSUMER

	Permit	Temporary Permit
Total Solids	500 (1,000)**	1,500 milligrams per liter
Sulphates	250 (500)**	600 " " "
Chlorides	250 (500)**	600 " " "
Magnesium	125 (125)	150 " " "

*This interim policy relates to potable water and is not intended to apply to a secondary mineralized water supply intended for domestic uses other than drinking and culinary purposes.

**Numbers in parentheses are maximum permissible, to be used only where no other more suitable waters are available in sufficient quantity for use in the system.

3. Exception: No temporary permit for drinking water supplies in which the mineral constituents exceed those listed under the heading "Temporary Permit" as set forth in #2 above may be issued unless the Board determines after public hearing:

   (a) The water to be supplied will not endanger the lives or health of human beings; and

1/ Author's Note: It is assumed in the absence of any later standards, that the 1962 edition of the Drinking Water Standards now applies.

(b) No other solution to meet the local situation is practicable and feasible; and

(c) The applicant is making diligent effort to develop, and has reasonable prospect of developing a supply of water which will warrant a regular permit within an acceptable period of time.

The burden of presenting evidence to fulfill the requirements as set forth in (a), (b), and (c) above is upon the applicant.

With respect to fluoride concentration, the State Board of Public Health has defined the maximum safe amounts of fluoride ion in relation to mean annual temperature as shown in Table

TABLE 9

CALIFORNIA STATE BOARD OF PUBLIC HEALTH, MAXIMUM FLUORIDE ION CONCENTRATIONS

Mean annual temperature, in degrees Fahrenheit*	Mean monthly fluoride concentration, in milligrams per liter
50	1.5
60	1.0
70 - above	0.7

*For temperature values between those shown in the table, the fluoride ion concentrations may be obtained by interpolation.

The State Board of Public Health's policy on fluoride ion further states that:

1. The concentration of the fluoride ion in public water systems, whether added or naturally occurring, should not exceed the fluoride ion concentrations stated in the above table.

2. In the development of new public water systems used for drinking and culinary purposes the above fluoride ion concentrations shall not be exceeded.

3. In existing public water systems used for drinking and culinary purposes in which the above fluoride ion concentrations are exceeded, the fluoride ion concentration shall be reduced to a safe level by the use of methods acceptable to the State Department of Public Health. Exception: In cases where the Department determines

after investigation that it is not practicable and feasible to reduce the fluoride ion concentration in the entire supply to a safe level, special methods, acceptable to the State Department of Public Health, shall be provided by the applicant to furnish water of suitable fluoride ion concentration to all children 10 years of age or under.

Agricultural Use. The major criteria for judging the suitability of water for irrigation are chloride concentration, specific electrical conductance (presented as EC x 10^6 at 25° C), boron concentration, and percent sodium.

Chlorides are present in nearly all waters. They are not necessary to plant growth, and in high concentrations cause subnormal growing rates and burning of leaves.

Electrical conductance indicates the total dissolved solids, and furnishes an approximate indication of the overall mineral quality of the water. For most waters, the total dissolved solids, measured in milligrams per liter (mg/l) may be approximated by multiplying the electrical conductance by 0.7. As the amount of dissolved salts in irrigation water increases, the crop yields are reduced until at high concentrations (the value depending on the plant, type of soil, climatological condition, and amount of water applied) plants cannot survive.

Boron is never found in the free state but occurs as borates or boric acid. This element is essential in minor amounts for the growth of many but not all plants. It is, however, extremely toxic to most plants in higher concentrations. Limits of tolerance for most irrigated crops vary from 0.5 to 2.0 mg/l. Citrus crops, particularly lemons, are sensitive to boron in concentrations exceeding 0.5 mg/l.

The percent sodium, as reported in analyses, is 100 times the proportion of the sodium cation to the sum of all cations, all expressed in milliequivalents per liter (meq/l). Water containing a high percent sodium has an adverse effect upon the physical structure of soils that contain clay by dispersing the soil colloids. This, in turn, retards the movement of water and the leaching of salts, and makes the soils difficult to work. The effect of potassium in water is similar to that of sodium.

Because of the diverse climatological conditions, crops, soils, and irrigation practices in California, criteria which may be set up to establish the suitability of water for irrigation must necessarily be of a general nature, and judgment must be used in applying these criteria to individual cases.

Based on studies by Dr. L. D. Doneen, Professor of Water Science and Engineering at the University of California at Davis, three classes of irrigation water have been established:

Class 1 Excellent to Good. Regarded as safe and suitable for most plants under any condition of soil or climate.

Class 2 Good to Injurious. Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher range of this class.

Class 3 Injurious to Unsatisfactory. Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Limiting values for concentrations of chloride, boron, specific electrical conductance, and percent sodium for these three classes of irrigation water have been established and are shown in Table 10.

TABLE 10

CRITERIA FOR IRRIGATION WATERS

Factors	Class 1 - Excellent to good	Class 2 - Good to injurious	Class 3 - Injurious to unsatisfactory
Specific electrical conductance, ECx10^6 at 25° C	Less than 1,000	1,000 - 3,000	More than 3,000
Boron, mg/l	Less than 0.5	0.5 - 2.0	More than 2.0
Chloride, mg/l	Less than 175	175 - 350	More than 350
Percent sodium	Less than 60	60 - 75	More than 75

Tables 11 and 12 were extracted from U. S. Department of Agriculture Technical Bulletin 962, "The Quality of Water for Irrigation Use, 1948", by L. V. Wilcox, and are presented to show the relative tolerance of crop plants to irrigation waters containing boron. Table 13 shows the relative tolerance of crop plants to salt.

TABLE 11

PERMISSIBLE LIMITS OF BORON FOR SEVERAL CLASSES OF IRRIGATION WATER

In milligrams per liter

Classes of water	Crop groups		
	Sensitive	Semitolerant	Tolerant
Excellent	< 0.33	< 0.67	< 1.00
Good	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
Unsuitable	> 1.25	> 2.50	> 3.75

TABLE 12

RELATIVE TOLERANCE OF CROP PLANTS TO BORON

(In each group the plants first named are considered as being more sensitive and the last named more tolerant)

Sensitive to boron	Semitolerant to boron	Tolerant to boron
Lemon	Lima bean	Carrot
Grapefruit	Sweet potato	Lettuce
Avocado	Bell pepper	Cabbage
Orange	Tomato	Turnip
Thornless blackberry	Pumpkin	Onion
Apricot	Zinnia	Broadbean
Peach	Oat	Gladiolus
Cherry	Milo	Alfalfa
Persimmon	Corn	Garden beet
Kadota fig	Wheat	Mangel
Grape (Sultanina and Malaga)	Barley	Sugar beet
Apple	Olive	Palm (Phoenix cararienses)
Pear	Ragged robin rose	Date palm (P. dactylifera)
Plum	Field pea	Asparagus
American elm	Radish	Tamarix, or athel (Tamarix aphylla and T. gallica)
Navy bean	Sweet pea	
Jerusalem-artichoke	Pima cotton	
Persian (English walnut)	Acala cotton	
Black walnut	Potato	
Pecan	Sunflower (native)	

TABLE 13

RELATIVE TOLERANCE OF CROP PLANTS TO SALT*

Low salt tolerance	Medium salt tolerance	High salt tolerance
Pear	Pomegranate	Date palm
Apple	Fig	Salt grass
Orange	Olive	Bermuda grass
Grapefruit	Sweet corn	Rescue grass
Prune	Potato (White Rose)	Western wheatgrass
Plum	Carrot	Barley
Almond	Onion	Sugar beet
Apricot	Sudan grass	Rape
Peach	Alfalfa (California common)	Cotton
Strawberry	Rye	
Lemon	Wheat	
Avocado	Oats	
Field bean	Orchardgrass	
Radish	Rice	
Celery	Meadow fescue	
Meadow foxtail	Sorghum (grain)	
Red clover	Corn (field)	
	Flax	
	Sunflower	
	Castorbean	

*Based on Agriculture Handbook No. 60, U. S. Department of Agriculture. February 1954.

Industrial Water Use. Criteria of quality of water for industrial purposes are exceedingly difficult to ascertain. Industrial usage of water is so varied that a single set of criteria for chemical, physical, and bacterial requirements would be meaningless.

Total Hardness

For purposes of classification, in the Southern District of the Department of Water Resources, the following definitions of relative hardness are used: Waters containing 100 mg/l or less of total hardness (as $CaCO_3$) are considered "soft", those containing 101 to 200 mg/l are considered "moderately hard", and those with more than 200 mg/l are considered "very hard".

Table 14 extracted from U. S. Department of Interior, Federal Water Pollution Control Administration Report "Water Quality Criteria", 1968, indicates in part the potential problems and suggested trace element tolerances for irrigation waters.

TABLE 14

TRACE ELEMENT TOLERANCES FOR IRRIGATION WATERS

Element	For water used continuously on all soils	For short-term use on fine textured soils only
	mg/l	mg/l
Aluminum	1.0	20.0
Arsenic	1.0	10.0
Beryllium	0.5	1.0
Boron	0.75	2.0
Cadmium	0.005	0.05
Chromium	5.0	20.0
Cobalt	0.2	10.0
Copper	0.2	5.0
Lead	5.0	20.0
Lithium	5.0	5.0
Manganese	2.0	20.0
Molybdenum	0.005	0.05
Nickel	0.5	2.0
Selenium	0.05	0.05
Vanadium	10.0	10.0
Zinc	5.0	10.0

Some trace elements are essential for plant growth in very small amounts, while others are nonessential. Certain ones may be toxic even in relatively low concentrations. Many factors affect the uptake and tolerance of plants to trace elements. The most important of these are genetic variability of plants and animals, reactions within the soil, and nutrient interactions - particularly in the plant.

Appendix B

SELECTED REFERENCES

Appendix B

SELECTED REFERENCES

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Appendix C

DEFINITIONS

Appendix C

DEFINITIONS

Brine. Water having a salinity greater than that of the ocean, generally containing more than 36,000 parts per million total dissolved solids.

Bittern. The bitter mother liquor that remains in saltworks after the salt has been crystallized.

Chemical Character. A classification based on the predominant chemical constituents, commonly expressed in equivalents per million (milliequivalents per liter), for the anion (-) and cation (+) groups.

Combining Weight. The atomic or molecular weight of an ion divided by its ionic charge.

Contamination. Defined by Section 13005 of the California Water Code as, "an impairment of the quality of the waters of the State by sewage or other waste to a degree which creates an actual hazard to public health through poisoning or through the spread of disease."

Degradation. Impairment of the quality of water due to causes other than disposal of sewage and industrial waste.

Deterioration. Impairment of water quality.

Electrical Conductivity (EC). The reciprocal of the resistance in ohms measured between opposite faces of a centimeter cube of an aqueous solution at a temperature of 25° C.

Equivalents. The value, usually expressed as equivalents per million (milliequivalents per liter), obtained by dividing the ion concentration in parts per million (milligrams per liter) by the combining weight of that ion.

Geothermal Area. Defined by Section 3702 of the Public Resources Code as, "The same general surface area which is underlaid, or reasonably appears to be underlaid, by geothermal resources."

Geothermal Resources. Defined by Section 6903 of the Public Resources Code as, "...the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances."

Geothermal Well. Defined by Section 3703 of the Public Resources Code as, "... any well for the discovery of geothermal resources or any well on lands producing geothermal resources or reasonably presumed to contain geothermal resources, or any special well, converted producing well or reactivated or converted abandoned well employed for reinjecting geothermal resources or the residue thereof."

Impairment. A change in the quality of water that decreases its suitability for beneficial use.

Ion. An electrically charged particle, anion (-) and cation (+).

Meteoric Water. Water that is in, or derived from, the atmosphere.

Milligrams per liter (mg/l). One milligram of dissolved substance per liter of solution at a temperature of 20° C. At moderate concentrations, mg/l is for practical purposes the same as parts per million (ppm).

Other Waste. (Commonly referred to as Industrial Waste). Defined by Section 13005 of the California Water Code as, "...any and all liquid or solid waste substances, not sewage, from any producing, manufacturing or processing operation of whatever nature."

Parts Per Million (ppm). One weight of dissolved substance per one million weights of solution at a temperature of 20° C. For practical purposes, ppm is the same as milligrams per liter (mg/l) in low concentrations.

Percent Reactance Value. The value, expressed in percent, obtained by dividing the equivalents per million (milliequivalents per liter) of each ion by the sum of its respective ion group (cations or anions).

Pollution. Defined by Section 13005 of the California Water Code as, "An impairment of the quality of the waters of the State by sewage or other waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational, or other beneficial use, or which does adversely and unreasonably affect the ocean waters and bays of the State devoted to public recreation."

Salt Balance. The relationship of salt input to salt output.

Sewage. Defined by Section 13005 of the California Water Code as, "Any and all waste substance, liquid or solid, associated with human habitation, or which contains or may be contaminated with human or animal excreta or excrement, offal, or any feculent matter." As used in this report, sewage is included as part of the waste waters carried by community sewer systems.

Total Dissolved Solids (TDS). The dry residue from the dissolved matter in an aliquot of a water sample remaining after evaporating the sample at a definite temperature.

Total Dissolved Solids by Summation. The TDS as determined by summing the individual dissolved constituents, less one-half the bicarbonate ion.

Total Radioactivity. The combination of alpha, beta, and gamma activity in water reported in picocuries per liter (10^{-12} curies/liter) or 2.22 disintegrations per minute per liter.

Waste Water. Water that has been put to some use, or uses, and has been disposed of, commonly to a sewer or wasteway. It may be liquid industrial waste or sewage or both.

Appendix D

SELECTED CHEMICAL ANALYSES

State well number / Date sampled	Temp. when sampled in °F	pH	Specific conductance (micromhos) at 25°C	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Carbonate CO_3	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Fluoride F	Boron B	Silica SiO_2	TDS Evaporated	TDS Computed*	Ammonium NH_4	Specific gravity at 25°C
				Chemical constituents in parts per million equivalents per million percent reactance value									Chemical constituents in parts per million						
GEOTHERMAL WELLS																			
PIONEER DEVELOPMENT, No. 3																			
11S/13E–10L3g																			
05/21/29[1a]	--	6.5	--	16,000	4,000	20,400[g]		--	300	200	68,000	1,050	--	--	--	110,000		--	--
				798	329	887			5	4	1,918	17				109,698			
				40	16	44			0	0	99	1							
IMPERIAL THERMAL PRODUCTS, I.I.D. 2																			
11S/13E–22J1g																			
00/00/67[1, 2a, b]	--	--	--	27,800	10	53,000	16,500	--	690	--	155,000	--	--	390	400	258,765		--	--
				1,387	1	2,304	420		11		4,370					252,649			
				34	0	56	10		0		100								
IMPERIAL THERMAL PRODUCTS, I.I.D. 1																			
11S/13E–23F1g																			
03/03/62[3d]	--	3.9	--	30,500	--	55,500	18,200	0	0	30	168,000	--	--	745[f]	10	278,000		--	1.2387
				1,522		2,413	460			1	4,740					272,230			
				35		55	10			0	100								
05/00/62[3d]	400	5.1	--	34,430	486	76,000	29,900	--	--	--	200,000	--	--	432	26	--		--	1.235
				1,718	40	3,304	765				5,640					340,816			
				29	1	57	13				100								
00/00/63[2, 4c]	--	--	--	40,000	35	51,000	24,000	--	--	56	185,000	35	18	520	> 110	319,000		482	1.264
				1,996	3	2,217	610			1	5,220	1				300,126			
				41	0	46	13			0	100	0							
04/21/66[1a, b]	--	--	--	28,000	54	50,400	17,500	--	> 150	5	155,000	--	15	390	400	298,360		409	--
				1,397	4	2,191	448		> 2	0	4,370					251,033			
				35	0	54	11		0	0	100								
JOSEPH O'NEILL, SPORTSMAN 1																			
11S/13E–23G1g	--	--	--	34,470	18	70,000	24,000	--	--	34	201,757	--	--	149[f]	5	334,987		--	1.207
08/31/61[2c]				1,720	2	3,044	614			1	5,690					330,279			
				32	0	57	11			0	100								
WESTERN GEOTHERMAL, SINCLAIR 4																			
12S/13E–4Q2g																			
06/04/64[3dh]	--	5.0	--	37,735	2,225	78,000	20,690	--	--	75	210,700[f]	--	--	--	625	387,500		--	--
				1,883	183	3,391	529			2	5,940					349,425			
				31	3	57	9			0	100								
07/05/67[5b'h]	> 212	5.3	--	36,992	736	58,443	14,918	--	0	19	154,590	5	14	332	90	266,560		442	1.22
				1,347	61	2,543	382			0	4,360	0				255,700			
				32	1	58	9			0	100	0							
WESTERN GEOTHERMAL, SINCLAIR 3																			
12S/13E–10D2g	--	5.3	247,360	14,550	780	36,340	7,820	0	60	58	93,650	--	2	210	--	183,700		340	1.1144
04/19/62[3dh]				726	64	1,580	200		1	1	2,637					153,258			
				28	3	61	8		0	0	100								
04/23/63[3dh]	--	4.3	362,400	23,000	1,940	50,600	13,200	0	0	0	141,500	0	5	--	--	276,100		570	1.1803
				1,150	160	2,200	338				3,985	0				230,240			
				30	4	57	9				100	0							
IMPERIAL THERMAL PRODUCTS, I.I.D. 3																			
11S/13E–23C1j (injection well)																			
03/18/65[4'b]	221	7.5	--	1,130	74	10,600	1,250	--	1,880	621	19,700	9	1	100	120	35,600		321	1.023
				56	6	461	32		31	13	556	0				34,310			
				10	1	84	5		5	2	93	0							

NOTE: (Geothermal wells only)

[1] California Division of Fish and Game, July 1929

[1'] Skinner et al., May 1967

[2] California Division of Mines and Geology, Mineral Information Service, July 1967

[3] Colorado River Basin Regional Water Quality Control Board (No. 7)

[4] White, 1965 or ('4') Muffler and White, 1969

[5] California Department of Water Resources

* Average analysis

[b] Corrected for steam loss, or ('b') steam loss minimized in sampling.

Not corrected for steam loss

[d] Probably not corrected for steam loss

* Computed TDS determination: Ca ppm + Mg + Na + K + CO_3 + (HCO_3 x .492) + SO_4 + Cl + NO_3

[f] Computed

[g] Sodium and potassium

[h] Data corrected (i.e., value/Sp. G. = ppm) or Sp. G. correction unnecessary because of analytical technique (status of other analyses presented is unknown)

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE												TDS 180C 105C COMP[a]	HARDNESS CACO 3
				CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2		
								WATER WELL									
7S/ 9E-16K 1	70	8.7	610	13	2	125	1	12	105	129	39	0	7.0	0.12	--		41
7-14-54				0.65	0.16	5.44	0.03	0.40	1.72	2.69	1.10					376	
				10	3	87		7	29	46	19					380	
	--	8.4	1340	34	9	257	2	3	207	368	63	3.1	12.0	0.52	19		122
5-11-55				1.70	0.74	11.17	0.05	0.10	3.39	7.66	1.78	0.05				855	
				12	5	82		1	26	59	14					872	
	--	8.1	704	11	3	152	3	0	166	174	27	3.5	8.2	0.24	--		40
9-15-55				0.55	0.25	6.61	0.08		2.72	3.62	0.76	0.06				450	
				7	3	88	1		38	51	11	1				464	
	70	8.0	540	4	0	113	1	0	122	124	11	1.3	6.0	0.10	--		10
4-11-56				0.20		4.91	0.03		2.00	2.58	0.31	0.02				318	
				4		96	1		41	53	6					320	
	--	8.2	1275	27	5	277	3	0	204	379	64	3.3	8.8	0.44	--		88
9-20-56				1.35	0.41	12.04	0.08		3.34	7.89	1.80	0.05				770	
				10	3	87	1		26	60	14					868	
	--	8.1	795	10	2	164	2	0	151	182	35	0	10.0	0.30	17	536	33
3-29-57				0.50	0.16	7.13	0.05		2.47	3.79	0.99						
				6	2	91	1		34	52	14					497	
	--	8.3	1318	25	7	260	3	8	252	271	94	1.5	1.4	0	13	918	92
9-19-57				1.25	0.58	11.30	0.08	0.27	4.13	5.64	2.65	0.02					
				9	4	86	1	2	32	44	21					808	
	--	8.4	1004	14	9	189	3	0	220	193	65	0.1	2.0	0.10	16	652	72
4-30-58				0.70	0.74	8.22	0.08		3.61	4.02	1.83						
				7	8	84	1		38	42	19					599	
	78	8.0	717	5	2	160	1	0	260	62	57	0	5.9	0.36	15	524	21
10-28-58				0.25	0.16	6.96	0.03		4.26	1.29	1.61						
				3	2	94			59	18	22					436	
	--	8.5	1129	17	5	221	3	14	240	181	96	2	6.4	0.45	17	785	63
5- 6-59				0.85	0.41	9.61	0.08	0.47	3.93	3.77	2.71	0.03					
				8	4	88	1	4	36	35	25					681	
	72	7.8	1341	22	6	260	6	0	287	213	129	2	6.2	0.56	14	930	80
12-16-59				1.10	0.49	11.30	0.15		4.70	4.43	3.64	0.03					
				8	4	87	1		37	35	28					800	
	69	8.4	1320	24	5	253	19	9	262	217	121	2.7	5.7	0.47	18	788	81
12-16-59				1.20	0.41	11.00	0.49	0.30	4.29	4.52	3.41	0.04					
				9	3	84	4	2	34	36	27					804	
	--	8.4	1035	14	2	183	4	6	220	127	83	4.7	5.5	0.35	17	552	43
6- 1-60				0.70	0.16	7.96	0.10	0.20	3.61	2.64	2.34	0.08					
				8	2	89	1	2	41	30	26	1				555	
	--	8.3	887	8	2	182	1	10	217	108	79	2.1	6.1	0.46	15	535	28
12-21-60				0.40	0.16	7.91	0.03	0.33	3.56	2.75	2.23	0.03					
				5	2	93		4	42	27	27					520	
	--	7.8	750	6	1	162	1	0	202	96	68	0	3.5	0.12	13		19
8-10-61				0.30	0.08	7.04	0.03		3.31	2.00	1.92					524	
				4	1	94			46	28	27					450	
	--	8.5	741	--	--	--	--	41	132	--	74	--	--	--	--		
12-27-61								1.37	2.16		2.09						
	--	8.7	720	6	0	155	1	4	188	67	77	0	3.5	0.29	18	456	15
5-15-62				0.30		6.74	0.03	0.13	3.08	1.39	2.17						
				4		95		2	45	21	32					424	
	--	8.4	730	8	2	165	1	5	207	100	73	0	6.0	0.33	11	530	28
10-17-62				0.40	0.16	7.17	0.03	0.17	3.39	2.08	2.06						
				5	2	92		2	44	27	27					473	
	--	8.6	725	4	2	160	1	6	180	110	54	0	5.0	0.29	10	442	18
4-30-63				0.20	0.16	6.96	0.03	0.20	2.95	2.29	1.52						
				3	2	95		3	42	33	22					441	
	--	8.7	786	6	0	167	1	12	184	109	52	3.3	9.1	0.28	--	456	15
1-28-64				0.30		7.26	0.03	0.40	3.02	2.27	1.47	0.05					
				4		96		6	42	31	20	1				450	
7S/ 9E-18M 1	90	9.0	277	5	1	55	1	7	83	31	17	1.4	0.8	0.01	13		17
8- 3-61				0.25	0.08	2.39	0.03	0.23	1.36	0.65	0.48	0.02				186	
				9	3	87	1	8	50	24	18	1				173	
7S/ 9E-21J 1	--	8.6	350	18	1	60	1	4	96	65	13	0	2.0	0.05	14		49
8- 4-61				0.90	0.08	2.61	0.03	0.13	1.57	1.35	0.37					198	
				25	2	72	1	4	46	39	11					225	

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE												PARTS PER MILLION	
				CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2	TDS 180C 105C COMP[a]	HARDNESS CACO 3
								WATER WELL									
7S/ 9E-28H 1	--	9.0	350	16	2	58	0	7	69	90	14	0	0.7	0.30	13	243	48
9-19-57				0.80	0.16	2.52		0.23	1.13	1.87	0.39						
				23	5	72		6	31	52	11					235	
	85	8.8	344	13	2	56	1	0	92	71	18	0	0.6	0.10	14	222	41
4-30-58				0.65	0.16	2.43	0.03		1.51	1.48	0.51						
				20	5	74	1		43	42	15					221	
	80	8.6	411	11	1	54	1	7	68	67	11	0	1.4	0.08	15	243	32
5- 6-59				0.55	0.08	2.35	0.03	0.23	1.11	1.39	0.31						
				18	3	78	1	8	37	46	10					202	
	67	9.3	343	--	--	--	--	11	56	--	13	--	--	--	--		
12-18-59								0.37	0.92		0.37						
	67	9.2	315	11	2	54	1	17	46	64	11	0.6	1.4	0.05	18	187	36
12-18-59				0.55	0.16	2.35	0.03	0.57	0.75	1.33	0.31	0.01					
				18	5	76	1	19	25	45	10					203	
	83	8.5	380	--	--	--	--	9	61	--	11	--	--	--	--		
6- 1-60								0.30	1.00		0.31						
	76	8.5	313	14	0	58	0	12	61	67	9	2.0	1.4	0.16	16	207	35
12-22-60				0.70		2.52		0.40	1.00	1.39	0.25	0.03					
				22		78		13	33	45	8	1				209	
7S/ 9E-29R 1	--	8.1	260	5	2	49	0	0	101	32	11	0	0.8	0.06	15		21
4-12-61				0.25	0.16	2.13			1.66	0.67	0.31					156	
				10	6	84			63	25	12					164	
	80	9.0	261	4	1	50	1	6	63	36	14	0.3	0.9	0.06	14		14
8- 3-61				0.20	0.08	2.17	0.03	0.20	1.03	0.75	0.39					182	
				8	3	88	1	8	43	32	16					158	
7S/ 9E-29R 2	78	9.0	242	3	0	56	1	22	61	35	13	1	2.4	0.09	--	170	8
4- 3-52				0.15		2.43	0.03	0.73	1.00	0.73	0.37	0.02					
				6		93	1	26	35	26	13	1				163	
	80	8.9	282	8	1	57	0	5	86	38	15	0.0	2.5	0.11	12	200	24
8- 3-61				0.40	0.08	2.48		0.17	1.41	0.79	0.42						
				14	3	84		6	51	28	15					181	
7S/ 9E-33B 1	75	9.2	258	3	0	60	1	24	58	35	12	1	2.4	0.08	--		8
4- 3-52				0.15		2.61	0.03	0.80	0.95	0.73	0.34	0.02				181	
				5		94	1	28	33	26	12	1				167	
	88	8.8	351	6	1	70	1	6	118	39	14	0	3.0	0.13	10		19
8- 3-61				0.30	0.08	3.04	0.03	0.20	1.93	0.81	0.39					238	
				9	2	88	1	6	58	24	12					208	
7S/ 9E-33F 1	80	9.0	292	5	2	59	0	7	80	40	15	0.6	2.5	0.12	13		21
8- 3-61				0.25	0.16	2.57		0.23	1.31	0.83	0.42	0.01				194	
				8	5	86		8	47	30	15					184	
7S/ 9E-33M 1	76	8.6	514	12	0	95	1	2	69	151	13	0	2.8	0.06	10		30
8- 3-61				0.60		4.13	0.03	0.07	1.13	3.14	0.37					366	
				13		87	1	1	24	67	8					321	
7S/10E-27L 1	--	7.2	4200	156	17	825	4	0	38	545	1167	0	3.5	3.50	8		459
8- 3-61				7.78	1.40	35.87	0.10		0.62	11.35	32.91					2502	
				17	3	79			1	25	73					2748	
7S/10E-30F 1	--	7.2	2200	36	2	425	23	0	105	371	378	0	2.2	0.08	11	1294	98
3-27-57				1.80	0.16	18.48	0.59		1.72	7.72	10.66						
				9	1	88	3		9	38	53					1300	
	--	8.7	980	9	0	191	2	6	127	56	185	0	1.4	0.30	14	570	23
9-19-57				0.45		8.30	0.05	0.20	2.08	1.17	5.22						
				5		94	1	2	24	13	60					527	
	--	8.3	1042	15	5	207	4	0	159	325	20	0	2.3	0.08	14	679	58
4-30-58				0.75	0.41	9.00	0.10		2.61	6.77	0.56						
				7	4	88	1		26	68	6					670	
	89	8.1	2302	22	5	432	4	0	123	104	567	0.0	6.8	0.26	16	1480	76
5- 6-59				1.10	0.41	18.78	0.10		2.02	2.17	15.99						
				5	2	92			10	11	79					1217	
	83	8.7	1385	20	4	255	2	11	113	78	298	0.6	4.4	0.08	16	729	67
12-16-59				1.00	0.33	11.09	0.05	0.37	1.85	1.62	8.40	0.01					
				8	3	89		3	15	13	69					745	

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE								PARTS PER MILLION					
				CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2	TDS 180C 105C COMP[a]	HARDNESS CACO 3
								WATER WELL									
7S/10E-32C 1	--	--	8387	--	--	--	--	0	67	--	1338	--	--	--	--		
4-17-50									1.10		37.73						
(DEPTH 750 FT)																	
	--	--	6709	489	--	--	--	0	73	2146	1140	--	4.0	0.95	--		1221
4-17-50				24.40					1.20	44.68	32.15						
(DEPTH 1050 FT)																	
7S/10E-34K 1	81	7.1	4800	413	54	700	6	0	66	1605	775	2.5	2.9	0.88	12		1254
9-19-61				20.61	4.44	30.44	0.15		1.08	33.42	21.86	0.04				4250	
				37	8	55			2	59	39					3604	
7S/10E-36K 1	--	7.8	6523	383	5	1065	6	0	27	744	1770	3.7	2.9	2.48	4	4350	977
10-14-61				19.11	0.41	46.31	0.15		0.44	15.49	49.91	0.06					
				29	1	70			1	24	76					3999	
8S/ 8E-13Q 1	90	9.2	304	0	0	66	1	4	103	37	11	0.0	2.4	0.90	--	204	
5-19-67						2.87	0.03	0.13	1.69	0.77	0.31						
						99	1	4	58	27	11					173	
8S/ 9E- 5D 1	79	8.0	300	3	1	60	2	0	110	27	11	0	2.5	0.15	12		12
8- 3-61				0.15	0.08	2.61	0.05		1.80	0.56	0.31					184	
				5	3	90	2		67	21	12					173	
8S/ 9E-29H 1	--	8.5	767	12	1	138	3	1	57	168	69	0	6.8	0.26	16	497	34
5- 6-59				0.60	0.08	6.00	0.08	0.03	0.93	3.50	1.95						
				9	1	89	1		15	55	30					443	
	--	8.2	980	25	4	167	2	0	52	233	108	0.4	5.1	0.41	18	586	79
12-18-59				1.25	0.33	7.26	0.05		0.85	4.85	3.05	0.01					
				14	4	82	1		10	55	35					588	
8S/ 9E-29Q 1	109	8.3	747	14	3	139	1	0	58	99	145	0.9	4.8	0.23	--		48
4-19-55				0.70	0.25	6.04	0.03		0.95	2.06	4.09	0.01				421	
				10	4	86			13	29	58					435	
8S/ 9E-29R 1	--	7.7	740	8	2	154	2	0	73	127	122	1.3	1.0	0.04	37	500	28
9-19-56				0.40	0.16	6.70	0.05		1.20	2.64	3.44	0.02					
				5	2	92	1		16	36	47					490	
	--	7.5	820	10	2	151	1	0	78	119	113	0	2.0	0.04	14	426	33
3-27-57				0.50	0.16	6.57	0.03		1.28	2.48	3.19						
				7	2	90			18	36	46					450	
	--	8.4	729	10	1	148	1	2	61	108	119	2.5	4.2	0.19	--	424	29
9-18-57				0.50	0.08	6.44	0.03	0.07	1.00	2.25	3.36	0.04					
				7	1	91		1	15	33	50	1				426	
	--	8.4	766	8	0	162	2	0	73	111	133	0	3.5	0.50	14	448	20
4-30-58				0.40		7.04	0.05		1.20	2.31	3.75						
				5		94	1		17	32	52					470	
	--	8.6	734	--	--	--	--	2	53	--	118	--	--	--	--		
5- 6-59								0.07	0.87		3.33						
	--	8.6	778	9	2	148	2	8	49	116	121	0.9	2.5	0.21	20	445	31
12-16-59				0.45	0.16	6.44	0.05	0.27	0.80	2.42	3.41	0.01					
				6	2	91	1	4	12	35	49					454	
	--	8.5	717	10	1	148	1	12	37	128	117	4.0	4.0	0.28	19	438	29
6- 1-60				0.50	0.08	6.44	0.03	0.40	0.61	2.66	3.30	0.06					
				7	1	91		6	9	38	47	1				462	
	--	8.1	795	11	1	144	10	0	64	119	122	2.5	4.4	0.11	21	435	32
12-22-60				0.55	0.08	6.26	0.26		1.05	2.48	3.44	0.04					
				8	1	88	4		15	35	49	1				466	
	--	7.1	801	--	--	--	--	0	68	--	126	--	--	--	--		
8-10-61									1.11		3.55						
	--	8.6	807	11	0	156	1	7	49	115	130	1.0	4.5	0.40	19	485	28
12-28-61				0.55		6.78	0.03	0.23	0.80	2.39	3.67	0.02					
				7		92		3	11	34	52					469	
	--	8.7	770	10	0	153	1	3	53	110	126	0	3.0	0.37	20	478	25
5-16-62				0.50		6.65	0.03	0.10	0.87	2.29	3.55						
				7		93		1	13	34	52					452	

STATE WELL NO DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION EQUIVALENTS PER MILLION PERCENT REACTANCE VALUE CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2	TDS 180C 105C COMP[a]	HARDNESS CACO 3
							WATER WELL										
8S/ 9E-29R 1	--	8.2	760	9	1	160	5	0	64	125	141	0	3.5	0.33	15	468	27
10-17-62				0.45	0.08	6.96	0.13		1.05	2.60	3.98						
				6	1	91	2		14	34	52					491	
	--	8.4	800	8	0	163	2	3	52	107	141	0	4.8	0.34	14	444	20
4-30-63				0.40		7.09	0.05	0.10	0.85	2.23	3.98						
				5		94	1	1	12	31	56					469	
	--	8.6	829	9	1	150	2	2	51	98	145	1.2	0.8	0.28	--	449	27
1-29-64				0.45	0.08	6.52	0.05	0.07	0.84	2.04	4.09	0.02					
				6	1	92	1	1	12	29	58					434	
8S/ 9E-31R 1	--	7.6	1193	42	20	195	11	0	222	276	102	6.0	0.8	0.40	25	765	187
7-21-60				2.10	1.64	8.48	0.28		3.64	5.75	2.88	0.10					
				17	13	68	2		29	46	23	1				787	
8S/10E- 1A	81	7.3	3300	101	1	625	1	0	19	403	825	0	3.1	3.70	12		256
9-20-61				5.04	0.08	27.18	0.03		0.31	8.39	23.27					2050	
				16		84			1	26	73					1984	
8S/10E-11A	--	7.4	7600	72	2	1650	5	0	46	171	2435	0	3.1	0.77	1	4814	188
9-20-61				3.59	0.16	71.74	0.13		0.75	3.56	68.67						
				5		95			1	5	94					4362	
8S/11E- 3C 2	84	7.7	1523	50	30	226	12	0	183	333	180	2.5	1.7	0.68	--	988	249
5-10-67				2.50	2.47	9.83	0.31		3.00	6.93	5.08	0.04					
				17	16	65	2		20	46	34					926	
9S/11E-12P 1	90	7.8	3200	38	27	700	4	0	234	144	968	0.0	3.0	2.75	--	1808	206
10-27-64				1.90	2.22	30.44	0.10		3.84	3.00	27.30						
				5	6	88			11	9	80					2002	
8S/11E-12P 2	90	7.8	3500	60	15	740	4	0	214	152	1046	0.0	3.0	0.08	--	2128	211
10-27-64				2.99	1.23	32.18	0.10		3.51	3.16	29.50						
				8	3	88			10	9	82					2125	
8S/12E-17K	--	--	1360	--	--	--	--	--	--	--	--	--	--	--	--		
8-12-50																	
8S/12E-36P 1	180	7.4	4963	98	17	910	34	0	242	206	1370	0.0	5.0	4.10	--	2921	315
5-11-67				4.89	1.40	39.57	0.87		3.97	4.29	38.63						
				10	3	85	2		8	9	82					2763	
9S/ 9E- 4K 1	115	7.1	17000	607	48	3320	21	0	29	463	5950	4.6	2.6	10.10	--	11076	1713
5-19-67				30.29	3.95	144.35	0.54		0.48	9.64	167.79	0.07					
				17	2	81				5	94					10441	
9S/ 9E- 8X 1	--	--	3650	275	23	498[b]	--	--	167	289	1012	--	--	1.40	--	2260	781
9-18-50				13.72	1.89	21.65			2.74	6.02	28.54						
9S/ 9E-16D 2	--	8.3	4000	74	25	720	12	0	146	303	990	2.5	2.8	1.00	--		288
4-26-55				3.69	2.06	31.31	0.31		2.39	6.31	27.92	0.04				2241	
				10	6	84	1		7	17	76					2202	
	--	8.0	3704	68	25	660	12	0	139	250	950	2.5	3.2	1.50	--	2170	273
5-19-67				3.39	2.06	28.70	0.31		2.28	5.21	26.79	0.04					
				10	6	83	1		7	15	78					2041	
9S/ 9E-23M 1	--	--	9110	297	89	1537	--	--	85	1399	2041	--	--	2.20	--	5450	1108
9- 4-50				14.82	7.32	66.83			1.39	29.13	57.56						
	80	7.8	8620	240	71	1842[b]	--	--	49	1372	2395	--	--	3.35	--		892
9- 5-57				11.98	5.84	80.09			0.80	28.57	67.54						
	80	7.8	9700	260	66	1817	12	0	76	1387	2360	6.0	3.6	3.25	--	6200	921
2- 1-56				12.97	5.43	79.00	0.31		1.25	28.88	66.55	0.10					
				13	6	81			1	30	69					5952	
9S/ 9E-35X 1	--	--	10000	492	169	3013[b]	--	--	1682	40	5006	--	--	22.30	--	10400	1924
9-18-50				24.55	13.90	131.01			27.57	0.83	141.17						
9S/12E- 1D 1	--	8.1	--	109	26	138	10	0	166	347	122	0.0	1.8	--	--	940	379
7- 6-63				5.44	2.14	6.00	0.26		2.72	7.22	3.44						
				39	15	43	2		20	54	26					835	
	--	8.0	1380	66	52	165	10	0	224	334	140	0.0	2.8	0.20	--	1050	379
10-27-64				3.29	4.28	7.17	0.26		3.67	6.95	3.95						
				22	29	48	2		25	48	27					880	
9S/12E- 1D 2	--	7.6	--	106	13	960	42	0	211	222	1420	1.3	5.5	--	--	3065	318
7-30-64				5.29	1.07	41.74	1.07		3.46	4.62	40.04	0.02					
				11	2	85	2		7	10	83					2874	

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION				PARTS PER MILLION EQUIVALENTS PER MILLION PERCENT REACTANCE VALUE					PARTS PER MILLION			IDS 180C 105C COMP[a]	HARDNESS CACO 3
				CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2		
								WATER WELL									
9S/12E- 1D 2	--	--	--	--	--	968	--	--	--	--	--	--	--	--	--		
8-17-65						42.09											
	--	7.8	--	132	33	980	46	0	305	207	1540	0.4	3.2	--	--	3270	465
1-26-67				6.59	2.71	42.61	1.18		5.00	4.31	43.43	0.01					
				12	5	80	2		9	8	82					3092	
9S/12E- 1D 3	--	7.8	--	109	30	276	19	0	226	420	240	2.6	2.4	--	--	1295	396
7- 6-63				5.44	2.47	12.00	0.49		3.70	8.74	6.77	0.04					
				27	12	59	2		19	45	35					1210	
9S/12E- 2A 1	159	--	6650	200	63	1141[b]	--	--	506	281	1800	--	0.6	4.10	--	3850	759
9- 6-48				9.98	5.18	49.61			8.29	5.85	50.76						
	174	7.0	5710	179	27	1107[b]	--	--	458	195	1745	1.9	--	4.45	--	3787	558
3-23-51				8.93	2.22	48.13			7.51	4.06	49.21	0.03					
				15	4	81			12	7	81					3484	
	174	6.7	5775	170	27	1120[b]	--	0	451	195	1680	4.9	2.7	3.60	--	3550	535
4-22-52				8.48	2.22	48.70			7.39	4.06	47.38	0.08					
				14	4	82			13	7	80					3425	
	170	7.7	4900	138	33	978	53	0	397	208	1530	0	2.0	0.92	26	3538	480
4-27-57				6.89	2.71	42.52	1.36		6.51	4.33	43.15						
				13	5	80	3		12	8	80					3164	
	--	6.8	--	132	26	960	50	0	294	212	1440	0.0	5.0	--	--	3098	437
12-19-60				6.59	2.14	41.74	1.28		4.82	4.41	40.61						
				13	4	81	2		10	9	81					2970	
	--	7.2	4717	139	20	942[b]	--	0	365	211	1391	0.0	7.6	0	8		429
1-20-64				6.94	1.64	40.96			5.98	4.39	39.23						
				14	3	83			12	9	79					2898	
	--	8.3	5300	144	24	940	56	--	372	180	1544	0	4.0	5.00	50	3029	458
6-15-64				7.19	1.97	40.87	1.43		6.10	3.75	43.54						
				14	4	79	3		11	7	82					3130	
	166	7.1	5000	117	47	1060	46	0	438	207	1574	0.0	2.6	5.00	--	3234	486
10-27-64				5.84	3.87	46.09	1.18		7.18	4.31	44.39						
				10	7	81	2		13	8	79					3274	
	--	6.8	--	164	26	1050	70	0	361	206	1610	0.0	4.0	--	--	3475	516
1-10-67				8.18	2.14	45.65	1.79		5.92	4.29	45.40						
				14	4	79	3		11	8	82					3308	
9S/12E- 2A 2	--	7.2	--	106	20	875	36	0	251	193	1320	0.0	5.5	--	--	2840	347
2- 6-67				5.29	1.64	38.05	0.92		4.11	4.02	37.22						
				12	4	83	2		9	9	82					2679	
9S/13E- 7M 1	140	6.5	7520	245	57	1380	77	0	773	171	2240	7.4	3.5	6.60	66	4670	847
2-21-64				12.23	4.69	60.00	1.97		12.67	3.56	63.17	0.12					
				16	6	76	2		16	4	79					4634	
9S/13E-20E 1	88	7.1	6882	191	39	1224	56	0	525	198	1918	1.0	3.9	5.00	--	4077	638
5-11-67				9.53	3.21	53.22	1.43		8.60	4.12	54.09	0.02					
				14	5	79	2		13	6	81					3894	
10S/10E-18N 1	--	--	6550	40	33	1887[b]	--	--	600	92	2663	--	--	4.60	--	5310	236
9- 4-50				2.00	2.71	82.05			9.83	1.92	75.10						
	--	7.8	6370	--	--	--	--	0	1210	--	1640	--	--	6.16	--		
11- 6-52									19.83		46.25						
	100	7.8	6460	11	6	1460	14	0	1180	1	1600	1.6	1.4	--	34	3750	52
12-20-55				0.55	0.49	63.48	0.36		19.34	0.02	45.12	0.03					
				1	1	98	1		30		70					3709	
	104	8.2	6489	9	6	1484	12	0	1213	0	1600	0.8	1.6	5.90	--	3754	47
5-19-67				0.45	0.49	64.52	0.31		19.88		45.12	0.01					
				1	1	98			31		69					3716	
11S/ 9E- 2B 1	136	8.1	3932	0	0	860	6	0	459	119	960	1.1	3.4	6.60	--	2256	
5-19-67						37.39	0.15		7.52	2.48	27.07	0.02					
						100			20	7	73					2182	
11S/13E-13D 1	130	6.3	27777	985	214	7200	560	0	1760	373	13300	0	0.3	49.30	--	24100	3340
6-10-52				49.15	17.60	313.06	14.32		28.85	7.77	375.06						
				12	4	79	4		7	2	91					23547	
11S/13E-13D 2	104	6.4	33784	854	232	7200	504	0	1684	377	12423	0	1.8	50.00	--	23271	3084
2- 8-68				42.61	19.07	313.06	12.90		27.60	7.85	350.33						
				11	5	81	3		7	2	91					22432	

STATE WELL NO / DATE SAMPLED	TEMP	PH	6 ECX10	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE: CA	MG	NA	K	CO_3	HCO_3	SO_4	CL	NO_3	F	B	SIO_2	TDS 180C 105C COMP[a]	HARDNESS CALC $_3$
							WATER WELL										
12S/10E-26M 1	--	--	--	56	13	270[b]	--	0	98	216	336	--	--	--	15	955	193
1- 8-18				2.79	1.07	11.74			1.61	4.50	9.48						
	--	--	1770	87	34	222[b]	--	--	97	284	355	--	--	0.22	--		357
1- 9-49				4.34	2.80	9.65			1.59	5.91	10.01						
	--	--	1920	61	14	292[b]	--	--	96	233	370	--	0.8	--	15		210
9-25-62				3.04	1.15	12.70			1.57	4.85	10.43						
	--	8.5	--	56	21	645	18	10	89	427	830	0.0	1.3	--	--	2035	226
1- 9-67				2.79	1.73	28.04	0.41	0.33	1.46	8.89	23.41						
				8	5	85	1	1	4	26	69					2050	
	75	7.7	1754	62	12	280	5	0	105	221	352	1.3	0.8	0.70	--	1024	204
5-12-67				3.09	0.99	12.17	0.13		1.72	4.60	9.93	0.02					
				19	6	74	1		11	28	61					986	
12S/10E-34G 1	--	--	--	140	67	1210[b]	--	0	104	25	2308	--	--	0.22	--		626
1- 4-49				6.99	5.51	52.61			1.70	0.52	65.09						
	--	6.6	8430	109	46	1590[b]	--	--	66	5	2740	--	--	--	0		461
9-25-62				5.44	3.78	69.13			1.08	0.10	77.27						
						SPRING OR MUD VOLCANO (MUD POT)											
7S/10E-11AS1	58	7.5	1280	41	24	226	7	0	393	234	92	4.5	4.3	1.20	15		201
2- 9-61				2.05	1.97	9.83	0.18		6.44	4.87	2.59	0.07				876	
				15	14	70	1		46	35	19	1				842	
8S/11E- 3CS1	--	--	--	96	63	908[b]	--	--	--	477	1400	--	--	--	--		499
1876				4.79	5.18	39.48				9.93	39.48						
	80	--	--	67	34	485[b]	--	17	204	182	688	5.1	--	--	31	1623	307
11-11-17				3.34	2.80	21.09		0.57	3.34	3.79	19.40	0.08					
				12	10	77		2	12	14	71					1609	
	82	7.7	2300	56	28	401	21	0	205	335	465	2.1	2.0	2.20	20	1460	255
2-13-61				2.79	2.30	17.44	0.54		3.36	6.97	13.11	0.03					
				12	10	76	2		14	30	56					1433	
	82	7.9	2293	53	31	376	15	0	205	316	432	2.2	2.0	1.90	--	1400	260
5-10-67				2.64	2.55	16.35	0.38		3.36	6.58	12.18	0.04					
				12	12	75	2		15	30	55					1330	
8S/11E- 3CS3	84	7.8	2165	57	30	348	16	0	195	295	406	3.5	1.8	1.60	--	1309	266
5-10-67				2.84	2.47	15.13	0.41		3.20	6.14	11.45	0.06					
				14	12	73	2		15	29	55					1255	
8S/11E- 9PS1	--	8.2	19000	135	182	4140	118	0	369	1603	5920	0	5.5	15.80	29	12582	1086
11-22-60				6.74	14.97	180.01	3.02		6.05	33.37	166.94						
				3	7	88	1		3	16	81					12330	
8S/11E-12PS1	80	8.5	3145	39	27	646	10	4	214	144	893	7.0	9.0	3.35	--	2006	209
3- 5-54				1.95	2.22	28.09	0.26	0.13	3.51	3.00	25.18	0.11					
				6	7	86	1		11	9	79					1888	
8S/12E-36NS1	80	7.7	1936	123	41	238	11	0	283	481	196	0.0	2.5	0.82	--	1335	476
5-11-67				6.14	3.37	10.35	0.28		4.64	10.01	5.53						
				30	17	51	1		23	50	27					1232	
9S/ 9E- 9HS	--	--	--	92	15	619[b]	--	0	102	240	923	--	--	--	30	1994	291
11-19-17				4.59	1.23	26.91			1.67	5.00	26.03						
9S/13E-20LS1	--	--	--	199	41	1198[b]	--	0	542	193	1858	--	--	--	55	3893	666
12-10-17				9.93	3.37	52.09			8.88	4.02	52.40						
	75	8.1	6000	124	41	1180	45	0	465	260	1720	0.0	2.8	4.00	--	3530	478
10-29-64				6.19	3.37	51.31	1.15		7.62	5.41	48.50						
				10	5	83	2		12	9	79					3605	
10S/ 9E-20NS	--	--	4070	73	26	775[b]	--	0	222	41	2141	0.0	--	1.2[c]	--	2260	289
1-10-49				3.64	2.14	33.70			3.64	0.85	60.38						
				9	5	85			6	1	93					3169	
10S/13E-27BS1	68	6.0	61730	2083	1714	13500	410	0	2013	1536	27900	17	3.6	84.00	--	51632	2255
3-15-67				103.94	140.96	586.98	10.48		32.99	31.98	786.78	0.27					
				12	17	70	1		4	4	92					48237	
11S/10E-1PAS	--	--	--	436	224	1678	4	--	1549	68	2028	0.0	--	--	--	5937	2011
1909				21.76	18.42	70.79	0.10		25.39	1.42	57.19						
				20	17	64			30	2	68					5150	

STATE WELL NO DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION EQUIVALENTS PER MILLION PERCENT REACTANCE VALUE CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2	TDS 180C 105C COMP[a]	HARDNESS CACO 3
SPRING OR MUD VOLCANO (MUD POT)																	
11S/10E-18AS 11-20-17	--	--	--	65 3.24 4	31 2.55 3	1554[b] 67.57 92	--	44 1.47 2	2160 35.40 48	7 0.15 [illegible]	1282 36.15 49	4.3 0.05	--	--	38	4108 4[illegible]	290
11S/13E-24ES1 11-23-64	100	7.4	25900	360 17.96 7	22 1.81 1	5540 240.88 90	307 7.85 3	0	1260 20.65 7	218 4.54 2	9010 254.23 91	[illegible]	2.5	[illegible]	71	16300 162[illegible]	[illegible]
12S/11E-21MS1 11-20-17	--	--	--	30 1.50 4	22 1.81 5	705[b] 30.65 90	--	0	207 3.39 10	451 9.39 28	748 21.09 62	1.4 0.02	--	--	26	2102 2085	167
5-12-67	67	8.0	5189	69 3.44 7	22 1.81 3	1070 46.52 90	4 0.10	0	610 10.00 19	491 10.22 20	1130 31.87 61	2.0 0.03	2.8	5.70	--	3161 3096	763
12S/12E-29NS1 5-12-67	70	6.8	6831	249 12.43 16	285 23.44 29	990 43.05 54	32 0.82 1	0	2300 37.70 47	453 9.43 12	1150 32.43 41	24 0.39	0.6	5.00	--	4656 4320	1795
SEA,RIVER,OR IRRIGATION CANAL																	
SALTON SEA																	
8S/10E- 2P 5- 8-67	80	6.9	39570	873 43.56 7	1073 88.24 15	10300 447.84 77	219 5.60 1	--	153 2.51	7910 164.69 28	14810 417.64 71	12 0.19	.0	3.00	--	36966 35274	6575
7- 3-67	89	7.9	41085	842 42.02 7	1138 93.59 16	10250 445.67 76	164 4.19 1	0	181 2.97 1	7851 163.46 28	14800 417.36 71	5.0 0.08	3.8	9.80	--	35988 35153	6786
9S/12E-31D 6- 7-67	--	8.4	41150	900 44.91 8	1075 88.41 15	10150 441.32 76	168 4.30 1	14 0.47	146 2.39	7871 163.87 28	14600 411.72 71	5.0 0.08	3.2	9.20	--	36142 34967	6671
10S/13E-17H 6- 7-67	72	8.2	40650	882 44.01 8	1060 87.17 15	10100 439.15 76	164 4.19 1	0	159 2.61	7861 163.67 29	14400 406.06 71	5.0 0.08	3.8	9.10	--	35596 34362	6564
11S/11E-21P 6- 8-67	77	7.7	42100	954 47.60 8	1078 88.65 15	10500 456.54 76	172 4.40 1	0	203 3.33 1	8146 169.60 28	15000 423.00 71	14 0.23	3.2	9.20	--	37032 35976	6818
11S/12E- 1R 8-21-64	88	8.3	44200	--	--	9620 418.28	--	--	--	--	13600 383.52	0.0	--	8.50	--	34100	
9-15-64	82	8.2	36800	--	--	9880 429.58	--	--	--	--	13500 380.70	0.0	--	10.00	--	33900	
11S/13E- 9E 6- 9-67	--	8.0	30300	687 34.28 8	730 60.04 15	7050 306.53 76	120 3.07 1	0	185 3.03 1	5544 115.43 29	10000 282.00 70	10 0.16	2.4	6.40	--	24862 24241	4720
11S/13E- 9M 8-21-64	86	8.2	43600	--	--	9620 418.28	--	--	--	--	13300 375.06	0.0	--	8.50	--	33500	
9-15-64	82	8.2	38000	--	--	9700 421.76	--	--	--	--	13600 383.52	0.0	--	10.00	--	34600	
11S/13E-15E 8-21-64	82	8.0	42200	--	--	9200 400.02	--	--	--	--	12600 355.32	0	--	8.20	--	31900	
9-15-64	80	8.0	28800	--	--	8150 354.36	--	--	--	--	7640 215.45	1.1 0.02	--	8.60	--	31400	
8-21-64	85	8.2	42800	--	--	9200 400.02	--	--	--	--	12800 360.96	0.2 0	--	8.30	--	32300	
11S/13E-16A 9-15-64	81	8.4	37900	--	--	10100 439.15	--	--	--	--	14000 394.80	0.8 0.01	--	9.90	--	35500	
WHITEWATER RIVER																	
7S/ 9E-30R 7- 2-57	87	7.6	3021	157 7.83 26	46 3.78 12	428 18.61 61	12 0.31 1	0	281 4.61 14	746 15.53 49	410 11.56 36	8.0 0.13	1.2	0.56	15	2112 1962	581
5- 4-60	70	7.9	4464	196 9.78 20	49 4.03 8	775 33.70 70	16 0.41 1	0	373 6.11 13	1118 23.28 49	608 17.15 36	33 0.53 1	3.8	1.68	21	3070 3005	691

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECx10^6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE												PARTS PER MILLION	
				CA	MG	NA	K	CO_3	HCO_3	SO_4	CL	NO_3	F	B	SiO_2	TDS 180C 105C COMP[a]	HARDNESS CACO3
				SEA,RIVER,OR IRRIGATION CANAL													
WHITEWATER RIVER continued																	
7S/ 9E-30R	71	8.0	3546	162	59	586	13	0	344	925	455	40	3.6	1.00	--	2520	647
3- 8-65				8.08	4.85	25.57	0.33		5.64	19.26	12.83	0.65					
				21	12	66	1		15	50	33	2				2416	
	78	8.1	3305	162	49	520	9	--	280	866	442	5	3.6	0.85	--	2326	606
5- 8-67				8.08	4.03	22.61	0.23		4.59	18.03	12.46	0.08					
				23	12	65	1		13	51	35					2195	
SALT CREEK																	
8S/11E-28B	62	8.0	6892	120	72	1344	24	0	369	1038	1550	0.0	5.5	5.00	--	4477	596
5-11-67				5.99	5.92	58.44	0.61		6.05	21.61	43.71						
				8	8	82	1		8	30	61					4340	
ALAMO RIVER																	
11S/13E-22H	64	--	3040	164	87	375[b]	--	--	194	544	605	4.6	--	--	11	1890	767
3- 6-59				8.18	7.15	16.31			3.18	11.33	17.06	0.07					
				26	23	52			10	36	54					1886	
	70	7.6	3040	175	84	430	11	0	217	629	595	6.0	0.9	0.42	12	2135	783
5-17-55				8.73	6.91	18.70	0.28		3.56	13.10	16.78	0.10					
				25	20	54	1		11	39	50					2050	
	69	7.8	3619	187	100	464	11	0	223	709	700	10	0.8	0.54	14	2420	878
5- 3-61				9.33	8.22	20.17	0.28		3.65	14.76	19.74	0.16					
				25	22	53	1		10	39	52					2306	
	88	7.8	4390	--	--	592	--	--	--	--	798	3.9	--	0.80	--	2790	
8-22-64						25.74					22.50	0.06					
	80	8.2	3800	--	--	505	--	--	--	--	753	3.6	--	0.70	--	2600	
9-15-64						21.96					21.23	0.06					
	76	7.4	4029	201	113	534	14	0	237	830	740	37	--	0.56	--	2748	967
5-11-65				10.03	9.29	23.22	0.36		3.88	17.28	20.87	0.60					
				23	22	54	1		9	41	49	1				2586	
	69	7.3	3425	185	95	450	11	0	212	783	590	17	1.0	0.60	--	2368	853
3-17-67				9.23	7.81	19.57	0.28		3.47	16.30	16.64	0.27					
				25	21	53	1		9	44	45	1				2237	
	75	8.0	3510	191	101	483	14	--	220	782	639	31	0.9	0.26	--	2538	893
5- 8-67				9.53	8.31	21.00	0.36		3.61	16.28	18.02	0.50					
				24	21	54	1		9	42	47	1				2350	
11S/13E-25N	70	7.3	3436	188	95	460	12	0	210	810	600	20	1.0	0.64	--	2340	860
3-17-67				9.39	7.81	20.00	0.31		3.44	16.86	16.92	0.32					
				25	21	53	1		9	45	45	1				2290	
NEW RIVER																	
12S/13E-19N	64	--	4300	201	90	615[b]	--	--	218	523	1050	5.5	--	--	13	2600	872
3- 6-59				10.03	7.40	26.74			3.57	10.89	29.61	0.09					
				23	17	61			8	25	67					2605	
	68	7.5	3077	174	74	460	11	0	232	560	685	4.5	0.8	0.68	12	2180	739
5-17-55				8.68	6.09	20.00	0.28		3.80	11.66	19.32	0.07					
				25	17	57	1		11	33	55					2096	
	70	7.4	4184	187	89	639	15	0	239	619	950	16	0.8	0.92	18	2698	833
5- 3-60				9.33	7.32	27.78	0.38		3.92	12.89	26.79	0.26					
				21	16	62	1		9	29	61	1				2652	
	87	7.7	6150	--	--	940	--	--	--	--	1390	2.3	--	1.50	--	3870	
8-20-64						40.87					39.20	0.04					
	80	8.3	5620	--	--	878	--	--	--	--	1430	2.5	--	1.70	--	3900	
9-15-64						38.18					40.33	0.04					
	65	7.4	5695	242	112	850	32	0	266	783	1365	37	0.9	1.24	--	3790	1065
3- 8-65				12.08	9.21	36.96	0.82		4.36	16.30	38.49	0.60					
				20	16	63	1		7	27	64	1				3554	
	--	7.3	5714	237	118	860	26	0	278	817	1340	24	0.9	1.45	--	3753	1077
1- 9-67				11.83	9.70	37.39	0.66		4.56	17.01	37.79	0.39					
				20	16	63	1		8	28	63	1				3561	
	75	7.6	5010	227	110	782	25	--	261	798	1144	14	0.7	0.28	--	3473	1020
5- 8-67				11.33	9.05	34.00	0.64		4.28	16.61	32.26	0.23					
				21	16	62	1		8	31	60					3229	

STATE WELL NO / DATE SAMPLED	TEMP	PH	EC x10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE: CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2	TDS 180C 105C COMP[a]	HARD-NESS CACO 3
SEA.RIVER.OR IRRIGATION CANAL																	
SAN FELIPE CREEK																	
12S/11E-17M	55	7.9	8547	396	170	1800	19	0	260	2358	2200	1.0	--	2.48	--	7000	1688
1-18-55				19.76	13.98	78.26	0.49		4.26	49.09	62.04	0.02					
				18	12	70			4	43	54					7074	
	--	8.0	10600	420	207	2225	23	0	112	2920	2610	0	--	6.40	--	9000	1901
4-12-55				20.96	17.02	96.74	0.59		1.84	60.79	73.60						
				15	13	71			1	45	54					8466	
	55	7.9	11098	353	197	2000	12	0	220	2489	2340	32.2	--	3.80	--	7982	1692
1-17-56				17.61	16.20	86.96	0.31		3.61	51.82	65.99	0.52					
				15	13	72			3	42	54					7535	
	55	7.9	11110	354	199	2140	20	0	224	2637	2460	4.0	--	2.80	--	8437	1703
2- 8-57				17.66	16.37	93.05	0.51		3.67	54.90	69.37	0.06					
				14	13	73			3	43	54					7927	
	59	7.8	13258	340	255	2438	24	0	293	2836	2970	0	1.4	2.20	29	9168	1899
12-17-57				16.97	20.97	106.00	0.61		4.80	59.05	83.75						
				12	15	73			3	40	57					9040	
IRRIGATION CANAL																	
8S/12E- 6J	70	8.2	1360	95	31	148	5	0	181	347	137	1.8	0.6	0.22	--	933	365
5-1 -67				4.74	2.55	6.44	0.13		2.97	7.22	3.86	0.03					
				34	18	46	1		21	51	27					855	
12S/13E- 9D	--	8.2	1490	98	44	142	6	0	290	163	230	2.3	0.6	0.26	10	990	401
4-27-57				4.39	3.62	6.17	0.15		4.75	3.39	6.49	0.04					
				31	25	43	1		32	23	44					829	
	86	8.0	1321	88	36	134	5	0	159	336	131	0	0.2	0.15	11	904	368
7- 2-57				4.39	2.96	5.83	0.13		2.61	7.00	3.69						
				33	22	44	1		20	53	28					819	
13S/12E- 4J	77	8.0	1388	94	34	152	5	0	182	354	142	1.5	0.6	0.23	--	935	375
5-12-67				4.69	2.80	6.61	0.13		2.98	7.37	4.00	0.02					
				33	20	46	1		21	51	28					873	
DRAINAGE SYSTEM																	
8S/11E-12C	70	8.0	2331	8	7	510	4	0	359	463	254	0.5	14.4	2.30	--	1480	49
5-10-67				0.40	0.58	22.17	0.10		5.88	9.64	7.16	0.01					
				2	2	95			26	42	32					1440	
11S/13E-23F	--	--	--	2240	220	5220	1690	--	--	690	13630	--	--	--	--		6499
5- -62				111.78	18.09	226.97	43.21			14.37	384.37						
11S/13E-28L	57	7.4	4375	237	116	582	15	0	256	1042	747	23.6	0.6	0.60	--	3036	1069
2- 8-68				11.83	9.54	25.32	0.38		4.20	21.69	21.07	0.38					
				25	20	54	1		9	46	45					2891	
11S/13E-33C	--	7.3	7310	338	191	947	172	0	265	1174	1580	5.1	0.5	0.80	12	4608	1630
4-26-57				16.87	15.71	41.18	4.40		4.34	24.44	44.56	0.08					
				22	20	53	6		6	33	61					4551	
12S/11E-16x	--	--	2800	--	--	--	--	--	--	--	--	--	--	--	--		
5- 7-65																	
12S/11E-16x 2	--	--	2500	--	--	--	--	--	--	--	--	--	--	--	--		
5- 7-65																	
12S/13E- 9Q	86	7.5	7380	--	--	--	--	0	412	--	1581	--	--	--	--		
7- 2-57									6.75		44.58						
12S/13E-22B	68	7.2	7520	453	209	957	13	0	540	1351	1529	6.2	0.6	0.68	17	5631	1991
1- 2-58				22.60	17.19	41.61	0.33		8.85	28.13	43.12	0.10					
				28	21	51			11	35	54					4802	
13S/13E- 6x	--	7.4	10400	--	--	--	--	--	--	--	--	14.0	0.1	--	--		
10-18-66												0.23					
DRAINAGE WELL OR SUMP																	
11S/13E-27x	83	6.8	13600	--	--	2120	--	--	--	--	3610	1.4	--	1.90	--	9390	
8-22-64						92.18					101.80	0.02					
12S/11E-25x	82	6.8	71600	--	--	12800	--	--	--	--	30400	2.4	--	0.70	--	63000	
8-20-64						556.54					857.28	0.04					

STATE WELL NO / DATE SAMPLED	TEMP	PH	ECX10 6	MINERAL CONSTITUENTS IN PARTS PER MILLION / EQUIVALENTS PER MILLION / PERCENT REACTANCE VALUE													TOS 180C COMP[a]	HARDNESS CACO 3
				CA	MG	NA	K	CO 3	HCO 3	SO 4	CL	NO 3	F	B	SIO 2			
DRAINAGE WELL OR SUMP																		
125/14E-17F	--	--	15440	1010	575	2187[b]	--	--	436	1472	5496	--	--	--	--			4888
11-28-53				50.40	47.29	95.09			7.15	30.65	154.99							
	--	--	6040	--	--	--	--	--	--	--	--	--	--	--	--			
1-11-56																		
SHALLOW TEST HOLE																		
115/14E- 8X	--	7.9	52000	1080	2920	13340	134	3	641	8800	23540	8.0	--	--	--			4713
12- 8-64				53.89	240.14	580.02	3.43	0.10	10.51	183.22	663.83	0.13						
				6	27	66			1	21	78					50143		
	--	7.9	30500	--	--	--	--	--	--	7500	14470		--	--	--			
8- 0-65										156.15	408.05							
125/11E-16X	72	7.6	2000	138	49	202	12	--	421	350	245	1.7	--	--	--			546
12- 7-64				6.89	4.03	8.78	0.31		6.90	7.29	6.91	0.03						
				34	20	44	2		33	34	33					1205		
	--	7.6	2900	--	--	--	--	--	--	889	330		--	--	--			
8- 0-65										18.51	9.31							
125/11E-24X	72	7.5	8600	385	77	1840	35	--	531	2450	1372	1.2	--	--	--			1278
12- 7-64				19.21	6.33	80.00	0.89		8.70	51.01	38.69	0.02						
				18	6	75	1		9	52	39					6422		
125/13E-20X	--	7.8	9600	597	165	1290	16	--	446	1750	1998	0.6	--	--	--			2170
12- 3-64				29.79	13.57	56.09	0.41		7.31	36.44	56.34	0.01						
				30	14	56			7	36	56					6035		
135/13F- 6X	73	7.7	4000	238	71	552	12	0	616	989	394	9.2	--	--	--			887
12- 7-64				11.88	5.84	24.00	0.31		10.10	20.59	11.11	0.15						
				28	14	57	1		24	49	26					2573		
	--	7.7	2200	--	--	--	--	--	--	--	--	3.0	--	--	--			
8- 0-65												0.05						
GEOTHERMAL WELL, CERRO PRIETO AREA, MEXICO																		
M-1A	--	--	--	210	30	4450	600	--	52	7	7420	--	--	7.00[c]	240			648
10- 0-66				10.48	2.47	193.49	15.34		0.85	0.15	209.24							
M-3	--	--	--	320	--	5610	1040	--	90	14	9694	--	0.9	--	--			799
8- 5-64				15.97		243.92	26.59		1.48	0.29	273.37							
	--	--	--	310	11	5310	1100	680	60	15	9680	--	--	8.00[c]	480			819
10- 0-66				15.47	0.90	230.88	28.13	22.66	0.98	0.31	272.98							
	157	6.9	28330	356	0	5700	1100	0	73	31	10500	3.1	2.5	14.00	--	18846		889
3-16-67				17.76		247.84	28.13		1.20	0.65	296.10	0.05						
				6		84	10				99					17742		
M-5	--	--	--	280	8	5820	1570	1600	73	0	10420	--	--	10.00[c]	740			732
10- 0-66				13.97	0.66	253.05	40.14	53.33	1.20		293.84							
M-6	--	--	--	388	33	5000	504	420	158	16	9000	--	--	3.00[c]	151			1104
10- 0-66				19.36	2.71	217.40	12.89	14.00	2.59	0.33	253.80							
M-7	--	--	--	230	18	5250	910	940	71	3	9310	--	--	4.50[c]	390			649
10- 0-66				11.48	1.48	228.27	23.27	31.33	1.16	0.06	262.54							
M-8	--	--	--	390	6	6100	1860	--	890	0	11750	--	--	16.00[c]	770			998
10- 0-66				19.46	0.49	265.23	47.56		14.59		331.35							
M-10	160	5.8	20000	328	13	3900	550	0	149	19	7175	2.5	1.2	11.00	--	12830		873
3-16-67				16.37	1.07	169.57	14.06		2.44	0.40	202.34	0.04						
				8	1.	84	7		1		99					12073		

NOTE:

a. Computed TDS: Ca ppm + Mg + Na + K + CO_3 + (HCO_3 x .492) + Cl + NO_3

b. Na + K

c. B computed from H_3BO_4

Appendix E

TRACE ELEMENT AND SPECIAL ANALYSES

Location	Date Sampled	Source	TDS in ppm	Ag	Al	As	Au	Ba	Be	Bi	Cd	Co	Cr	Cs	Cu	Fe
															TRACE ELE–	
																GEOTHERMAL
IMPERIAL THERMAL PRODUCTS, I.I.D. 2																
11S/13E–22J1g	0/ 0/67[a,b]	A,B	258,765					250						20		2,000
IMPERIAL THERMAL PRODUCTS, I.I.D. 1																
11S/13E–23F1g	3/ 3/62[d]	C	278,000													2,000
	5/ 0/62[d]	C	340,816[e]													3,416
	0/ 0/63[c]	B,D	319,000	1	450	15		200						22	10	3,200
	4/21/66[a,b]	A	258,360	.8		12		235						16	8	2,090
JOSEPH O'NEILL, SPORTSMAN 1																
11S/13E–23G1g	8/31/61[c]	B	334,987													4,200
WESTERN GEOTHERMAL, SINCLAIR 4																
12S/13E–4Q2g	7/ 5/67[b,1]	E		1.0	<100			1,100	<.002	<.0005	<005	<.0005	<4		6	1,200
		F													.47	1,370
		G		1.4											2.5	
		H[f]	266,557			10										1,148
WESTERN GEOTHERMAL, SINCLAIR, 3																
12S/13E–10D2g	4/19/62[d]	C[f]	183,700	0		10		540							0.0	
	4/23/63[d]	C[f]		0		10		570							1	
ANALYSES OF GEOTHERMAL EVAPORITE (SALT SAMPLE FROM POND)																
	3/17/67	E	– –	2.5	<60			20				<.1	<.1		.25	2.4
		F			11							.396	1.815			11.6
[illegible] THERMAL PRODUCTS, I.I.D. 3																
11S/13E–23C1[illegible]	3/18/65[b,1]	[illegible]	35,600		2	0.16		3								0.7

NOTE: (Geothermal Wells Only)

A. Skinner et al., May 1967

B. California Division of Mines and Geology, Mineral Information Service, July 1967

C. Colorado River Basin Regional Water Quality Control Board (No. 7)

D. White, 1965 or (D[1]) Muffler and White, 1969

E. Analyses by Gordon Bradford, University of California at Riverside, using a direct-reading emission spectograph for most elements and an atomic adsorption spectograph for Li

F. Analyses by the United States Geological Survey, Water Resources Division, Sacramento District, using the emission spectographic method for Ge and an atomic adsorption spectrograph for the other elements

G. Analyses by George Uman, Los Angeles Department of Water and Power, using an arc atomic emission spectograph (semiquantitative results)

H. California Department of Water Resources

1. When no figure appears for a constituent, its concentration was not determined

SPECIAL ANALYSES

MENTS in ppm[g]																	Special analyses in ppm			
Ga	Ge	Hg	La	Li	Mn	Mo	Ni	Pb	Rb	Sb	Sn	Sr	Ti	Tl	V	Zn	Br	I	NH_4	PO_4
WELLS																				
				210	1,370			80	70			440				500				
					1,300															
					30															
		.008		300	2,000			104	168	.5	.65	740				970	146	22	482	
		.006		215	1,560			84	137	.4	.5	609		1.5		790	120	18	409	
				149.9																
<.0005	<.1	<.2			2,000	<.1	<4	70		<.2	<.04	610	<.04		6	600				
	.005				1,400															
				400				50				300								
				287	1,025							434					25	13	442	
				49	410			80		.2		360							340	
				80	1,000			200		.2		510							570	
				1.5	40	<.1	<.1	400				<20	<20		.25	3				
					>30		.231						.220		.297					
				40	6.4							85					15	4.5	321	

[a]Average analysis

[b]Corrected for steam loss, or (b') steam loss minimized in sampling

[c]Not corrected for steam loss

[d]Probably not corrected for steam loss

[e]Computed TDS: Ca ppm + Mg + Na + K + Co_3 + (HCO_3 x .492) + SO_4 + Cl + NO_3

[f]Data corrected (i.e., value/Sp.G. = ppm) or Sp.G. correction made unnecessary by analytical technique sources E, F, and G uncorrected for Sp.G., status of others unknown

[g]Trace Elements: The symbol (<) indicates value less than amount shown; the symbol (≤) indicates value equal to, but slightly less than amount shown; and the symbol (>) indicates value more than amount shown

Location[1]	Date Sampled	Source[2]	TDS in ppm	Ag	Al	As	Au	Ba	Be	Bi	Cd	Co	Cr	Cs	Cu	Fe
																TRACE ELE-
																WATER
7S/ 9E-16K1	5/11/55	DWR	855													.2
	1/28/64	DWR	456													
7S/10E-36K1	10/14/61	DWR	4,350													
8S/ 8E-13Q1	5/19/67	UCR		.0001	<.05			<.01	<.002	<.0005	<.005	<.0005	<.0005		.0012	.0035
		DWR	204			.10										
8S/11E- 3C2	5/10/67	UCR		.0001	<.1	<.04		<.02	<.002	<.0005	<.005	<.0005	.0013		.0057	.4400
		DWR	988													
8S/12E-36P1	5/11/67	UCR		.0002	<.2			.12	<.002	<.0005	<.005	<.0005	<.0010		.0030	.0450
		DWR	2,921			.08										
9S/ 9E- 4K1	5/19/67	UCR		.0002	<.6			<.04	<.002	<.0005	<.005	<.0005	<.0010		.0027	.1400
		DWR	11,076			.00										
9S/12E- 1D1	7/ 6/63	PHD	940													.01
9S/12E- 1D2	7/30/64	PHD	3,065													.06
	8/17/65	PL				<.01										
	1/26/67	PHD	3,270													.10
9S/12E- 1D3	7/ 6/63	PHD	1,295													.03
9S/12E- 2A1	12/19/60	PHD	3,098													.20
	6/15/64	PHD	3,029			.066					.00		.00		.01	.95
	1/10/67	PHD	3,475													.30
9S/12E- 2A2	2/ 6/67	PHD	2,840													.78
9S/13E- 7M1	2/21/64	DWR	4,670			.00										
9S/13E-20E1	5/11/67	UCR		.0002	<.2			.02	<.002	<.0005	<.005	<.0005	<.0010		.0034	.0060
		DWR	4,077			.02										
10S/10E-18N1	11/ 6/52	DWR														.0
	12/20/55	DWR	3,750		.0											.18
	5/19/67	UCR		.0001	<.10			3.7	<.002	<.0005	<.005	<.0005	<.0010		.0085	.0700
		DWR	3,754			.00										
11S/9 E- 2B1	5/19/67	UCR		.0001	<.10			.30	<.002	<.0005	<.005	<.0005	<.0010		.0034	.0200
		DWR	2,256			.25										
11S/13E-13D2	2/ 8/68	UCR			<2			<1				.017	<.001		.067	5.2
		DWP		.035	2.2			<5							.05	6
		DWR	23,271			.03										
12S/10E-26M1	1/ 9/67	PHD	2,035													.10
	5/12/67	UCR		.0003	<.1	<.04		.02	<.002	<.0005	<.005	<.0005	<.0005		.0023	.1100
		DWR	1,024													
																SPRING OR MUD
8S11E-36S1	1876	USGS	2,944													
	11/11/17	USGS	1,623													.08
	5/10/67	DWR	1,400													

MENTS[3] in ppm																	Special analyses[4] in ppm			
Ga	Ge	Hg	La	Li	Mn	Mo	Ni	Pb	Rb	Sb	Sn	Sr	Ti	Tl	V	Zn	Br	I	NH_4	PO_4
WELLS																				
																				.3
																			1.8	
<.0005	<.1	<.2		.02	.0017	.0085	<.0005	.0008		<.2	<.04	<.02	<.04		.0850	.0037				
				.05													.24	.02		
<.0005	<.1	<.2		.47	.0050	.0300	.0075	.0020		<.2	<.04	1.0	<.04		.0130	.0045				
																	.8			
<.0005	<.1	<.2		3.6	.0850	.0120	<.0010	.0012		<.2	<.04	3.3	<.04		<.0010	.0045				
				2.6													1.3	.29		
<.0005	<.1	<.2		1.5	.0720	.0046	<.0010	.0012		<.2	<.04	19	<.04		<.001	.0260				
				1.4													.8	1.45		
					.00															
					.05															
					.00															
					.00															
					.15															
					.10	.50		.00						.00		.01			1.3	.1
					.00															
					.00															
<.0005	<.1	<.2		3.44	.0010	.0080	.0010	.0013		<.2	<.04	5.2	<.04		.0050	.0055				
				4.8													3.0	.24		
					.00															.1
<.0005	<.1	<.2		.94	.0050	.0044	<.0010	.0020		<.2	<.04	1.0	<.04		<.0010	.0180				
				.64													.16	.24		
<.0005	<.1	<.2		.36	.0070	.0320	<.0010	.0017		<.2	<.04	.56	<.04		<.0010	.0580				
				.24													2.7	.62		
						.006	.010	.0016				24	<2		.0026	.012				
	<.4			30	2.5			<.3				18								
																	2.5	3.9	100	
					.00															
<.0005	<.1	<.2		.13	.0080	.0180	.0005	.0012		<.2	<.04	.32	<.04		.0006	.0045				
VOLCANO (MUD POT)																				
					trace															trace
																	1.4			

Location[1]	Date Sampled	Source[2]	TDS in ppm	Ag	Al	As	Au	Ba	Be	Bi	Cd	Co	Cr	Cs	Cu	Fe
															TRACE ELE-	
															SPRING OR MUD	
8S/11E-3CS3	5/10/67	UCR		.0002	<.1			<.02	<.002	<.0005	<.005	<.0005	<.0010		.0023	.0070
		DWR	1,309			.00										
8S/12E-36NS1	5/11/67	DWR	1,335													
9S/ 9E- 9HS	11/19/17	USGS	1,994													.09
9S/13E-20LS1	12/10/17	USGS	3,893													.19
10S/ 9E-20NS	12/30/55	DWR	16,600		.4											.13
10S/13E-27BS1	3/15/67	UCR		<.004	<1.5		<.04	<.2	<.004	<.08	<.4	.046	<.002		.009	.10
		DWR	51,632			.00										
11S/10E-18AS	00/00/09	USGS	5,937													
	11/20/17	USGS	4,108													.35
11S/13E-24ES1	11/23/64	USGS[a]			≤1.4				<.57	<.29	<1.4	<1.4	<1.4		<1.4	316
		USGS	16,300			.01										
12S/11E-21MS1	11/20/17	USGS	2,102													.21
	5/12/67	UCR		.0001	<.2			.04	<.002	<.0005	<.005	<.0005	<.0010		.0031	.0550
		DWR	3,161			.00										
12S/12E-29NS1	5/12/67	UCR		.0001	.2			.04	<.002	<.0005	<.005	<.0005	<.0010		.0054	.0800
		DWR	4,656			.00										
															SEA, RIVER, OR	
SALTON SEA																
9S/12E-31D	6/ 7/67	DWR	36,192			.00										
11S/11E-21P	6/ 8/67	UCR		.0008	<6			<1	<.002	<.0005	<.005	<.0005	<.002		.0050	.0100
		DWR	37,082			.00										
11S/12E-18	8/21/64	DWR	34,100													
	9/15/64	DWR	33,900													
11S/13E-9F	6/ 9/67	DWR	24,862			.00										
11S/13E-9M	8/21/64	DWR	33,500													
	9/15/64	DWR	34,600													
11S/13E-15F	8/21/64	DWR	31,900													
	9/15/64	DWR	31,400													
11S/13E-16A	8/21/64	DWR	32,300													
	9/15/64	DWR	32,500													
WHITEWATER RIVER																
7S/ 9E-30R	5/ 4/60	DWR	3,070													
	5/ 9/66	UCR	2,100		.26			.32					<.001		.007	.020
SALT CREEK																
8S/11E-28R	5/11/67	UCR		.0002	<.2			<.02	<.002	<.0005	<.005	<.0005	<.0010		.0033	.0290
		DWR	4,477			.00										
ALAMO RIVER																
11S/13E-22H	5/ 3/60	DWR														
	8/22/64	DWR	2,790													
	9/15/64	DWR	2,600													

MENTS[3] in ppm																	Special analyses[4] in ppm			
Ga	Ge	Hg	La	Li	Mn	Mo	Ni	Pb	Rb	Sb	Sn	Sr	Ti	Tl	V	Zn	Br	I	NH_4	PO_4
VOLCANO (MUD POT) continued																				
<.0005	<.1	<.2		.9	.0006	.0080	<.001	.0011		<.2	<.04	1.1	<.04		.0090	.0014				
				.6													1.5	.00		
																	1.3			
					.00															.5
<.08	<.2	<.4	<.08	60	3.0	.001	.066	.0044		<.4	<.08	150	<.5	<.08	.01	.02				
				75															127	
																				0
<5.7	16				943	<.29	5.4	<1.4					<.57		31	<5.7				
				12								7.8							49	.10
<0005	<.1	<.2		1.23	.0120	.0180	.0010	.0017		<.2	<.04	.68	<.04		.002	.0085				
				.9													1.1	.03		
<.0005	<.1	<.2		2.5	.2400	<.0020	.0040	.0024		<.2	<.04	8.4	<.04		<.0020	.0080				
				1.8													4.3	.05		
IRRIGATION CANAL																				
				3.1													12	.1		
<.0005	<.1	<.2			.01	.016	.003	<.002		<.2	<.04	11	<.04		.003	.062				
				3.2													12	.15		
																			.02	.00
																			.05	.00
				2.1													10	.1		
																			.15	.00
																			.01	.00
																			25	.09
																			.03	.00
																			.13	.02
																			.04	.00
																				.48
					.002	.065	.002	<.001				.72			.018	.011				
<.0005	<.1	<.2		.8	.0020	.0630	.0021	.0020		<.2	<.04	1.7	<.04		.0055	.0045				
				1.2													3.1	.15		
																				.94
																			30	15
																			.40	16

Location[1]	Date Sampled	Source[2]	TDS in ppm	Ag	Al	As	Au	Ba	Be	Bi	Cd	Co	Cr	Cs	Cu	Fe
															TRACE ELE-	
ALAMO RIVER -- continued																
	5/9/66	UCR	2,890		.8		<.04	.26							.006	.01
	3/17/67	USGS[a]		<.02	4.530				<.0013	<.00067	<.0033	.023	.147		<.0033	427
		UCR		<.004	<.1		<.04	.02	<.004	<.08	<.4	<.002	<.002		.0074	.032
		DWR	2,368			.00										10
11S/13E-25N	3/17/67	USGS[a]		<.02	5.870				<.0013	<.00067	<.0033	.029	.130		<.0033	1.130
		UCR		<.004	<.1		<.04	.02	<.004	<.08	<.4	<.002	<.002		.0070	.016
		DWR	2,340			.00										.10
NEW RIVER																
12S/13E-19N	5/3/60	DWR	2,698			.0										
	8/20/64	DWR	3,870													
	9/15/64	DWR	3,900													
	3/8/65	DWR	3,790			.4										
	5/9/66	UCR	3,990		.7			.44					<.001		.004	.02
	1/9/67	DWR	3,753													
IRRIGATION CANAL																
8S/12E-6J	5/10/67	UCR		.0002	<.1			.11	<.002	<.0005	<.005	<.0005	<.0010		.0034	.0170
		DWR	933			.00										
13S/12E-4J	5/12/67	DWR	936													
															DRAINAGE	
8S/11E-12C	5/10/67	DWR	1,480													
11S/13E-23F	5/00/62	PL														trace
13S/13E-6X	10/18/66	USDA														.062
															SHALLOW	
11S/14E-8X	12/8/64	USDA	50,628[b]													.05
12S/11E-16X	12/7/64	USDA	1,308[b]													0
12S/11E-24X	12/7/64	USDA	6,495[b]													0
12S/13E-20X	12/3/64	USDA	6,072[b]													.52
13S/13E-6X	12/7/64	USDA	3,129[b]													0
												GEOTHERMAL WELLS IN THE				
M-1A	10/00/66	M														
M-3	8/5/64	M		.05			trace	57.0							.09	
	10/00/64	M														.2
	3/16/67	DWR	18,846			.55										72
	6/7/67	DWR														
M-5	10/00/67	M														.2
M-6	10/00/66	M														
	6/7/67	DWR														
M-7	10/00/66	M														
M-8	10/00/66	M														
M-10	3/16/67	USGS[a]		<.2	.045				<.00067	<.00033	<.0017	<.0017	<.0017		<.0017	.050
	3/16/67	UCR		<.004	<.5		<.04	12	<.004	<.08	<.4	<.002	<.002		.005	.05
		DWR	12,830			.38										.64
	6/7/67	DWR														

MENTS[3] in ppm																	Special analyses[4] in ppm			
Ga	Ge	Hg	La	Li	Mn	Mo	Ni	Pb	Rb	Sb	Sn	Sr	Ti	Tl	V	Zn	Br	I	NH_4	PO_4
					.001	.029	.001	.002				.76			.007	.001				
<.013	<.00067				.587	<.00067	.015	<.0033				3.0	.012		.011	<.013				
<.08	<.2	<.4	<.08	.133	.038	.0016	.0032	.0034		<.4	<.08	.76	<.04	<.08	.0066	.011				
				2															0	
<.013	<.00067			.14	.787	<.00067	.017	<.0033				3.0	.017		.017	<.013				
<.08	<.2	<.4	<.08	.124	.012	.0018	.0024	.0024		<.4	<.08	1.03	<.04	<.08	.0060	.005				
				2															0	
																				.54
																			.00	4
																			.15	2
					.003	.022	.002	<.001				.84			.005	.025				
																				.80
<.0006	<.01	<.2		.1	.0021	.0040	.0020	.0011		<.2	<.04	40	<.04		.0030	.0035				
				.06													1.1	.00		
																	.3			
SYSTEM																				
																	1.6			
				nil																
					42															
TEST HOLE																				
					1.20															
					0															
					.06															
					1.80															
					.80															
CERRO PRIETO AREA, MEXICO																				
				12													5.2	1.0		
				13.6								27.4								
				17													10.0	2.8		
				17.6															20	
																	6.0	.45		
				19													14.1	3.1		
				11													12.6	2.5		
																	6.0	4		
				13													9.2	2.6		
				17													14.3	3.2		
<.0067	.050			8.0	.517	<.00033	.0031	<.0017				6.7	<.00067		<.00033	<.0067				
<.08	<.2	<.4	<.08	15.0	.64	<.001	.0022	.0046		<.4	<.08	10	<.12	<.08	<.002	.005				
				9.4															45	
																	5.0	.4		

NOTE:

1/ Locations: Shown on Plate 1; geothermal wells in the Cerro Prieto Area, Mexico, shown on Figure 9

2/ Source:

DWR – Chemical analyses by California Department of Water Resources

UCR – Analyses by Gordon Bradford, University of California at Riverside, using a direct-reading emission spectograph for most elements and an atomic adsorption spectograph for Li

PHD – Analyses for the Public Health Department, Imperial County

PL – Analyses by a private laboratory

DWP – Analyses by George Uman, Los Angeles Department of Water and Power, using an arc atomic emission spectograph (semiquantitative results)

USGS – Analyses for the United States Geological Survey

USDA – Analyses for United States Department of Agriculture

M – Analyses by the Geothermal Energy Commission of Mexico

3/ Trace Elements: The symbol (<) indicates value less than amount shown; the symbol ($\leq$) indicates value equal to, but slightly less than amount shown; and the symbol (>) indicates value more than amount shown

4/ Special Analyses: Br and I values are roughly quantitative, accuracy ± 10 percent

a. Analyses by the United States Geological Survey, Water Resources Division, Sacramento District, using an emission spectrographic method on most elements and an atomic adsorption spectrograph for Ag, Li, and Sr

b. Computed TDS determination: Ca ppm + Mg + Na + K + CO_3 + (HCO_3 x .492) + SO_4 + Cl + NO_3

c. When no figure appears for a constituent its concentration was not determined.

d. Variations in trace element concentrations of similar samples from the same station are attributed to differences in sampling techniques and laboratory procedures and methods

SPECIAL ANALYSES FOR DWR

Selected samples of various surface and ground waters and geothermal brines were collected by the Department in 1967 for isotope and radioactivity studies.

OXYGEN-HYDROGEN

According to the results of a preliminary oxygen-hydrogen isotope study of these samples by Dr. Samuel Epstein of the California Institute of Technology's Department of Geochemistry, all water in the Salton Sea Area--including geothermal brines and effluent from the Salton Sea and Cerro Prieto geothermal fields--are meteoric in origin. This brief isotope study also indicates that Cerro Prieto geothermal water and Colorado River water (Coachella Canal) have had a common source. However, the thermal water along the San Andreas fault zone, as well as that along the west side of the Salton Sea, originate, at least in part, from a local source as runoff from their respective watersheds. Although of meteoric origin, oxygen-hydrogen studies indicate that the source of the geothermal brines from the Salton Sea Area is more complex than that of other water.

TRITIUM

Analyses of tritium at the University of California at Los Angeles, Department of Chemistry and Institute of Geophysics, indicate that Tritium Unit (TU) measurements (derived from hydrogen bomb detonations) for the geothermal water of both the Buttes thermal area ($12S/13E-4Q2_g$) and Cerro Prieto area (M-3), as well as those of the ground water from a thermal well (10S/10E-18N1), are in the order of magnitude of 10 ± 10 TU. These values may possibly reflect contamination from atmospheric or laboratory conditions. Tritium concentrations of surface water, because of exposure to the atmosphere, were in the order of magnitude of 200 TU for the Salton Sea (8S/10E-2P) and 500 TU for the Colorado River water in the Coachella Canal (8S/10E-2P). The low levels of tritium in the ground water are indicative of the water's lack of hydrologic continuity with a recent near surface source and/or the impermeability of the confining sediments.

RADIOACTIVITY

An aerial radiological survey was conducted of the Salton Sea Area during July 1967 by EG&G, Inc., in conjunction with a project for the U. S. Atomic Energy Commission, Civil Effects Branch, and the Department of Water Resources. It indicated that, in general, the gross-count radioactivity measurements

were fairly uniform. However, slightly higher values were found in a zone roughly coinciding with the trace of the San Andreas fault system (Figure 1). Aerial spectral analyses at selected sites disclosed that the major sources of radioactivity are the isotopes of K-40 (potassium), Bi-214 (bismuth), and Tl-208 (thallium).

Total net radioactivity (Table 15) values were determined by EG&G on 5 samples (4 from the study area and 1 from the San Jacinto Valley). The radioactivity of the geothermal waters (12S/13E-4Q2g), for purposes of comparison, measured 260 times that of a water sample from well 4S/3W-10E3 in the San Jacinto Valley (1.4 picocuries per liter) and 9 times that of water from the thermal well (10S/10E-18N1); that water, measured more than 25 times as much as the San Jacinto Valley well. Measurements of the Salton Sea (8S/10E-2P and 11S/11E-21P), about 4 picocures per liter were about twice as high as that of ground water from the San Jacinto Valley well.

Net radioactivity tests by the Los Angeles Department of Water and Power (Table 15) of 2 samples indicate that the radioactivity of geothermal waters from well 12S/13E-4Q2g is about 12 times that of water from Massions Well, Hot Mineral Spa 11S/13E-13D2. The TDS values (Appendix D) of these two waters are approximately in the same ratio as the radioactivity values.

SPECIAL ANALYSES IN THE LITERATURE

The origin of the sediments in the Salton Trough and the source and nature of the highly saline geothermal brines were studied by numerous investigators. Some of the findings reported are discussed below.

The Cenozoic sediments in the Salton Trough were derived from the upper Colorado River drainage basin, with subordinate contributions from bordering ranges (Dibblee, 1954; Merriam and Bandy, 1965; Muffler and Doe, 1968; and Muffler and White, 1969).

The water of the geothermal system was first believed to be of magmatic origin (White et al, 1963) because of the brine's unique composition and its extremely high temperatures. Subsequent isotope studies of the geothermal system indicate that the waters of the geothermal brines are predominantly meteoric in origin (White, 1965; Berry, 1966; Helgeson, 1968; Muffler and Doe, 1968; White, 1968; and Craig, 1969).

Investigators differ as to the source of this meteoric water. Helgeson (1968) believes that it is Colorado River water originally trapped in the pore spaces of the reservoir sands. White

TABLE 15

RADIOACTIVITY ANALYSES OF SELECTED WATERS

Location	Date sampled	Gross CPM (α)[1]	Net CPM (α)	Gross CPM (β-γ)[2]	Net CPM (β-γ)	Net pc/l (β-γ)[3]
Salton Sea at Salton Sea State Park 8S/10E–2P	7/ 3/67	0.267	—	31.7	3.0	4.5
Salton Sea at Naval Base Pier 11S/11E–21P	7/ 7/67	0.133	—	30.7	2.0	3.0
Ballard's Truckhaven Well 10S/10E–18N1	7/ 7/67	0.467	0.067	67.2	38.5	58.8
Western Geothermal, Sinclair 4 12S/13E–4Q2$_g$	7/ 5/67	0.333	—	701.3	672.6	550
San Jacinto Valley Well 4S/3W–10E3	6/23/67	0.534	0.134	30.1	1.4	2.1
Control Sample	8/ 3/67	0.467	0.067	27.4	—	—

NOTE:

1. Background Alpha (α) = 0.4 counts per minute (CPM)
2. Background Beta–Gamma (β-γ) = 28.7 counts per minute (CPM)
3. Net pc/l = net picocuries per liter
4. Analyses by Mr. J. McDonald of EG&G, 8–3–67.

Location	Date sampled	Net pc/l (α)	Net pc/l (β-γ)
Western Geothermal, Sinclair 4 12S/13E–4Q2$_g$	7/5/67	22.68	1,464
Massions Well, Hot Mineral Spa 11S/13E–13D2	2/8/68	0.29	124

NOTE:
Analyses by Mr. C. McCormick of Los Angeles Department of Water and Power, 2–29–68.

(1968), on the other hand, believes that it is largely or entirely local precipitation that has fallen on the Chocolate Mountains, seeped underground to a depth of 10,000 feet or more along range-front faults, then moved westward and upward to the geothermal system. Isotope evidence (Craig, 1969) indicates that the source of fluid for the geothermal system was percolation from local precipitation.

The source of the dissolved salts in the geothermal brines and the method of their enrichment have been the subject of much discussion. Berry (1966) proposed that the predominantly interstitial meteoric water was concentrated within a thermal convection cell by "hyperfiltration of relatively dilute hydrothermal solutions through electrostatic semipermeable membranes" (clays). According to isotopic evidence, most of the strontium and much of the lead (Doe et al, 1966), and similarly most of the other geothermal brine constituents (Skinner et al, 1967), were obtained by leaching and exchange processes during metamorphism of the host sediments. Helgeson (1968) believed that the dissolved salts in the brines were concentrated by thermally induced evaporation of water trapped in reservoir sands. White (1968) believed that some enrichment of the deep percolating waters, which formed the geothermal brines, was caused, in part, by a solution of buried chloride-rich evaporite deposits.

In short, it may be said that the source waters for the geothermal brines were predominantly meteoric in origin and the dissolved solids were largely acquired from the host sediments.

Appendix F

TECHNIQUES UTILIZED IN EVALUATING EFFECTS

Appendix F

TECHNIQUES UTILIZED IN EVALUATING EFFECTS

A system showing chemical analyses of water graphically, similar to that suggested by Stiff (1951), is presented on Plate 1. Because of the extremes in chemical concentrations--less than 200 to more than 200,000 ppm TDS--it was necessary to develop a modified method for presenting and comparing the data. As shown in the legend on Plate 1, concentrations of the 4 cations, plotted to the left of their zero point, and 4 anions, plotted to the right of their zero point, are expressed as percent reactance values. The TDS in ppm is also presented in the diagram along 2 vertical axes. Connecting the points gives a closed figure, or "pattern", whose shape is more or less characteristic of a given kind of water.

A comparison of trace elements (Appendix E) in waters from selected sources is shown on Plate 2. These waters were analyzed by Mr. Gordon Bradford of the University of California at Riverside. He treated the preconcentrated samples with a chelating agent to separate most of the trace elements from major constituents. Trace element concentrations were then determined with a Jarrel-Ash Direct-reading Emission Spectograph.

Trace element data (ppm) are plotted in a pattern similar to that of a wind rose, hence it is termed a Trace Element Rose (Plate 2). The 10 constituents are copper, iron, lead, strontium, vanadium, zinc, manganese, molybdenum, barium, and lithium. Their concentrations are plotted radially on a logarithmic scale. To form the closed rosette diagram, arcs are drawn at the end of these radii.

The relationship between the various waters occurring within the hydrologic environment of the Salton Sea Area is shown in the trilinear diagram of Figure 8. The plotting of percent reactance values for both cations and anions on a trilinear diagram is a graphic method of presenting the chemical character of a water. Each vertex represents 100 percent of a particular ion or combination of ions.

The composition of the water with respect to cations, or anions, or both, is indicated by a point plotted in its respective triangle on the basis of the percentages of the constituents present. The trilinear diagram (after Piper, 1944) represents an analysis plotted by 3 points. The cation and anion triangles occupy positions at the lower left and lower right, respectively, with their bases aligned horizontally. The central portion of the diagram, or third portion, is the diamond-shaped upper field.

Each corresponding point in the cation and anion triangles is projected into the upper diamond-shaped field along a line parallel to the upper margin of the field. The point where the extensions intersect represents the composition of the water as shown by the relationships between the cations and the anions.

Appendix G

GEOPHYSICAL SURVEY OF THE SOUTHERN SALTON SEA

Appendix G

GEOPHYSICAL SURVEY OF THE SOUTHERN SALTON SEA

A marine survey of the southern Salton Sea was conducted by the Department from June 4 to June 9, 1967

SEISMIC SURVEY EQUIPMENT

Geophysical equipment furnished by Marine Advisors, Inc. under contract consisted of 5,000-joule (watt-second) seismic sparker system and 1,000-joule seismic boomer system. Navigation control for the survey was contracted with Lewis and Lewis, Ventura, California, using a Cubic Autotape (DE-40), an electronic (microwave) positioning system. The vessel, an LCM 56 feet in length, was furnished by the U. S. Navy Base at Salton Sea, California. Continuous fathometer and partial temperature records were also made (Plate 1).

The first two surveys, numbers 2-49 and 59-89 (Lines A and B, Figure G-1), were made, using the sparker source (an acoustical wave generator), while the remaining surveys were all done utilizing the boomer (a mechanical sound generator). Signal penetration using the sparker system occasionally attained a maximum depth of 1,200 feet under favorable conditions, while the maximum recorded depth attained with the boomer was only 600 feet.

RESULTS OF THE SEISMIC SURVEY

The seismic survey consisted of five lines, marked A through E in Figure G-1. The line designation is related to the station numbers as shown in Figure G-1. In addition, a single fathometer line was run across the Sea, unaccompanied by seismic recording. It is designated as Line 1 on the map.

A detailed evaluation of the seismic records was made by Dr. Meidav (Geology Department, University of California at Riverside) and presented in "Report on a Marine Seismic Survey, Salton Sea, Southern Part, for the Department of Water Resources, State of California". This confirmed the Department's findings of the existence of several faults.

Dr. Meidav found 16 possible faults, located and numbered in Figure G-1. The salient information, which has been extracted from Dr. Meidav's report, is incorporated in the remainder of this appendix:

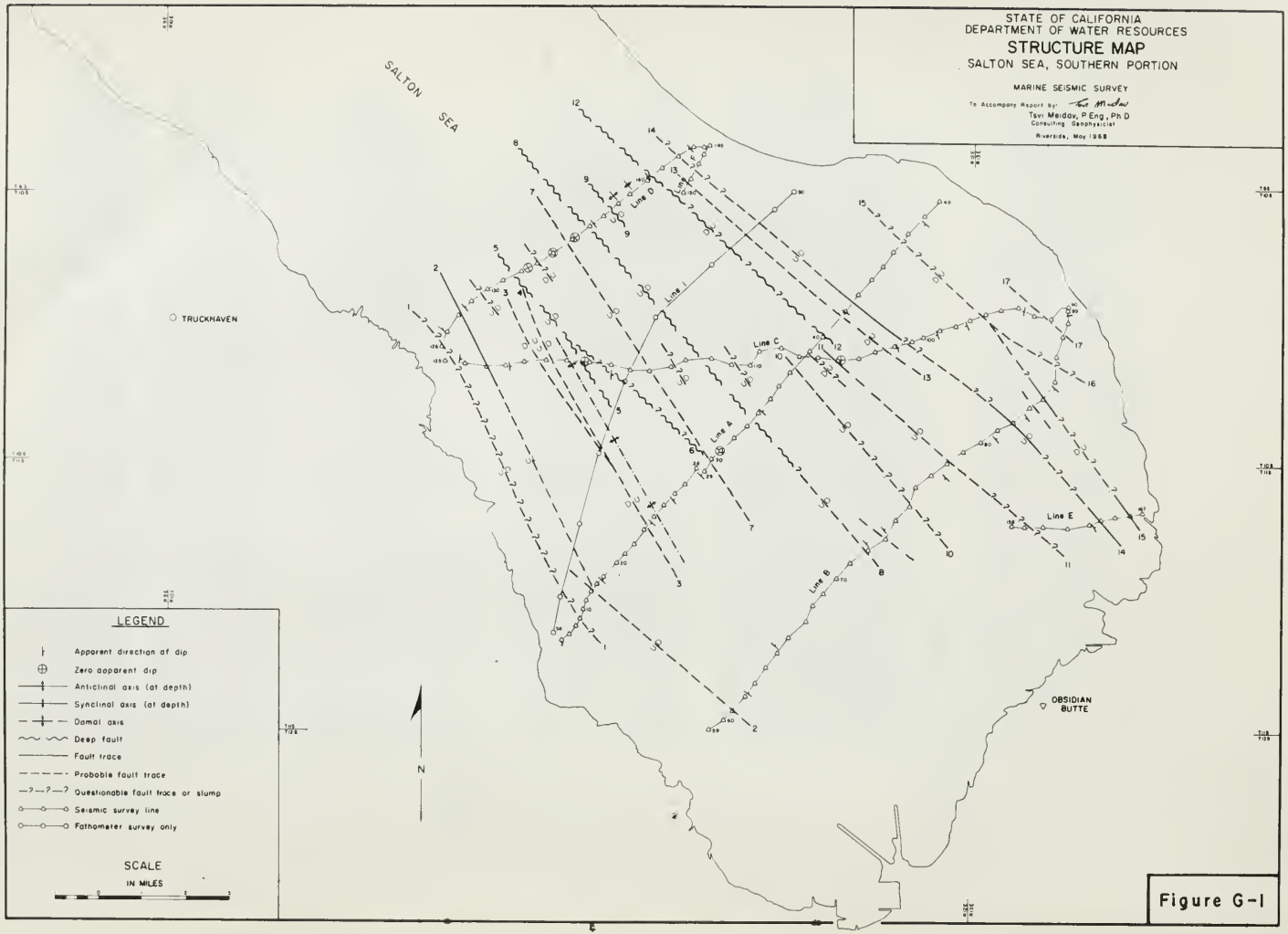

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
STRUCTURE MAP
SALTON SEA, SOUTHERN PORTION
MARINE SEISMIC SURVEY
To Accompany Report by:
Tsvi Meidav, P.Eng., Ph.D.
Consulting Geophysicist
Riverside, May 1968
SALTON SEA
TRUCKHAVEN
OBSIDIAN BUTTE
Line A
Line B
Line C
Line D
Line E
Line F
Line I
N
LEGEND
Apparent direction of dip
Zero apparent dip
Anticlinal axis (at depth)
Synclinal axis (at depth)
Domal axis
Deep fault
Fault trace
Probable fault trace
Questionable fault trace or slump
Seismic survey line
Fathometer survey only
SCALE
IN MILES

Figure G-1

"The seismic records were analyzed individually and any indication of faulting, slumping and change of character of reflection were noted.... The map /Figure G-1/ provides information on the direction of faults (generally, N35° -40°W). A distinction was made between faults which had a near-bottom expression (i.e., displacement), and a few which had more noticeable expression at a greater depth (150-200 feet below bottom), which are indicated on the map as 'deep faults'. The faults are numbered on the map from No. 1 to No. 16 for discussion purposes.

"Not all the lines indicating faults are necessarily faults. Ancient shorelines and strand /beach/ lines, when accompanied by small terraces, will give an impression of a fault on the seismic records, and the higher the order of the multiple reflection*, the higher is the apparent displacement of the imaginary fault. Slumping due to recent earthquake activity may create the impression of faulting in deeper beds.... Uncertain faulting or uncertain correlation are indicated, as usual, by a series of question marks /Figure G-1/.

"The apparent sense of motion on either side of the identified disturbances are indicated wherever identified, and the apparent dip noted. It is believed that the apparent dip in this case is fairly close to the true dip, because the survey lines cross the major tectonic features at almost a right angle.

"An axis of an elongated anticline, which lies unconformable under more recent sediments has been detected crossing Lines A and C, east of fault No. 3. The thickness of the sedimentary cover above the unconformity is about 150 feet. The anticlinal feature is truncated on its eastern and western sides by steep faults (No. 3 and No. 7), and is apparently a horst. Near-surface evidence suggests that the upward movement may not have ceased, and hence that faults No. 3 and No. 7 are active faults. Likewise, the

* Multiple reflections are defined as "seismic energy which has been reflected more than once". A body of water, such as the Salton Sea, because of its shallow depth, causes multiple reflections, or nearly duplicate reflections, repeated many times at intervals equal in depth to the Sea. This created a problem in interpreting these seismic records.

block between faults No. 2 and No. 3 is probably a graben, whose relative downward movement may not have stopped to date. Along Lines C and D, there is evidence for some low-angle faulting which is atypical to the high angle faults in the rest of the area.

" Faults No. 8 and No. 12 block off another graben which has probably not reached dynamic equilibrium as yet, at least along fault No. 8. The sediments inside the graben form essentially a syncline, with a smaller anticlinal feature superimposed on it. The trace of the San Andreas fault passes through the Salton Sea, probably as fault No. 17. It is not easily identified on the records, because of the shallowness of the Sea in that area (about 10 feet or less). It is associated here with an abrupt destruction of reflection and possibly a dip change in the sediments. The latter point is not certain because of the effect of multiples /multiple reflections/.

" Line F indicates convincingly that individual shallow beds thicken seaward by a factor of two or three. One possible reason for such a thickening is the gradual downwarping of the area between the coast and station 149 on Line F. The data suggests that this downwarping movement has probably gone on in historic times, and possibly has not ceased yet.

" This evidence of movement in the Recent epoch is common to practically all the survey lines and all faults, although the data at hand does not permit one to assess the relative importance of such movements, without a more complete and thorough study. However, it is safe to invoke the recent seismological evidence and the principle of uniformitarianism in assessing the potential future movement along any or all of the indicated faults. On the other hand, it will be very difficult to assess the relative dynamism of the individual faults with any confidence without some further study, seismic or microseismological.

" As for the effect of the faulting on groundwater, it is reasonable to assume that the active faults which possess wide gouge zones, may serve as better conduits to the deeply seated brines. Geochemical and geothermal measurements may reveal the actual effect of contamination or the rates of upwelling

of the hot, briny fluids from great depths. It is beyond the scope of this study to evaluate the hydrological effects of such phenomena."

Dr. Meidav also made the following interpretations regarding sediment types from the seismic records, which were not included in his report: at station 23, clay appears to the west, while gravels and sandy clays are apparently to the east; at stations 37-43, sediments grade eastward from clay to sand and gravel; at stations 134-135, sandy clay is to the west and clay to the east; at stations 140-144, sediments grade eastward from sand to sandy clay to clay; and at station 166, sediments grade eastward from sand and gravel to clay.

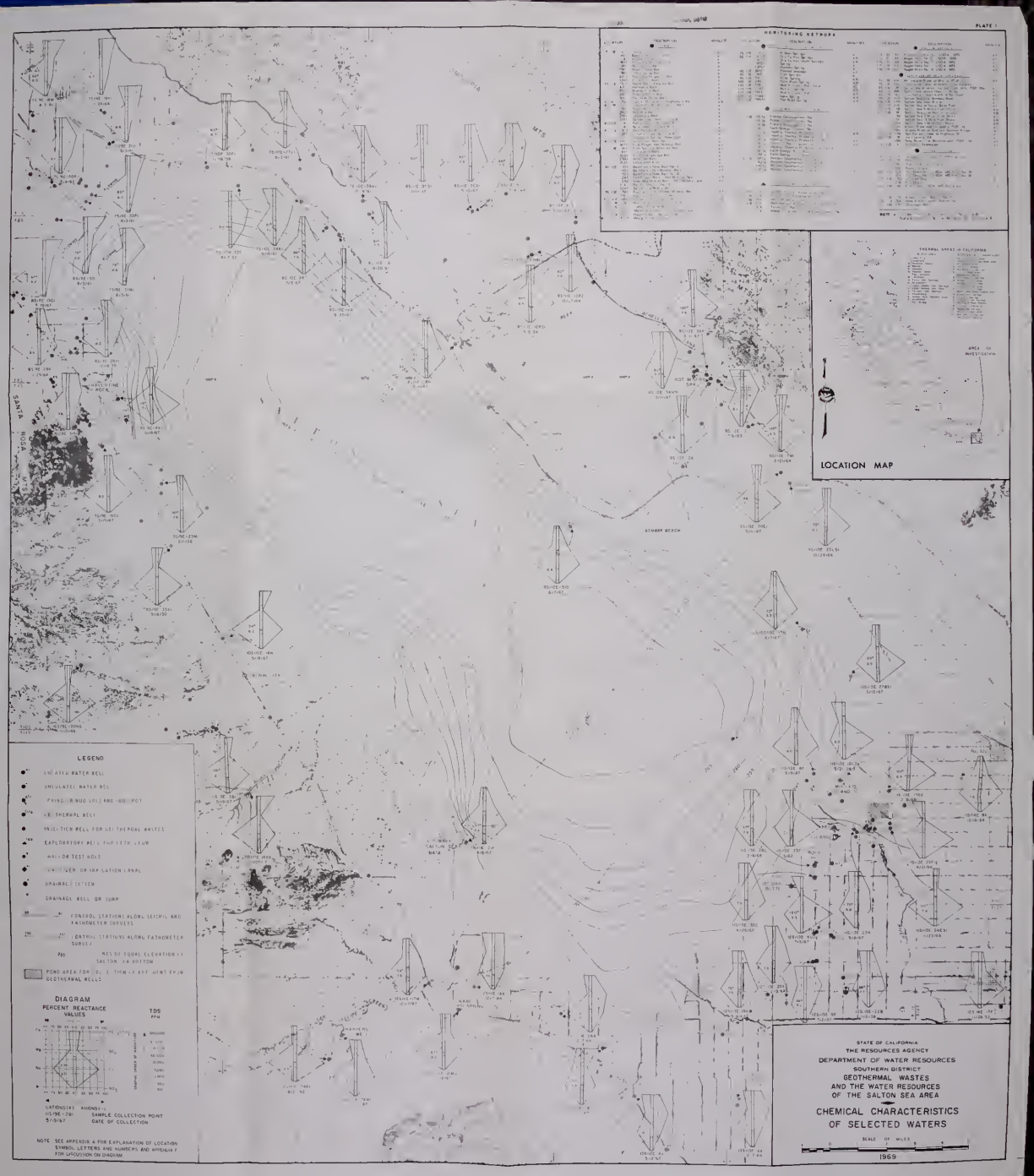
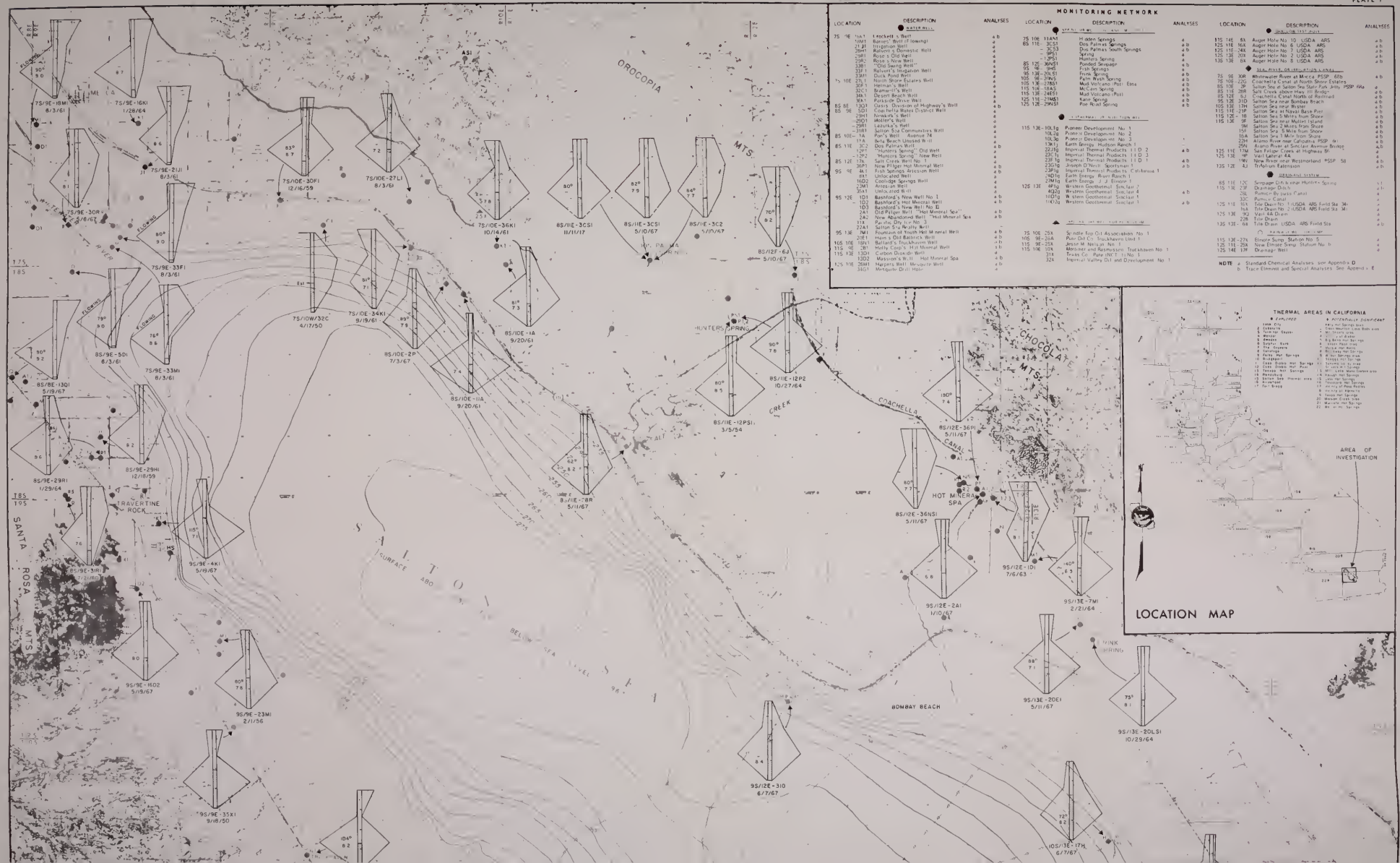


PLATE 1
MONITORING NETWORK
LOCATION MAP
THERMAL AREAS IN CALIFORNIA
AREA OF INVESTIGATION
SANTA ROSA MTS
CHOCOLATE MTS
ACHILLA LAKE
BOMBAY BEACH
LEGEND
UNCOLATED WATER WELL
GEOTHERMAL WELL
INJECTION WELL FOR GEOTHERMAL WASTES
EXPLORATORY WELL FOR FETH FLOW
DRAINAGE SYSTEM
DRAINAGE WELL OR SUMP
CONTROL STATIONS ALONG SEISMIC AND FATHOMETER SURVEYS
CONTROL STATIONS ALONG FATHOMETER SURVEY
POND AREA FOR COLLECTION OF EFFLUENT FROM GEOTHERMAL WELLS
DIAGRAM
PERCENT REACTANCE VALUES
TDS PPM
CATIONS(+) ANIONS(-)
115/96-28 SAMPLE COLLECTION POINT
5/10/67 DATE OF COLLECTION
NOTE SEE APPENDIX A FOR EXPLANATION OF LOCATION SYMBOL LETTERS AND NUMBERS AND APPENDIX F FOR DISCUSSION ON DIAGRAM
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOTHERMAL WASTES
AND THE WATER RESOURCES
OF THE SALTON SEA AREA
CHEMICAL CHARACTERISTICS
OF SELECTED WATERS
SCALE OF MILES
1969



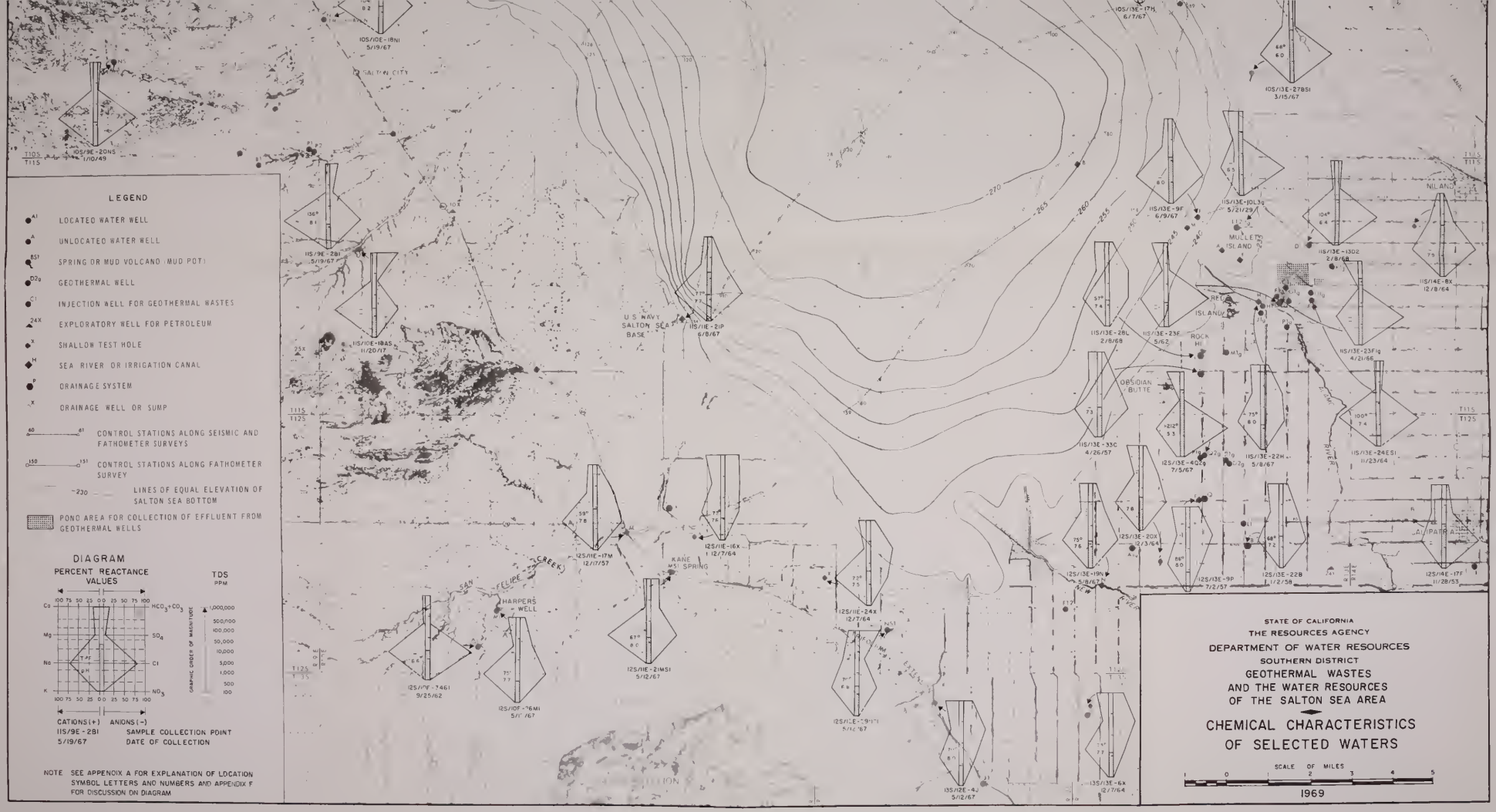
MONITORING NETWORK

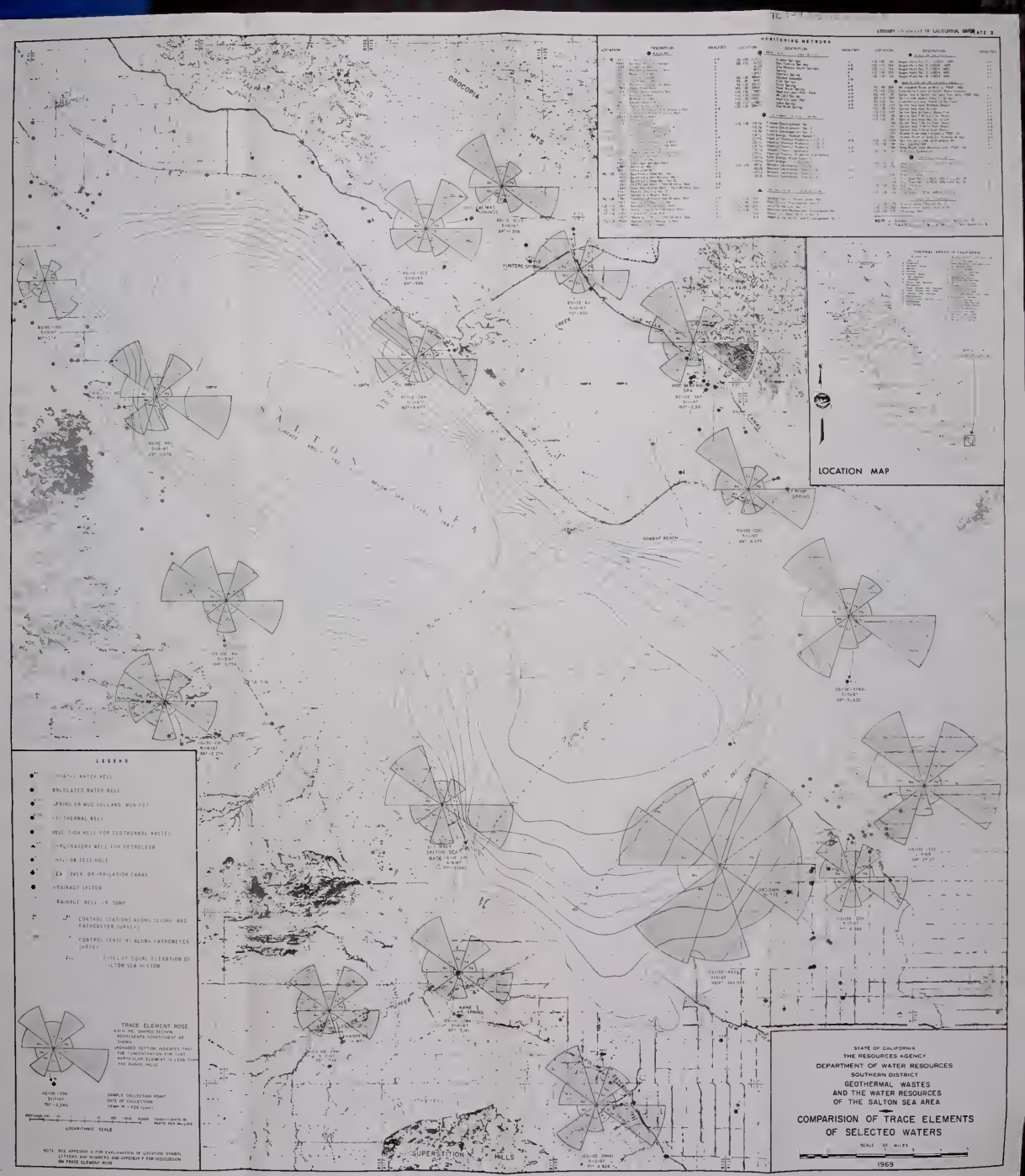
LOCATION	DESCRIPTION	ANALYSES
	WATER WELL	
7S 9E 16A1	Lockett's Well	a b
16M1	Bonert' Well (Flowing)	a
24J1	Irrigation Well	a
29H1	Rahrer's Domestic Well	a
29K1	Rose's Old Well	a
33B1	Rose's New Well	a
33E1	"Old Sewing Well"	a
33F1	Rahrer's Irrigation Well	a
33H1	Rose's Pond Well	a
7S 10E 31A1	Nash Shore Estates Well	a
33F1	Helman's Well	a
3CC1	Bramer's Well	a
3KA1	Desert Beach Well	a
3KA1	Pickacho Cross Well	a
8S 8E 13D1	Oasis Division of Highway's Well	a b
8S 9E 5D1	Coachella Water District Well	a
29H1	Nowak's's Well	a
29D1	Molter's Well	a
29B1	Lazurka's Well	a
31B1	Salton Sea Communities Well	a
8S 10E 1A	Pon's Well - Avenue 74	a
11A	Bella Beach Unused Well	a
8S 11E 3C2	Dos Palmas Well	a b
3CF1	"Hunters Spring" Old Well	a
12P2	"Hunters Spring" New Well	a
8S 12E 17A	Salt Creek Well No. 1	a
36P1	New Pflager Hot Mineral Well	a b
9S 9E 4A1	Fish Springs Artesian Well	a b
8X1	Unlocated Well	a
16D2	Coolidge Springs Well	a
23M1	Artesian Well	a
35A1	Unlocated Well	a
9S 10E 1D1	Bashford's New Well No. 1	a b
1D2	Bashford's Hot Mineral Well	a b
1D3	Bashford's New Well No. 6	a
1D4	Old Pflager Well "Hot Mineral Spa"	a
2A2	New Abandoned Well "Hot Mineral Spa"	a b
11A	Pon's Dairy Well No. 1	a
22A1	Salton Sea Realty Well	a
9N1	Fountain of Youth Hot Mineral Well	a b
20E1	Hunt's Old Bathrick Well	a b
10S 10E 15H1	Ballard's Truckhaven Well	a b
11S 10E 3B1	Holly Cole's Hot Mineral Well	a b
11S 13E 13D1	Carbon Dioxide Well	a
13D2	Masson's Well - Hot Mineral Spa	a b
12S 10E 26M1	Harpers Well - Mecquite Well	a b
34G1	Mecquite Drill Hole	a

LOCATION	DESCRIPTION	ANALYSES
	SPRING	
7S 10E 11AN1	Hidden Springs	a b
8S 11E 3CS1	Dos Palmas Springs	a b
3CS3	Dos Palmas South Springs	a b
9PS1	Spring	a
13PS1	Hunters Spring	a
8S 12E 36NS1	Ponded Seepage	a b
9S 9E 9HS	Fish Springs	a
9S 13E 20LS1	Frink Spring	a b
10S 9E 29NS	Palm Wash Spring	a b
10S 13E 27BS1	Mud Volcano (Pot) Elba	a b
11S 11E 18AS	McCain Spring	a b
11S 13E 24ES1	Mud Volcano (Pot)	a b
12S 11E 21MS1	Kane Spring	a b
12S 12E 29NS1	Poe Road Spring	a b
	THERMAL (HOT WATER)	
11S 13E 10L1g	Pioneer Development No. 1	
10L2g	Pioneer Development No. 2	
10L3g	Pioneer Development No. 3	
13K1g	Earth Energy Hudson Ranch 1	
22J2g	Imperial Thermal Products (1) D 2	a b
23C1g	Imperial Thermal Products (1) D 3	a
23F1g	Imperial Thermal Products (1) D 1	a b
23G1g	Joseph D'Nolli Sportsman 1	a b
23P1g	Imperial Thermal Products California 1	
14D1g	Earth Energy River Ranch 1	
24M1g	Earth Energy J. J. Elmore 1	
12S 13E 4P1g	Western Geothermal Sinclair 2	
4Q2g	Western Geothermal Sinclair 4	a b
10D1g	Western Geothermal Sinclair 1	a
11K1g	Western Geothermal Sinclair 1	a b
	OIL	
7S 10E 25X	Scindle Top Oil Association No. 1	
10S 9E 26A	Pure Oil Co. Truckhaven Unit 1	
11S 9E 25X	Jesse M. Nelson No. 1	
11S 11E 10X	Metzner and Rasmussen Truckhaven No. 1	
31X	Texas Co. Pure (NCT-1) No. 1	
32X	Imperial Valley Oil and Development No. 1	

LOCATION	DESCRIPTION	ANALYSES
	SURFACE WATER	
11S 14E 6X	Auger Hole No. 10 USDA ARS	a b
12S 11E 16X	Auger Hole No. 8 USDA ARS	a b
12S 11E 24X	Auger Hole No. 7 USDA ARS	a b
12S 13E 20X	Auger Hole No. 2 USDA ARS	a b
13S 13E 8X	Auger Hole No. 8 USDA ARS	a b
	SEA, RIVER, OR IRRIGATION CANAL	
7S 9E 30R	Whitewater River at Mecca PSSP 66b	a b
7S 10E 22G	Coachella Canal at North Shore Estates	
8S 10E 3N	Salton Sea at Salton Sea Sun Park Jetty PSSP 66a	a
8S 11E 28R	Salt Creek above Hwy. III Bridge	a
8S 12E 2B	Coachella Canal North of Railroad	a
9S 13E 31Q	Salton Sea near Bombay Beach	a b
10S 11E 27H	Salton Sea near Wister	a b
11S 11E 27P	Salton Sea at Naval Base Pier	a b
11S 12E 1B	Salton Sea 5 Miles from Shore	a b
11S 13E 9F	Salton Sea at Mullet Island	a b
9M	Salton Sea 2 Miles from Shore	a b
15F	Salton Sea 5 Miles from Shore	a b
16A	Salton Sea 1 Mile from Shore	a b
23H	Alamo River near Calipatria PSSP 7a	a b
25N	Alamo River at Sinclair Avenue Bridge	a
12S 11E 17M	San Felipe Creek at Highway 86	a
12S 13E 9P	Vail Lateral 4A	a
9Q	New River near Westmorland PSSP 58	a
13S 12E 4J	Trifolium Extension	a b
	DRAINAGE SYSTEM	
8S 11E 12C	Seepage Ditch near Hunters Spring	a b
11S 13E 23F	Drainage Ditch	a b
28L	Pumice By-pass Canal	a
32C	Pumice Canal	a
12S 11E 16X	Tile Drain No. 1 USDA ARS Field Sta. 34	a
9xA	Tile Drain No. 2 USDA ARS Field Sta. 34	a
12S 13E 9Q	Vail 4A Drain	a
22B	Tule Drain	a
13S 12E 6A	Tule Drain USDA ARS Field Sta	a b
	OTHER SURFACE WATER	
11S 13E 27X	Elmore Sump Station No. 5	a
12S 11E 25X	New Elmore Sump Station No. 6	a
12S 14E 17F	Drainage Well	a

NOTE a Standard Chemical Analyses see Appendix D
b Trace Element and Special Analyses See Appendix E


LEGEND
LOCATED WATER WELL
UNLOCATED WATER WELL
SPRING OR MUD VOLCANO (MUD POT)
GEOTHERMAL WELL
INJECTION WELL FOR GEOTHERMAL WASTES
EXPLORATORY WELL FOR PETROLEUM
SHALLOW TEST HOLE
SEA RIVER OR IRRIGATION CANAL
DRAINAGE SYSTEM
DRAINAGE WELL OR SUMP
CONTROL STATIONS ALONG SEISMIC AND FATHOMETER SURVEYS
CONTROL STATIONS ALONG FATHOMETER SURVEY
LINES OF EQUAL ELEVATION OF SALTON SEA BOTTOM
POND AREA FOR COLLECTION OF EFFLUENT FROM GEOTHERMAL WELLS
DIAGRAM
PERCENT REACTANCE VALUES
TDS PPM
GRAPHIC ORDER OF MAGNITUDE
CATIONS (+) ANIONS (-)
11S/9E-2B1 SAMPLE COLLECTION POINT
5/19/67 DATE OF COLLECTION
NOTE SEE APPENDIX A FOR EXPLANATION OF LOCATION SYMBOL LETTERS AND NUMBERS AND APPENDIX F FOR DISCUSSION ON DIAGRAM
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOTHERMAL WASTES
AND THE WATER RESOURCES
OF THE SALTON SEA AREA
CHEMICAL CHARACTERISTICS
OF SELECTED WATERS
SCALE OF MILES
1969
SALTON CITY
U S NAVY SALTON SEA BASE
MULLET ISLAND
NILAND
OBSIDIAN BUTTE
KANE MSI SPRING
HARPERS WELL
SAN FELIPE CREEK
ALAMO RIVER
NEW RIVER
CALIPATRIA



LOCATION MAP
HORIZONTAL NETWORK
LEGEND
UNLOCATED WATER WELL
SPRING OR MUD VOLCANO MUD POT
GEOTHERMAL WELL
INJECTION WELL FOR GEOTHERMAL WASTES
EXPLORATORY WELL FOR PETROLEUM
HOLE OR TEST HOLE
SEA LEVEL OR IRRIGATION CANAL
DRAINAGE SYSTEM
DRAINAGE WELL OR SUMP
CONTROL STATIONS ALONG SEISMIC AND PATHOMETER SURVEY
CONTROL STATIONS ALONG PATHOMETER SURVEY
LINES OF EQUAL ELEVATION OF SALTON SEA HISTORY
TRACE ELEMENT ROSE
SAMPLE COLLECTION POINT
DATE OF COLLECTION
LOGARITHMIC SCALE
NOTE: SEE APPENDIX A FOR EXPLANATION OF LOCATION SYMBOL LETTERS AND NUMBERS AND APPENDIX F FOR DISCUSSION ON TRACE ELEMENT ROSE
OROCOPIA MTS
CHOCOLATE MTS
SALTON SEA
SUPERSTITION HILLS
HUNTERS SPRING
HOT MINERAL SPA
ROMBAY BEACH
SALTON SEA BASE
OBSIDIAN BUTTE
NAME SPRINGS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOTHERMAL WASTES
AND THE WATER RESOURCES
OF THE SALTON SEA AREA
COMPARISION OF TRACE ELEMENTS
OF SELECTED WATERS
SCALE OF MILES
1969

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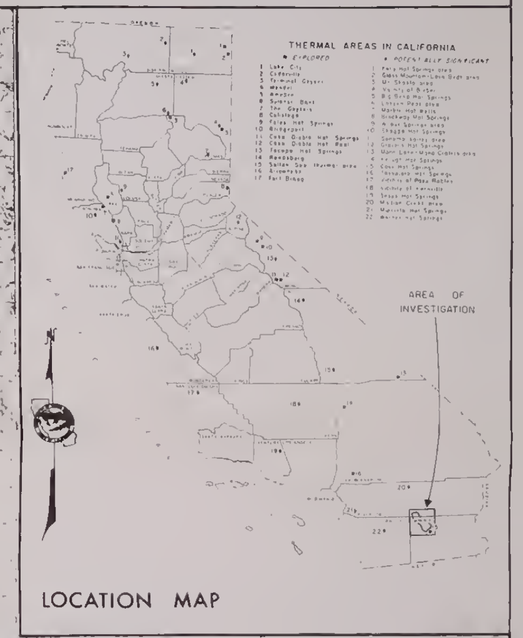
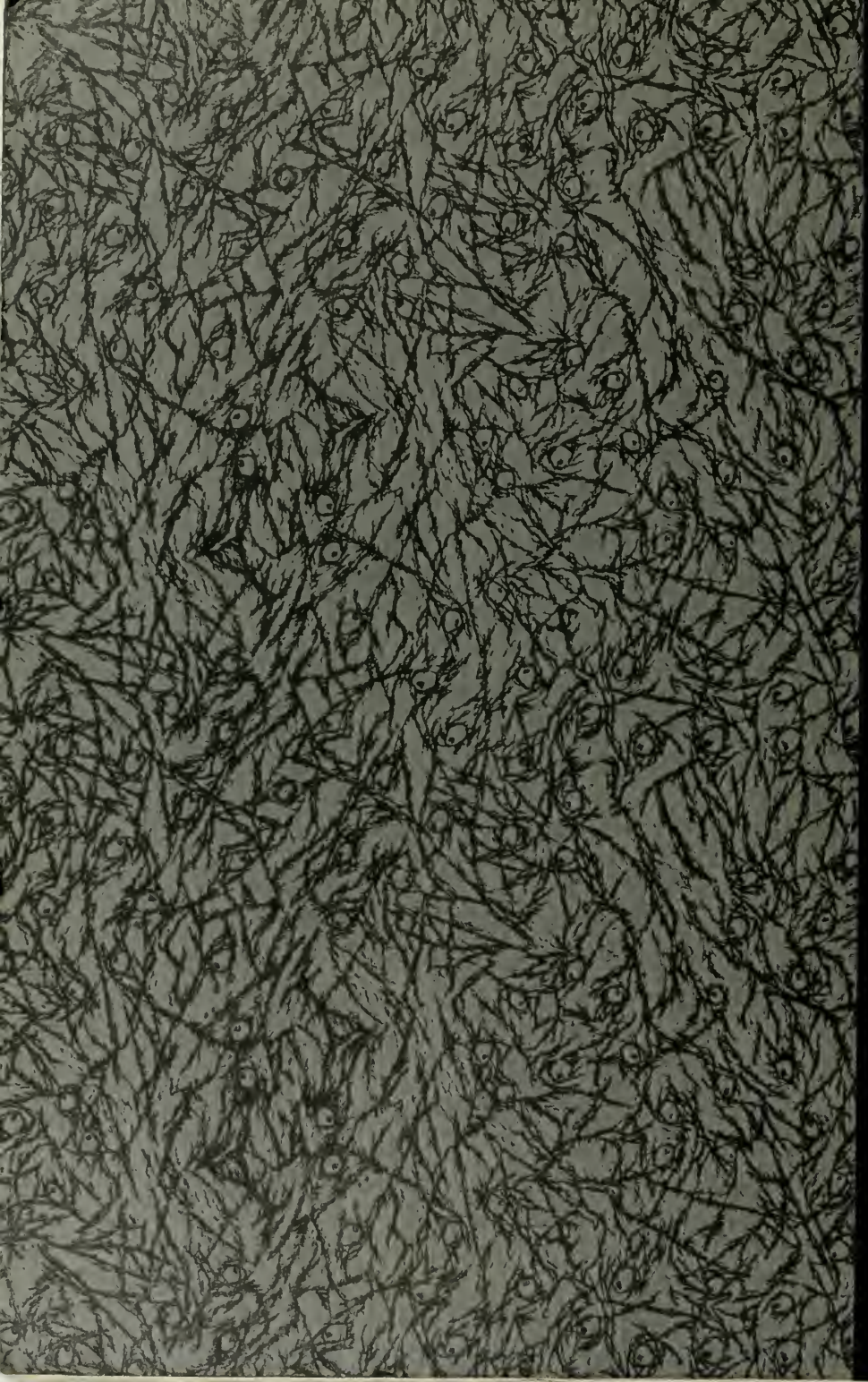
MONITORING NETWORK

LOCATION	DESCRIPTION	ANALYSES
	WATER WELL	
7S 9E-16K1	Crockett's Well	a b
-18H1	Barnes' Well (Flowing)	a
-21J1	Irrigation Well	a
-28H1	Ralvert's Domestic Well	a
-29R1	Rose's Old Well	a
-29R2	Rose's New Well	a
-33B1	"Old Swing Well"	a
-33F1	Ralvert's Irrigation Well	a
-33M1	Duck Pond Well	a
7S 10E-27L1	North Shore Estates Well	a
-30F1	Helman's Well	a
-32C1	Bramwell's Well	a
-34K1	Desert Beach Well	a
-36K1	Parkside Drive Well	a
8S 8E -13D1	Oasis Division of Highway's Well	a b
8S 9E- 5D1	Coachella Valley District Well	a
-29H1	Newark's Well	a
-29Q1	Moller's Well	a
-29R1	Lazurka's Well	a
-31R1	Salton Sea Communities Well	a
8S 10E- 1A	Pon's Well – Avenue 24	a
-11A	Bela Beach Unused Well	a
8S 11E- 3C2	Dos Palmas Well	a b
-12P1	"Hunters Spring" Old Well	a
-12P2	"Hunters Spring" New Well	a
8S 12E-17k	Salt Creek Well No 1	a
-36P1	New Fidget Hot Mineral Well	a b
9S 9E -4K1	Fish Springs Artesian Well	a b
- 8X1	Unlocated Well	a
-16D2	Coolidge Springs Well	a
-23M1	Artesian Well	a
-35X1	Unlocated Well	a
9S 12E- 1D1	Bashford's New Well No. 1	a b
- 1D2	Bashford's Hot Mineral Well	a b
- 1D3	Bashford's New Well No II	a b
- 2A1	Old Pierce Well "Hot Mineral Spa"	a b
- 2A2	New Abandoned Well "Hot Mineral Spa"	a b
-11k	Pacific Dry Ice No 3	–
-22A1	Salton Sea Realty Well	–
9S 13E- 7M1	Fountain of Youth Hot Mineral Well	a b
20E1	Hain's Old Bathrick Well	a b
10S 10E 18N1	Ballard's Truckhaven Well	a b
11S 9E- 2B1	Holly Corp's Hot Mineral Well	a b
11S 13E 13D1	Carbon Dioxide Well	a
-13D2	Masson's Well "Hot Mineral Spa"	a b
12S 10E-26M1	Harpies Well (Mesquite Well)	a b
34G1	Mesquite Drill Hole	a

LOCATION	DESCRIPTION	ANALYSES
	SPRING OR MUD VOLCANO (MUD POT)	
7S 10E-11AS1	Hidden Springs	a
8S 11E- 3CS1	Dos Palmas Springs	a b
- 3CS3	Dos Palmas South Springs	a b
- 9PS1	Spring	a
-12PS1	Hunters Spring	a
8S 12E-36NS1	Ponded Seepage	a b
9S 9E- 9HS	Fish Springs	a
9S 13E-20LS1	Frink Spring	a b
10S 9E-20NS	Palm Wash Spring	a b
10S 13E-27BS1	Mud Volcano (Pot) Elna	a b
11S 10E-18AS	McCain Spring	a b
11S 13E-24ES1	Mud Volcano (Pot)	a b
12S 11E-21MS1	Kane Spring	a b
12S 12E-29NS1	Pon Road Spring	a b
	GEOTHERMAL OR INJECTION WELL	
11S 13E-10L1g	Pioneer Development No 1	–
-10L2g	Pioneer Development No 2	–
-10L3g	Pioneer Development No 3	a
-13k1g	Earth Energy Hudson Ranch 1	–
-22J1g	Imperial Thermal Products I I D 2	a b
-23C1g	Imperial Thermal Products I I D 3	–
-23F1g	Imperial Thermal Products I I D 1	a b
-23G1g	Joseph O'Neill Sportsman 1	a b
-23P1g	Imperial Thermal Products California 1	–
24D1g	Earth Energy River Ranch 1	–
27M1g	Earth Energy J. J. Elmore 1	–
12S 13E 4P1g	Western Geothermal Sinclair 2	–
4Q2g	Western Geothermal Sinclair 4	a b
10D1g	Western Geothermal Sinclair 1	–
10D2g	Western Geothermal Sinclair 3	a b
	EXPLORATORY WELL FOR PETROLEUM	
7S 10E 25X	Spindle Top Oil Association No 1	–
10S 9E-26A	Pure Oil Co Truckhaven Unit 1	–
11S 9E-25X	Jesse M Nelson No 1	–
11S 10E-10X	Mariner and Rasmussen Truckhaven No 1	–
-31X	Texas Co Pure INCT 11 No 1	–
-32X	Imperial Valley Oil and Development No 1	–

LOCATION	DESCRIPTION	ANALYSES
	SHALLOW TEST HOLE	
11S 14E- 8X	Auger Hole No 10 USDA ARS	a b
12S 11E-16X	Auger Hole No 6 USDA ARS	a b
12S 11E-24X	Auger Hole No 7 USDA ARS	a b
12S 13E-20X	Auger Hole No 2 USDA ARS	a b
13S 13E- 6X	Auger Hole No 8 USDA ARS	a b
	SEA, RIVER, OR IRRIGATION CANAL	
7S 9E-30R	Whitewater River at Mecca PSSP 68b	a b
7S 10E-22G	Coachella Canal at North Shore Estates	–
8S 10E- 2P	Salton Sea at Salton Sea State Park Jetty PSSP 68a	a
8S 11E-26R	Salt Creek above Hwy III Bridge	a b
8S 12E- 6J	Coachella Canal North of Railroad	a b
9S 12E-31D	Salton Sea near Bombay Beach	a b
10S 13E-17H	Salton Sea near Wister	a b
11S 11E-21P	Salton Sea at Naval Base Pier	a b
11S 12E- 1B	Salton Sea 5 Miles from Shore	a b
11S 13E- 9F	Salton Sea near Mullet Island	a b
- 9M	Salton Sea 2 Miles from Shore	a b
15F	Salton Sea 5 Mile from Shore	a b
-16A	Salton Sea 1 Mile from Shore	a b
-22H	Alamo River near Calipatria PSSP 69	a b
25N	Alamo River at Sinclair Avenue Bridge	a b
12S 11E- 17M	San Felipe Creek at Highway 86	a
12S 13E- 9P	Vail Lateral 4A	a
-19N	New River near Westmorland PSSP 58	a b
13S 12E- 4J	Trifolium Extension	a b
	DRAINAGE SYSTEM	
8S 11E 12C	Seepage Ditch near Hunters Spring	a b
11S 13E 22F	Drainage Ditch	a b
28L	Pumice By-pass Canal	a
33C	Pumice Canal	a
12S 11E 16k	Tile Drain No 1 (USDA ARS Field Sta 34)	a
16A	Tile Drain No 2 (USDA ARS Field Sta 34)	a
12S 13E- 9Q	Vail 4A Drain	a
22B	Tile Drain	a
13S 13E 6X	Tile Drain (USDA ARS Field Sta)	a b
	DRAINAGE WELL OR SUMP	
11S 13E-27X	Elmore Sump Station No. 5	a
12S 11E 25X	New Elmore Sump Station No 6	a
12S 14E-17F	Drainage Well	a

NOTE a Standard Chemical Analyses See Appendix D
b Trace Element and Special Analyses See Appendix E



LEGEND
LOCATED WATER WELL
UNLOCATED WATER WELL
SPRING OR MUD VOLCANO (MUD POT)
GEOTHERMAL WELL
INJECTION WELL FOR GEOTHERMAL WASTES
EXPLORATORY WELL FOR PETROLEUM
SHALLOW TEST HOLE
SEA RIVER, OR IRRIGATION CANAL
DRAINAGE SYSTEM
DRAINAGE WELL OR SUMP
CONTROL STATIONS ALONG SEISMIC AND FATHOMETER SURVEYS
CONTROL STATIONS ALONG FATHOMETER SURVEY
LINES OF EQUAL ELEVATION OF SALTON SEA BOTTOM
TRACE ELEMENT ROSE
EACH PIE-SHAPED SECTION REPRESENTS CONSTITUENT AS SHOWN
UNSHADED SECTION INDICATES THAT THE CONCENTRATION FOR THAT PARTICULAR ELEMENT IS LESS THAN THE RADIUS VALUE
11S/13E-25N
3/17/67
70°-2,340
SAMPLE COLLECTION POINT
DATE OF COLLECTION
TEMP °F - TDS (ppm)
CONSTITUENTS IN PARTS PER MILLION
LOGARITHMIC SCALE
NOTE SEE APPENDIX A FOR EXPLANATION OF LOCATION SYMBOL LETTERS AND NUMBERS AND APPENDIX F FOR DISCUSSION ON TRACE ELEMENT ROSE
10S/10E-18N1
5/19/67
104°-3,754
11S/9E-28I
5/19/67
106°-2,258
U.S. NAVY SALTON SEA BASE 11S/11E-21P
6/8/67
77°-3,082
10S/13E-27BS1
3/15/67
68°-51,632
11S/13E-13D2
2/8/68
104°-23,271
11S/13E-22H
3/17/67
75°-2,368
OBSIDIAN BUTTE
12S/13E-4Q2q
7/5/67
>212°-266,557
KANE MS1 SPRING
12S/11E-21MS1
5/12/67
67°-3,161
HARPER'S WELL
12S/10E-26M1
5/12/67
75°-1,024
12S/12E-29NS1
5/12/67
70°-4,656
SUPERSTITION HILLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOTHERMAL WASTES AND THE WATER RESOURCES OF THE SALTON SEA AREA
COMPARISION OF TRACE ELEMENTS OF SELECTED WATERS
SCALE OF MILES
1969