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STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

BULLETIN No. 104-3

MEETING WATER DEMANDS IN THE CHINO-RIVERSIDE AREA

Appendix A: WATER SUPPLY

SEPTEMBER 1970

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Secretary for Resources
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FOREWORD

At present, about half the water supply of Southern California's South Coastal Area comes from its ground water basins. In general, extractions from this source exceed replenishment, resulting in a decline of ground water level elevations.

The Department of Water Resources, recognizing the need for information to be used to cope with the potentially detrimental effects of such a water level decline, has undertaken a series of comprehensive investigations of various plans by which Southern California's major ground water basins could be used in conjunction with possible surface water supplies. The Coastal Plain of Los Angeles County was selected as the first area to be investigated. The San Gabriel Valley was the second and the Chino-Riverside Area is the third.

Statutory authority for the Department to conduct investigations of surface and subsurface water conditions is contained in Section 226 of the California Water Code. Statutory authority for investigation of ground water conditions is also conferred under the Porter-Dolwig Ground Water Basin Protection Law (Water Code Section 12910 and those that follow) and Water Code Section 231.

In this investigation, comprehensive studies were made of the geology, hydrology, and operation-economics of the Chino-Riverside Area Ground Water Basin. The studies are summarized in Bulletin No. 104-3, which is to be published by the Department. Detailed information on the geohydrology of the area is given in this appendix; details on the operation-economics will be given in Appendix B, which will be published separately as a memorandum report.

William R. Gianelli

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State of California
July 8, 1970

TABLE OF CONTENTS

FOREWORD iii

ORGANIZATION vii

CALIFORNIA WATER COMMISSION vii

TECHNICAL ADVISORY COMMITTEE vii

ABSTRACT viii

CHAPTER I. INTRODUCTION 1

Objective 1

Scope and Conduct 1

Related Investigations and Reports 1

CHAPTER II. GEOLOGIC FEATURES 5

Water-Bearing Formations 5
- Recent Alluvium 6
- Older Alluvium 6
- Terrace Deposits 7
- Residual Soils 8

Nonwater-Bearing Formations 8
- San Timoteo Beds 8
- Undifferentiated Pre-Pleistocene Formations 8
- Basement Complex (Santiago Peak Volcanics, Metasediments, Igneous Rocks) 9

Strictures 9
- San Jacinto Fault Zone 9
- Cucamonga Fault Zone 10
- Chino Fault Zone 10
- Internal Faults 10
  - San Jose Fault 10
  - Indian Hill Fault 11
  - Red Hill Fault 11
  - "Barrier J" 11
  - Rialto-Colton Fault 11

Soils 11
- Soil Groups 12
- Infiltration Rate 12

CHAPTER III. HYDROLOGIC FEATURES 13

Ground Water Storage and Movement 13
- Supply to the Zone of Saturation 13
  - Artificial Recharge 14
  - Percolation of Precipitation 14
  - Percolation of Delivered Water 19
- Extractions from the Zone of Saturation . . 19
  - Pumpage 19
  - Extractions by Phreatophytes 22
  - Rising Water 22
- Vadose Water in the Zone of Aeration 22
- Ground Water in Storage 23
  - Volume in Storage 25
  - Change in Storage 25
- Ground Water Movement 28
  - Lytle Creek Fan 28
  - Rialto-Colton Barrier 29
  - Bloomington Area 29
  - Riverside-Arlington Area 29
  - Pomona 29
  - San Jose Fault 29
  - Red Hill Fault 30
- Study Period 30
  - Overall Length 30
  - Gaps in the Record 32
- Inventory 32
  - Supply 32
  - Disposal 46
- Evaluation 52

Water Quality 53
- Local Water 53
  - Ground Water 53
  - Surface Water 59
  - Reclaimable Waste Water 63
- Imported Water 64
  - Colorado River Water (MWD) 64
  - Local Imports 66

CHAPTER IV. FUTURE WATER SUPPLY 77

Quantity of Water 77
- Surface Water Diversions 77
- Imported Water Supplies 77
  - Availability of MWD Water 77
  - Availability of SBVMWD Water 78
- Local Ground Water 78

Quality of Water 78
- Surface Water Diversions 78
- Imported Water Supplies 79
- Local Ground Water 80

ATTACHMENTS

1: BIBLIOGRAPHY 83

2: ESTIMATES OF FUTURE INFLOW AND OUTFLOW TO THE ZONE OF SATURATION 99

FIGURES

1 Flow Chart of Geologic and Hydrologic Phases of the Investigation 2

2 Generalized Stratigraphic Column of Water-Bearing Sequence, Chino-Riverside Area . . . 7

3 Diagram Showing Generalized Hydrologic Elements of Subsurface Water 14

4 Pattern of Ground Water Pumpage in 1960 . . . 21

5 Hydrograph of State Well No. 1N/5W-17K1 (No. 1) 68

6 Hydrograph of State Well No. 1N/5W-16K1 (No. 2) 68

7 Hydrograph of State Well No. 1N/5W-28J1 (No. 3) 69

8 Hydrograph of State Well No. 1S/5W-2K1 (No. 4) 69

9 Hydrograph of State Well No. 1S/5W-16C1 (No. 5) 70

10 Hydrograph of State Well No. 1S/4W-28H1 (No. 6) 70

11 Hydrograph of State Well No. 1S/4W-29H1 (No. 7) 71

12 Hydrograph of State Well No. 2S/5W-23Q1 (No. 8) 71

13 Hydrograph of State Well No. 3S/6W-13M2 (No. 9) 72

14 Hydrograph of State Well No. 1N/6W-35A1 (No. 10) 72

15 Hydrograph of State Well No. 1S/7W-1A1 (No. 11) 73

16 Hydrograph of State Well No. 1N/7W-29R3 (No. 12) 73

17 Hydrograph of State Well No. 1S/6W-20B1 (No. 13) 74

18 Hydrograph of State Well No. 1S/8W-1D2 (No. 14) 74

19 Hydrograph of State Well No. 1S/8W-17K1 (No. 15) 75

20 Hydrograph of State Well No. 2S/8W-4P1 (No. 16) 75

21 Hydrograph of State Well No. 3S/7W-8A1 (No. 17) 76

22 Hydrograph of State Well No. 1S/8W-2B1 (No. 18) 76

23 The Zone of Saturation as a Free Body . . 27

24 Precipitation Characteristics at Ontario 31

25 Runoff Characteristics at San Antonio Creek 38

26 Frequency Distribution of Dissolved Solids Content of Ground Water in Chino Basin in 1930, 1950, 1960, and 1965 58

27 Total Dissolved Solids Pickup in Sewage in Southern California 64

28 Comparative Magnitude of 1965 Supply . . 78

29 Major Public Water Agencies and Main Water Distribution Lines in 1965 79

30 Criteria for Percolation of Precipitation in the Chino-Riverside Area 104

31 Criteria for Streambed Percolation . . . 105

32 Criteria for Artificial Recharge 106

TABLES

1 Geologic Sequence 4

2 Estimated Historical Annual Supply to the Zone of Saturation in the Chino-Riverside Ground Water Basin 15

3 Estimated Historical Annual Change in Storage of Ground Water in the Chino-Riverside Ground Water Basin 16

4 Artificial Recharge Spreading Grounds in the Chino-Riverside Area 17

5 Quantities of Water Artificially Recharged by Spreading Ground in the Chino-Riverside Ground Water Basin 18

6 Estimated Historical Annual Extractions from the Zone of Saturation in the Chino-Riverside Ground Water Basin . . . 20

7 Estimated Historical Annual Amounts of Rising Water in the Chino-Riverside Area 23

8 Specific Yield Values Assigned to Sediments in the Chino-Riverside Area 24

9 Subsurface Inflow to the Chino-Riverside Area 26

10 Estimated Historical Annual Surface Water Supply to the Chino-Riverside Ground Water Basin 33

11 Location of Selected Precipitation Stations in and Adjacent to the Chino-Riverside Area 34

12 Annual Depth of Precipitation at Selected Stations in and Adjacent to the Chino-Riverside Area 36

13 Location of Selected Stream Gaging Stations in and Adjacent to the Chino-Riverside Area 39

14 Annual Runoff at Selected Gaging Stations in and Adjacent to the Chino-Riverside Area 40

15 Diverted Water Inflow to the Chino-Riverside Ground Water Basin 42

16 Total Diverted Water Inflow and Outflow in the Chino-Riverside Ground Water Basin 43

17 Imports of Colorado River Water Discharged into Streams in the Water-Bearing Area 43

18 Fresh Water Import to the Chino-Riverside Ground Water Basin 44

19 Waste Water Import to the Chino-Riverside Ground Water Basin 46

20 Estimated Historical Annual Surface Water Use and Disposal in the Chino-Riverside Ground Water Basin 47

21 Chino-Riverside Area, Exports of Colorado River Water from the Water-Bearing Area 48

22 Subsurface Outflow from the Chino-Riverside Area 48

23 Estimates of Land Use in the Chino-Riverside Area for Survey Years Water-Bearing Area 49

24 Estimates of Average Seasonal Unit Values of Consumptive Use in the Chino-Riverside Area for the Base Period 1934-35 through 1959-60 50

25 Estimated Components of the Gaged Flow at Prado 51

26 Waste Water Effluent in the Chino-Riverside Ground Water Basin 54

27 Waste Water Production in the Chino-Riverside Ground Water Basin 56

28 Estimated Past Annual Amounts of Difference between Supply and Disposal in the Chino-Riverside Ground Water Basin 57

29 Summary of Data Used in Figure 26 59

30 Ground Water Mineral Quality 60

31 Criteria for Irrigation Waters 60

32 Selected Mineral Analyses of Surface Waters, Chino-Riverside Area 62

33 Guidelines for Mineral Quality of Waste Water for Reclamation Purposes 63

34 Normal Range of Mineral Pickup in Water Used for Domestic Purposes 64

35 Selected Mineral Analyses of Waste Water, Chino-Riverside Area 65

36 Mineral Analyses of Colorado River Water at La Verne 66

37 Selected Mineral Analyses of Canals and Conduit Water, Chino-Riverside Area 67

38 Recent Quality of Canal and Conduit Waters (1968) 67

39 Range of Mean Dissolved Solids Concentrations at Silverwood Lake for the Years 1975, 1980, and 1985 80

40 Water Quality Objectives for The Metropolitan Water District of Southern California 81

41 Estimated Inflow to and Outflow from Zone of Saturation Common to All Plans of Operation for Chino-Riverside Under Water Supply Conditions of Historical Precipitation, 1965-2015 107

PLATES

1 Generalized Geologic Map Showing Location of the Study Area and Relationship of Geomorphic Provinces

2 Geologic Map

3 Geologic Sections

4. Lines of Equal Elevation on the Effective Base of the Ground Water Reservoir

5 Location of Well Log Sections and Hydrographs

6 Well Log Section A-A'

7 Well Log Sections B-B', D-D', and E-E'

8 Well Log Section C-C'

9 Well Log Sections F-F' and G-G'

10 Well Log Sections H-H' and I-I'

11 Soil Infiltration Characteristics

12 Lines of Equal Elevation of Ground Water in Wells, Fall 1933

13 Lines of Equal Elevation of Ground Water in Wells, Fall 1960

14 Change in Elevation of Ground Water Levels in Wells, Fall 1933 - Fall 1960

15 Lines of Equal Average Seasonal Precipitation for Base Period 1934-35 Through 1959-60

16 Isosalinity Map of Extracted Ground Water in 1930

17 Isosalinity Map of Extracted Ground Water in 1950

18 Isosalinity Map of Extracted Ground Water in 1960

19 Isosalinity Map of Extracted Ground Water in 1965

20 Location of Stream and Canal Water Samples

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ABSTRACT

This Appendix presents the results of comprehensive geologic, hydrologic, and water quality studies of the Chino-Riverside Area. The Chino-Riverside Area is in Los Angeles, San Bernardino, and Riverside Counties. Contained in this report are data on the geologic properties of the basin including the volume of ground water in storage (about 12,000,000 acre-feet in 1960), the thickness and lithology of the aquifers, and the structural features within the basin that influence ground water movement. Also presented is information on the quantity and quality of the historical amounts of each of the items of water supply, use, and disposal. In addition, seasonal fluctuations in ground water levels and ground water in storage are included. / The information in this Appendix was used in the operational-economic phase of the overall investigation. The results of the investigation will provide local agencies with the operational and economic information needed for optimum management of the Chino-Riverside Area Ground Water Basin.

CHAPTER I. INTRODUCTION

This appendix presents information regarding water supplies available to the Chino-Riverside area to meet the area's water demands. These supplies include locally available ground water, local surface water, and water that could be made available from outside sources. Geology, hydrology, and water quality studies were conducted to develop this information

Objective

The objective of the geology study was twofold: (1) to determine the hydraulic properties of water-bearing material in the area and (2) to evaluate the influence of geologic phenomena on the occurrence and transmission of ground water. The objective of the hydrology and water quality studies was to evaluate the amount of water available from various sources and its present and future quality.

Scope and Conduct

The geologic information developed includes data and conclusions on the extent, thickness, and lithology of the aquifers forming the Chino-Riverside ground water basins. The hydrologic information developed in this study includes analyses of past water use and disposal for the period 1934-35 to 1959-60 and estimates of future water supplies and water quality.

The studies were primarily based on geologic and hydrologic data previously measured, compiled, and reported by the Department of Water Resources, United States Geological Survey, Los Angeles County Flood Control District, San Bernardino County Flood Control District, Riverside County Flood Control and Water Conservation District, and other agencies and individuals. An exhaustive survey was made of these basic data and reports; a limited amount of field work was undertaken to supplement basic data. In evaluating imported water supply available to the area in the future, extensive review was made of the reports published by the Department of Water Resources and The Metropolitan Water District of Southern California.

Because of the complexities of determining the extent of the possible water supply from ground water basins many short studies were conducted. The interrelationship and sequence of these studies is shown in the attached flow chart (Figure 1).

Related Investigations and Reports

The literature pertaining to the water supply in the study area comprises approximately 220 documents that include reports of government bodies at all levels, masters' theses, doctoral dissertations, articles in professional journals, glossaries, and maps. These are listed in the bibliography (Attachment 1) by publisher. Unpublished papers are included in the alphabetic listing by principal author.

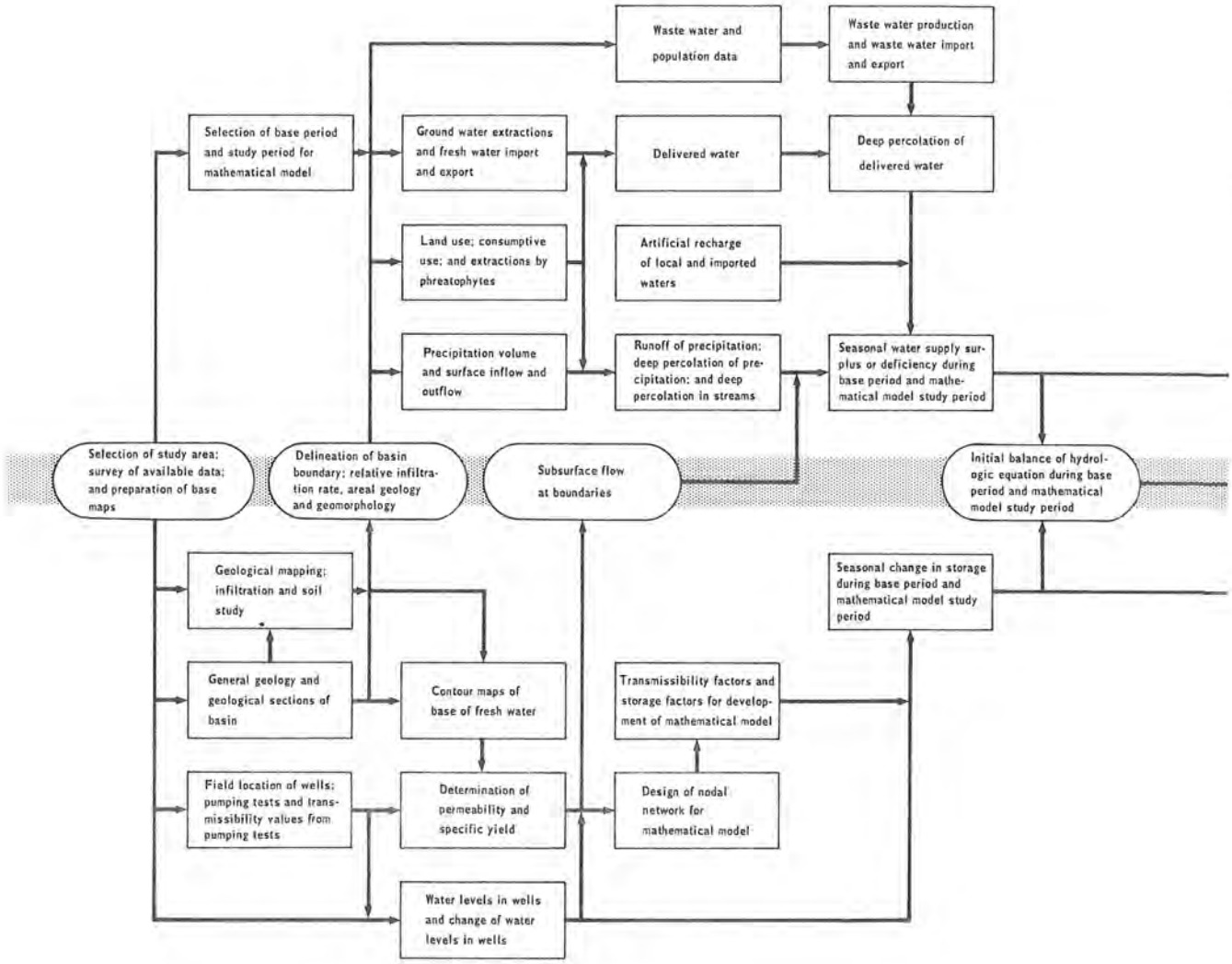
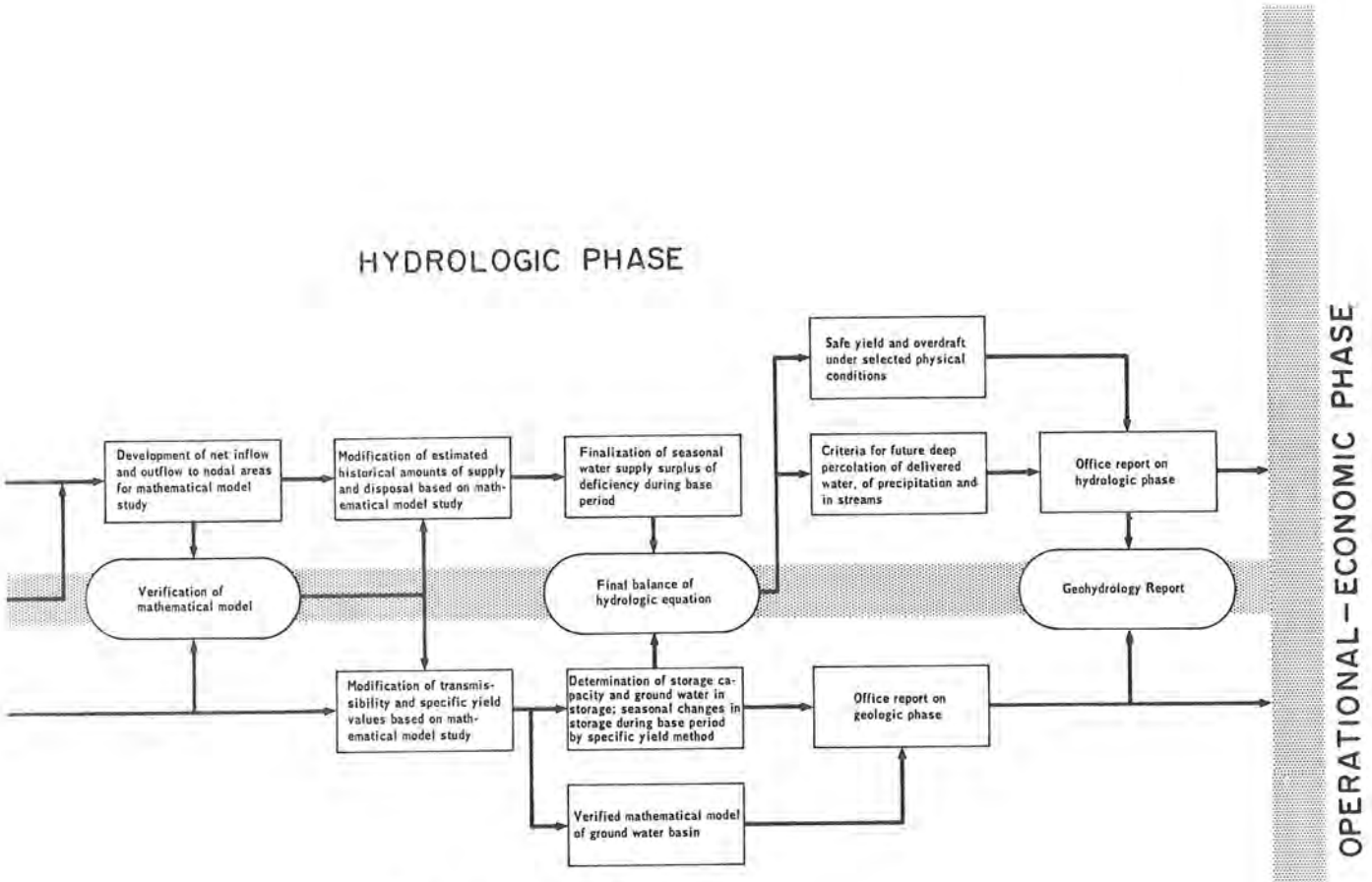


Figure I — FLOW CHART OF GEOLOGIC AND



HYDROLOGIC PHASES OF THE INVESTIGATION

TABLE 1

GEOLOGIC SEQUENCE

System or Period	Series or Epoch	Estimated ages of time boundaries in millions of years
Quaternary	Recent	
	Pleistocene	1
Tertiary	Pliocene	
		10
	Miocene	
		25
	Oligocene	
		40
	Eocene	
		60
	Paleocene	
Cretaceous	Upper (Late) Lower (Early)	
		125
Jurassic	Upper (Late) Middle (Middle) Lower (Early)	
		150
Triassic	Upper (Late) Middle (Middle) Lower (Early)	
		180

CHAPTER II. GEOLOGIC FEATURES

The Chino-Riverside area lies within a region of large-scale crustal disturbance at the intersection of the west-trending Transverse Range and the northwest-trending Peninsular Range. The Transverse Range extends from Point Conception to Coachella Valley; the Peninsular Range extends from the western and southern parts of the study area into Baja California (Plate 1). Major active faults associated with these trends bound four distinct blocks within the area. These blocks are the upraised San Gabriel, Chino, and Santa Ana Blocks, and the downdropped Perris block (Dudley, 1936). These blocks correspond to present-day surface features (Plate 1). The San Gabriel Mountains are bounded on the south by the Cucamonga fault system. The Chino-Puente-San Jose Hills region is bounded on the east by the Chino fault. The Santa Ana Mountains are bounded on the east and separated from the Chino block by the curving Elsinore-Whittier fault system and the lower-lying plains and hills south and east of these uplifted areas (Plate 1).

The San Gabriel block was the most highly elevated, the Santa Ana block less so, and the Chino block least of all. During the latter part of the Quaternary epoch, (Table 1) alluvium from these blocks washed into the low lying areas of the downwarped margins of the Perris block. This accumulated alluvium now forms the main ground water reservoir of the Chino-Riverside area.

Water-Bearing Formations

The distribution of the formations in the area is indicated on Plate 2. To accentuate their hydraulic properties, they are divided into water-bearing and nonwater-bearing formations. The latter are further differentiated as (a) consolidated stratified rocks, and (b) metamorphic and igneous rocks of the basement complex. Water-bearing formations underlie the central valley, called the Chino Plain in this report, with nonwater-bearing formations coming to the surface in the hills and highlands that make up the watersheds (Plate 3). The formations are described in reverse stratigraphic order, the youngest formations first.

Plate 4 shows, in a generalized fashion, the configurations of the boundary between water-bearing formations and nonwater-bearing formations. The distinction between water-bearing and nonwater-bearing formations is based primarily on yield; water-bearing formations are those that (a) can deliver 100 gallons or more per minute (gpm) to a normally developed well, or (b) are potentially capable of doing so, i.e., alluvium above the water table. Acceptable water quality was not a requirement of water-bearing materials.

In the alluvial formations of the central Chino-Riverside area, the base of the deepest useful permeable

horizon was considered to be the effective base of the water-bearing material. Other permeable formations, the San Timoteo beds and certain tertiary sandstones are excluded from the water-bearing category.

The water-bearing formations of the Chino-Riverside area, as shown on the geologic map (Plate 2), are younger alluvium that includes dune sands, older alluvium, terrace deposits, and residuum. The stratigraphic sequence of the water-bearing formations is shown in Figure 2. The general character of these formations is known from drillers' logs of representative wells (Plate 5). These data have been used to construct diagrammatic sections of the water-bearing formations (Plates 6, 7, 8, 9, and 10).

Recent Alluvium

Relatively unweathered sand, gravel, and silt in deposits up to 150 feet thick occupy streambeds, washes, and other areas of recent sedimentation. Oxidized particles tend to be flushed out of the sediments during transport. Thus recent alluvium is commonly light yellow, brown or gray. The alluvium consists of rounded fragments derived from direct erosion of bedrock, from reworked older alluvium and from the mechanical breakdown of larger fragments within the alluvium itself.

During transport, the larger the fragment the less distance it travels. The northern part of the Chino Plain, close to the foot of the San Gabriel Mountains, therefore, shows an alluvium of coarser material mixed with some clay and sand. Farther from the mountain front the slope of the land is gentler and the particles are of smaller size. The alluvium here is in layers of gravel, sand and silt. The finest particles settled farthest from the mountains, near Prado Dam.

In most places the younger alluvium, that is highly permeable, is above the water table. Water percolates readily through this layer.

The sand dunes in the east-central part of the Valley floor were formed as a result of the "Santa Ana" wind storms, carrying sand winnowed from alluvial deposits lying to the northeast of the dune area. The spread of irrigated agriculture and the planting of windbreaks in the Valley, however, have probably acted to stabilize the dunes. The dune sand has been grouped with the recent alluvium because of its similar water-bearing characteristics and is not differentiated on the geologic map.

Older Alluvium

A thick section of stabilized, moderately to deeply weathered alluvium of Pleistocene Age unconformably underlies the recent alluvium. The older alluvium, distinguishable by its red-brown or brick-red color, does not form the bedload of existing drainage systems. Beneath the older alluvium are formations that range in age from Pleistocene to Precambrian, in an unconformable sequence. Around the edge of the Chino Plain the alluvium layers can be readily distinguished, but in many places in the central part of the valley, the base of the older alluvium could not be defined. This alluvium may grade into similar deposits of Pliocene age. Thick bodies of clayey, fine-grained sediment are interstratified with the more permeable alluvium in the central part of the study area (Plates 6 through 10), and the total depth of unconsolidated, valley-filling material is unknown. Even though more than 1,100 feet of fresh water-bearing older alluvium has been encountered in water wells southwest of Fontana, the average thickness is estimated to be not more than 500 feet.

The older alluvium was deposited under conditions similar to those at

SYSTEM	SERIES	FORMATION	LITHOLOGY	MAXIMUM THICKNESS	DESCRIPTION
QUATERNARY	RECENT	YOUNGER ALLUVIUM AND DUNE SANDS		200+	Unconsolidated stream and wind-transported material in streambeds and on open slopes.
	UPPER PLEISTOCENE	OLDER ALLUVIUM		1,100+	Semiconsolidated fan and floodplain type deposits underlying Chino Plain. Coarser-grained toward San Gabriel Mountains. Equivalent to terrace deposits in age.
		TERRACE DEPOSITS		100 ±	Semiconsolidated veneer on bedrock benches
		RESIDUUM		50 ±	Weathered, decomposed bedrock
TERTIARY	UPPER PLIOCENE	SAN TIMOTEO BEDS		2,000+	Folded, faulted sedimentary rocks of similar origin to alluvium above.

LEGEND

Gravel | Sand | Silt | Clay | Bedded and consolidated material

Figure 2 – **GENERALIZED STRATIGRAPHIC COLUMN OF WATER-BEARING SEQUENCE, CHINO–RIVERSIDE AREA**

present; this alluvium is made up of boulders, gravel, sand, silt, and clay derived largely from basement rocks in the San Gabriel Mountains. Other highlands supplied much smaller amounts of detritus in local areas, mostly in the southern part of the area. The accumulation of the older alluvium began, probably in middle-Pleistocene time, when the present valley first began to form south of the rising San Gabriel structural block.

The combined effects of sorting and weathering give the older alluvium in the central part of the area the lowest clay content and the highest well yields and transmissibility of the alluvium of this area. Transmissibility values range from less than 100,000 gallons per day per foot (gpdpf) near the bedrock to 600,000 gpdpf near the center. Yield values of 500 to 1,000 gallons per minutes are common. In the southern part of the Chino Plain, where the sediments tend to be more clayey, wells generally yield between 100 and 500 gpm.

Terrace Deposits

The terrace deposits consist of dark red and red-brown alluvial material resting on planed-off bedrock surfaces above stream level. Terraces on the north side of the valley are on the upthrown side of the Cucamonga

fault. As the San Gabriel Mountain fans grew, the Santa Ana River channel was shifted southward. In the southern part of the basin, the river waters incised and eroded the land, until the river channel was below the base of the terraces.

Generally the terrace deposits lie flat and resemble the older alluvium in lithology. They were probably deposited during the early stages of basin filling, before the present structure and stream pattern of the basin was fully established. They are the same age as the material that comprises the lower levels of the older alluvium.

Because the terrace deposits, by definition, consist of alluvium resting on bedrock above stream level, they are mainly above the water table and do not store significant amounts of water.

Residual Soils

In the areas of low relief where there is little erosion, in-place, deep weathering of basement and consolidated sediments has resulted in extensive residual formations which locally store and yield water. Structures of the disintegrated and decomposed parent rock are preserved in the residuum and grade into those of the underlying fresh bedrock.

The residual materials are marked by oxidation colors or red and brown. Because of their relatively high clay content and generally thin and disconnected occurrence, they are inferior to transported and reworked alluvium as a source of water to wells. In the vicinity of Norco, however, the major part of the water supply is drawn from a horizon of decomposed granite from 20 to 80 feet thick (Plate 3, Section Z-Z') having an average specific capacity of 2.5 gallons per minute per foot of drawdown.

Nonwater-Bearing Formations

The nonwater-bearing formations of the Chino-Riverside area include continental deposits of late Pliocene to middle-Pleistocene age, marine sedimentary and volcanic strata of late Cretaceous to late Tertiary age, and crystalline igneous and metamorphic rocks of the basement complex. Pervious strata or fracture zones in these formations may yield water to wells in local areas. In general, however, the storage capacity is inadequate for sustained production. Otherwise, these rocks are essentially impervious or are unfavorably located with respect to the water table.

Below a certain level of the lower part of the alluvium, low transmissibility and poor water quality, has been observed. This zone is, therefore, considered to be nonwater-bearing.

San Timoteo Beds

San Timoteo beds in the easternmost part of the area belong to the lower levels of a thick sequence of deposits in which fossils of middle to late Pliocene age have been found (Frick, 1921; Eckis, 1934). These beds resemble the older alluvium of the Chino Plain, but are cut by numerous faults and are sharply folded, as a result of the mid-Pleistocene mountain building (Shuler, 1953). Wells drilled into these beds in Reche Canyon are generally unsuccessful. San Timoteo beds form a major ground water reservoir in the adjoining San Bernardino Valley.

Undifferentiated Pre-Pleistocene Formations

In the western part of the area (Plate 2), consolidated sedimentary and volcanic rocks ranging in age from late Cretaceous to Pliocene

consist of well-stratified marine sandstones, shales, and conglomerates, and interlayered lava flows (Tv). According to Yerkes (1965, p. 14), this sequence reaches a total stratigraphic thickness of more than 24,000 feet in the Puente Hills and is downwarped more than 8,000 feet below sea level in the Prado Dam area. Wherever mapped, these strata are folded and faulted, and in most places dip from 20 to 60 degrees. Near Norco, one successful well, which yields mildly sulfurous water, has been developed in Miocene rocks; but in general, the strata, where they are accessible to drilling, lack the permeability and water quality required of water-bearing formations.

Basement Complex (Santiago Peak Volcanics, Metasediments, Igneous Rocks)

The basement complex consists of deformed and recrystallized metamorphic rocks that have been invaded and displaced in places by huge masses of granite and related igneous rocks. The intrusive granitic rocks, which make up most of the basement complex, were emplaced about 110 million years ago in the late Middle Cretaceous (Larsen, 1958). These were subsequently uncovered by erosion, especially in the San Gabriel Mountains and in the uplands of the Perris block (Plate 1). They have been the major source of detritus to the younger sedimentary formations, in particular, to the water-bearing deposits of the Chino Plain.

Structures

Faults are one of the principal agents in the development of the landscape and in the restriction of subsurface flow within the Chino-Riverside area. The ground water basin is bounded by major fault systems, along which the hills and mountains have been uplifted. Other faults within the ground water reservoir that markedly affect the flow of ground water are detectable mainly by the discontinuities in water level elevations. In the south and southeastern sides of the area, the water-bearing formations pinch out against the basement complex in the central highlands of the Perris Block.

The downfolding of the Perris block, which began in Cretaceous time, is one of the principal factors in the origin of the ground water reservoir. Although most of the smaller folds in the area are confined to the pre-Pleistocene rocks, young folds associated with the recently active faults are of local importance in determining the pattern of ground water flow within the aquifer.

San Jacinto Fault Zone

In the alluviated stretch between the San Gabriel Mountains and Reche Canyon, the westernmost discernible shear plane is found on the northwest-trending San Jacinto Fault zone. This plane was chosen as the study area boundary of the Chino-Riverside area.

The San Jacinto Fault stems from the San Andreas Fault on the north side of the San Gabriel Mountains. Both fault systems show similar numerous shear planes of horizontal displacement. Because of the intensity and relative youth of these displacements, fault gouge and cementation along the shear planes form impediments to ground water movement in all but the most recently deposited alluvium.

The northern part of this boundary is a buried extension of the San Jacinto Fault zone called "Barrier E" by Dutcher and Garrett (1963, page 70). Little evidence exists to suggest that it extends north of the point where it is intersected by "Barrier J" (Plate 5). Southeastward from the point of intersec-

tion "Barrier E" is evident as a distinct subsurface feature which effectively retards the movement of ground water.

About halfway across the valley, "Barrier E" appears to come together with several other branches of the San Jacinto Fault system, to form a single (or perhaps double) shear plane, marked by surface traces such as low scarp lines, benches, and ridges, including the well-known Bunker Hill Dike (Mendenhall, 1905; Eckis, 1934; Dutcher and Garrett, 1963, p. 37). This southern segment of the fault greatly retards the movement of ground water, except where the Santa Ana River channel crosses "Barrier E" in Colton Narrows.

Cucamonga Fault Zone

The front of the San Gabriel Mountains is marked by a complex, interbranching zone of shear planes, called the Cucamonga Fault (Plate 5). In the western part of the area, the mountain block on the north side of this fault has been uplifted nearly 1,000 feet and at the east end as much as 5,000 feet, where it intersects the San Jacinto Fault zone (Eckis, 1934,p.74).

In most places the Cucamonga Fault planes dip northward under the mountain block. The slope indicates reverse movement, with the upthrown side of the fault overriding the valley block. Much of the movement on the fault system dates from post-Middle Pleistocene time. The presence of low but distinct escarpments in alluvium along the trace of the fault system is evidence that uplift is continuing (Burnham, 1953, p. 28; Eckis, 1934, p. 74). The map presented by Hill (1954, Chapter IV, p. 6) shows that the Cucamonga Fault zone is a continuation of the high-angle reverse Sierra Madre Fault zone in San Gabriel Valley.

Chino Fault Zone

Along the western side of the valley the Chino and Santa Ana blocks override the Perris block. The Chino Fault is an extension of the Elsinore-Whittier Fault zone. Where the latter swings westward, the Chino Fault diverges northward (Hill, 1954, Ch. IV, p. 6) but its northern terminus is not known. In places, this major break shows high-angle, reverse components. In these places, the difference in elevation of the blocks is as much as 21,000 feet (Yerkes, 1965, p. A4). The Chino Fault zone passes through bedrock exposures along the flanks of the Chino and Puente Hills (Troxel, 1954, p. 16). Since the Puente Hills are neither permeable nor contain any significant amount of ground water, the effect of the Chino Fault on the migration of ground water into the watershed is not significant.

Internal Faults

Two groups of fault breaks exist in the floor of the Chino-Riverside area. One group probably relates to the east-west trending Cucamonga Fault zone. The other is associated with the northwest-trending San Jacinto Fault zone. Their effects on the flow of ground water depend on their location and permeability more than on their magnitude of displacement.

San Jose Fault. Elevations on the effective base of ground water in the Pomona-Claremont area (Plate 4) clearly demonstrate the presence of a major structural discontinuity from San Jose Wash to the Cucamonga Fault zone.

Although the surface of the recent alluvial fan seems to be undisturbed, the base of water-bearing materials is sharply displaced. Markedly different trends were observed on op-

posite sides of the well-defined plane of the San Jose Fault. Near Pomona, the northwest side of the fault is downdropped about 250 feet. In the vicinity of Claremont, it is as much as 400 feet higher than its southeast side. Further north, beyond the intersection of the Indian Hill Fault, the northwest scarp is as much as 500 feet higher than the southeast face (Plate 3 , Section X-X', and Plate 9 , Section F-F'). Hydrologic data (Chapter IV) suggest that the fault cuts all but the most recent sediments.

Indian Hill Fault. On the north side of Claremont a low rounded knoll formed by older alluvium marks the upthrown side of the Indian Hill Fault. This fault can be followed in the subsurface due west from its intersection with the San Jose Fault to the boundary of the area, in the alluviated saddle north of the San Jose Hills (Plate 2). Water level disparities and displacements in the base of the ground water reservoir indicate that the fault extends more than six miles into the San Gabriel Valley. In the valley, the same fault is called the Lone Hill-Way Hill Fault (Department of Water Resources, Bulletin No. 104-2, 1966, p. 47 and Plate 11) because of two uplifted hills to the north. Unlike most of the other faults in the Chino-Riverside area, the blocks on either side of the Indian Hill Fault do not have sharply contrasting structures. Except where the fault dies out at its western end, its north side shows a consistent upthrow of between 300 to 400 feet. It seems likely, therefore, that the Indian Hill Fault is a simple gravity fault which was caused by the recent upward movement of the basement on the north (Plate 3, Section X-X', and Plate 9, Section F-F').

Red Hill Fault. East of Upland, a rounded knoll of reddish, older alluvium projects above the valley floor. Eckis (1928, p. 245) believed this hill (Red Hill) to be an erosional remnant of a once extensive terrace. Subsurface data, however, (Plates 5 and 9, Section G-G') clearly indicate that the hill is the result of upward movement on the north side of a peculiar, flap-like fault that curves around the base of the hill. In the subsurface, both ends of the fault strike upslope toward the Cucamonga Fault zone.

"Barrier J". Where Barrier J intersects Barrier E and the Rialto-Colton Fault, (Plates 2 and 4) the base of fresh water is displaced upward about 100 feet. Despite the name given by Dutcher and Garrett (1963), Barrier J is not an impediment to ground water flow. Ground water cascades over the barrier. The barrier has no surface expression, but is believed to be a normal fault caused by uplift of the San Gabriel block.

Rialto-Colton Fault. The Rialto-Colton Fault trends approximately parallel with the San Jacinto fault zone and is probably of similar age and origin. Its subsurface effect is seen in the low rounded hill in the upper middle four sections of T1S, R5W. The east side of the hill appears to have been moved toward the northwest. Southeast of the low hill, as much as 450 feet of downthrow on the east side is shown on the base of the ground water reservoir (Plate 4). The net vertical separation, however, is much less or even reversed elsewhere, a common feature along strike-slip faults. Subsurface data suggest that what seems to be a southern segment of the fault is actually a parallel branch and that a gap exists between the branches north of Slover Mountain.

Soils

Except where erosion is active, rocks and sediments in the Chino-Riverside

area are covered by a surface layer of soil. Because direct precipitation and some runoff and applied water must pass through the soil layer to reach the zone of saturation, the character of local soils in the area is of great hydrologic importance.

Soil Groups

Soils in the Chino-Riverside area are mainly sandy or sandy-loam with a low humus content and poorly to moderately developed profiles. The U. S. Department of Agriculture divides soils into four groups that reflect the geologic formations from which they evolved:

(1) residual soils, developed in situ on bedrock formations;

(2) secondary soils, developed on older alluvium;

(3) recent alluvium and floodplain deposits;

(4) windlaid deposits.

Unweathered riverwash deposits and rough, broken, and stony land in areas of outcropping bedrock are considered to be soil-free.

Infiltration Rate

The most important hydrologic property of soils is the rate at which water enters the soil and passes through the zone of aeration. Factors affecting the infiltration rate are the slope and relief of the surface and the physical properties of the soil, such as its structure, texture, wettability, and permeability. The infiltration rate is also affected by the antecedent moisture condition of the soil.

Plate 11 shows the soil types in the Chino-Riverside area, grouped by infiltration rates. The infiltration rate represents the relative ease with which various soils absorb and transmit water impinging on their surface. The groups are:

High (over 2 inches per hour)
Medium (1 to 2 inches per hour)
Low (less than 1 inch per hour)

Most of the soils in the Chino-Riverside area were assigned infiltration rates by the Soil Conservation Service of the U. S. Department of Agriculture by examining the physical properties of the soils. These examinations did not include consideration of antecedent soil moisture conditions, which vary with season and place. Infiltration rates, for soils not assigned a rating by the SCS, were assigned by soils specialists of the Department of Water Resources.

Infiltration is enhanced by cultivation and soil conditioners. The nature of the soil itself may change with a change in vegetation.

Soils on the dune sands and the alluvial fan materials have infiltration rates of up to six inches per hour. Infiltration rates in soils developed from younger alluvium are more variable and tend to reflect the clay content. Residual soils and the soils developed on older alluvium, including terrace deposits, have low infiltration rates. These soils have a relatively high content of residual clay and other fine-grained weathering products which tend to reduce porosity. Clay-rich soils, developed on mudflat deposits, may accept only a little over 0.1 inch per hour.

CHAPTER III. HYDROLOGIC FEATURES

The hydrology of the Chino-Riverside area is typical of a California coastal basin characterized by dry summers and moist winters. Most of the streams in the area are ephemeral or intermittent. From the point of view of the ultimate consumer, most of the area's water supply is derived from pumped ground water. However, the ground water resulted in nature from percolation of runoff and precipitation and underflow from adjoining areas. The hydrologic cycle is an endless chain consisting of the links of evaporation, precipitation, percolation, extraction, then back to evaporation and transpiration. This chapter describes the cycle within the Chino-Riverside area. Since ground water is relatively of greatest interest to most water-oriented people within the basin, this subject is stressed.

Ground Water Storage and Movement

Figure 3 depicts schematically the zones in which the subsurface waters of the ground water basins appear. Subsurface waters can be broadly classified into two groups, according to the zone in which they are found; vadose water in the zone of aeration, and ground water in the zone of saturation. The zone of aeration can be further broken down into three different zones: a belt of soil water extending downward from the ground surface from which water is subject to removal by evaporation and by plants, an intermediate belt of free-draining water between the soil water and the capillary fringe; and a capillary fringe immediately overlying the zone of saturation in which water is suspended above the actual water table by capillary tension. The thickness of the capillary fringe depends upon the texture of the water-bearing material and may be virtually nonexistent in coarse-grained, highly porous material. The depth of the soil water depends upon seasonal moisture conditions and the character of local soil and vegetation. If the belt of soil water and capillary fringe are not contiguous, an intermediate belt is present and will expand or contract as the water table rises or falls and as the soil moisture condition changes. This intermediate belt, which is present in the Chino-Riverside area, exists in basins where the zone of saturation lies some distance below the ground surface. Although subsurface water in both the zones of aeration and saturation will be described, emphasis will be placed on the latter because of its importance to the operation of the basin.

Supply to the Zone of Saturation

Supply to the zone of saturation is comprised of waters which percolate below the belt of soil water and eventually reach the zone of saturation and subsurface inflow.

In the Chino-Riverside area, effects of water passing the belt of soil are

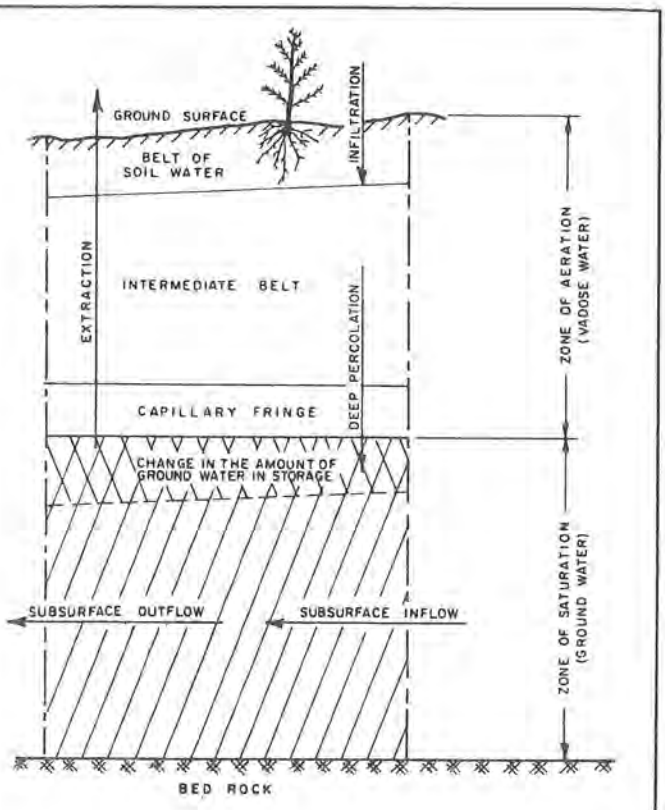


Figure 3

DIAGRAM SHOWING
GENERALIZED HYDROLOGIC ELEMENTS OF SUBSURFACE WATER

felt in the zone of saturation within one year; it was therefore assumed that percolation to the zone of saturation was equal to the percolation to the intermediate belt. Components of percolation, as considered in this study, are artificial recharge, percolation of precipitation, percolation in stream channels, and percolation of delivered water. The amount of percolation of each item, except artificial recharge, was not directly measured, but was determined as the residual of the amount of surface water supply and disposal.

The average seasonal total supply to the zone of saturation during the base period was estimated to be about 287,400 acre-feet. During this period, supply varied from a minimum of 180,100 acre-feet in 1950-51 to a maximum of 508,700 acre-feet in 1940-41. Table 2 shows the seasonal amounts of surface supply to the zone of saturation. The seasonal total supply to the zone of saturation is summarized in Table 3.

Artificial Recharge. Two major types of recharge facilities are used in the Chino-Riverside area. The first type is located at various points throughout the basin and consists of abandoned gravel pits which have been converted into recharge basins. The second type consists of a complex of levees, interconnecting ditches, and small shallow basins generally located in the alluvial fan just south of the San Gabriel Mountains.

Records of the amount of water spread in some of the major artificial recharge basins were available during the study period, while records of the amount of water spread in the majority of the smaller spreading grounds were generally unavailable. Table 4 presents a list of all the fresh water artificial recharge spreading grounds in the Chino-Riverside area. The amounts of water spread in the major spreading grounds during the base period are presented in Table 5.

Average seasonal water artificial recharge in the Chino-Riverside area during the base period amounted to about 18,300 acre-feet. Seasonal amounts of water used for artificial recharge varied during the base period from a low of 2,100 acre-feet in 1950-51 to a high of 56,500 acre-feet in 1940-41. Approximately 98 percent of the total artificial recharge was in the alluvial fan area just south of the San Gabriel Mountains. The total seasonal amounts of water spread in the Chino-Riverside area are shown in Table 2.

Percolation of Precipitation. Average seasonal percolation of precipitation in the Chino-Riverside area during the base period was about 96,400 acre-feet and varied from a maximum of 302,200 acre-feet in 1940-41 to a

TABLE 2

ESTIMATED HISTORICAL ANNUAL SUPPLY TO THE ZONE OF SATURATION IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE-FEET

SEASON(A)	ARTIFICIAL RECHARGE	PERCOLATION OF DELIVERED WATER(B)	PERCOLATION OF PRECIPITATION(C)	TOTAL
1934-35	20.5	116.3	82.5	219.3
1935-36	11.4	142.4	59.3	213.1
36-37	46.1	122.0	269.2	437.3
37-38	50.1	133.8	273.1	457.0
38-39	12.0	119.0	90.3	221.3
39-40	14.4	136.8	68.3	219.5
1940-41	56.5	111.7	302.2	470.4
41-42	7.4	128.7	31.6	167.7
42-43	49.2	137.7	202.4	389.3
43-44	28.9	133.9	124.6	287.4
44-45	19.6	146.0	74.9	240.5
1945-46	16.9	153.7	49.3	219.9
46-47	16.3	165.3	66.1	247.7
47-48	3.3	156.3	22.9	182.5
48-49	3.2	164.2	27.1	194.5
49-50	4.0	133.6	39.9	177.5
1950-51	2.1	142.5	9.4	154.0
51-52	22.1	162.2	217.6	401.9
52-53	4.2	176.6	28.8	209.6
53-54	10.0	165.0	90.9	265.9
54-55	6.5	176.0	32.0	214.5
1955-56	7.6	200.1	77.2	284.9
56-57	6.1	172.0	38.9	217.0
57-58	42.6	225.1	190.2	457.9
58-59	10.1	180.0	14.5	204.6
59-60	5.1	156.6	21.1	182.8
TOTAL	476.2	3,957.5	2,504.3	6,938.0
26-YEAR AVERAGE	18.3	152.2	96.4	266.9

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES CESSPOOL PERCOLATION.
C. INCLUDES PERCOLATION IN STREAM CHANNELS.

TABLE 3

ESTIMATED HISTORICAL ANNUAL CHANGE IN STORAGE OF GROUND WATER
IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE-FEET

1	2	3	4	5	6	7	8		9	
SEASON(A)	PERCOLATION	SUBSURFACE INFLOW	(2+3) TOTAL SUPPLY	EXTRACTIONS	SUBSURFACE OUTFLOW	(5+6) TOTAL OUTFLOW	(4-7) WATER SUPPLY SURPLUS OR DEFICIENCY SEASONAL	ACCUMULATED	CHANGE IN STORAGE BY SPECIFIC YIELD METHOD(B) SEASONAL	ACCUMULATED
1934-35	219.3	38.0	257.3	252.4	6.9	259.3	- 2.0	- 2.0	- 57.7	- 57.7
1935-36	213.1	38.7	251.8	309.8	6.9	316.7	- 64.9	- 66.9	+ 2.7	- 55.0
36-37	437.3	40.2	477.5	258.6	6.5	265.1	+212.4	+145.5	+137.6	+ 82.6
37-38	457.0	32.9	489.9	278.9	8.1	287.0	+202.9	+348.4	+144.7	+227.3
38-39	221.3	34.5	255.8	256.5	9.4	265.9	- 10.1	+338.3	+ 25.1	+252.4
39-40	219.5	36.0	255.5	295.4	8.1	303.5	- 48.0	+290.3	+ 30.3	+282.7
1940-41	470.4	38.3	508.7	233.7	6.4	240.1	+268.6	+558.9	+ 92.7	+375.4
41-42	167.7	32.6	200.3	280.0	7.9	287.9	- 87.6	+471.3	- 1.2	+374.2
42-43	389.3	36.5	425.8	286.0	7.9	293.9	+131.9	+603.2	+ 11.2	+385.4
43-44	287.4	36.0	323.4	274.9	8.4	283.3	+ 40.1	+643.3	+ 43.0	+428.4
44-45	240.5	35.9	276.4	303.5	8.5	312.0	- 35.6	+607.7	+ 47.3	+475.7
1945-46	219.9	36.2	256.1	304.8	8.5	313.3	- 57.2	+550.5	- 29.0	+446.7
46-47	247.7	32.8	280.5	340.2	8.4	348.6	- 68.1	+482.4	- 80.6	+366.1
47-48	182.5	28.2	210.7	321.4	8.4	329.8	-119.1	+363.3	- 83.8	+282.3
48-49	194.5	30.9	225.4	338.4	7.9	346.3	-120.9	+242.4	-121.8	+160.5
49-50	177.5	26.2	203.7	313.4	7.9	321.3	-117.6	+124.8	-188.2	- 27.7
1950-51	154.0	26.1	180.1	336.5	7.7	344.2	-164.1	- 39.3	-124.6	-152.3
51-52	401.9	28.1	430.0	307.0	6.3	313.3	+116.7	+ 77.4	- 33.3	-185.8
52-53	209.6	22.0	231.6	359.5	7.1	366.6	-135.0	- 57.6	+ 5.6	-180.0
53-54	265.9	24.3	290.2	341.7	7.7	349.4	- 59.2	-116.8	-105.4	-285.4
54-55	214.5	23.4	237.9	358.8	7.1	365.9	-128.0	-244.8	- 30.9	-316.3
1955-56	284.9	23.9	308.8	385.8	7.7	393.5	- 84.7	-329.5	- 89.6	-405.9
56-57	217.0	21.7	238.7	352.4	7.1	359.5	-120.8	-450.3	- 21.9	-427.8
57-58	457.9	28.1	486.0	344.8	7.7	352.5	+133.5	-316.8	+120.8	-307.0
58-59	204.6	22.2	226.8	383.1	8.0	391.1	-164.3	-481.1	-173.2	-480.2
59-60	182.8	20.4	203.2	353.0	7.9	360.9	-157.7	-638.8	-158.6	-638.8
TOTAL	6,938.0	794.1	7,732.1	8,170.5	20 .4	8,370.9	-638.8		-638.8	
26-YEAR AVERAGE	266.9	30.5	297.4	314.3	7.7	322.0	- 24.6		- 24.6	

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. COMPUTED BY USING SPECIFIC YIELD, AREA AND CHANGE IN WATER LEVEL.

TABLE 4

ARTIFICIAL RECHARGE SPREADING GROUNDS IN THE CHINO-RIVERSIDE AREA

PROJECT NUMBER (A)	NAME OF SPREADING GROUNDS	LOCATION	OWNER OR OPERATOR (B)	SOURCE OF WATER	BEGAN OPERATION
1	ALTA LOMA STORM DRAIN	3 MILES NORTH OF CUCAMONGA AND ONE-QUARTER MILE EAST OF ARCHIBALD AVENUE	SBCFCD	ALTA LOMA	1964
2	STREET RUNOFF FROM ARCHIBALD AVENUE	TWO AND THREE-QUARTER MILES SOUTH OF CUCAMONGA AND TWO AND ONE-QUARTER MILES EAST OF ONTARIO	SBCFCD	ARCHIBALD AVENUE	1956
3	STORM RUNOFF, IRRIGATION WASTE AND SUB-SURFACE DRAINAGE TO ARLINGTON AND LA SIERRA STORM DRAINS FROM LA SIERRA AND MOCKINGBIRD CANYON AREA	1000 FEET EAST OF INTERSECTION OF SAMPSON ST. AND KUSTER RD. IN CORONA	RCFC AND WCD	ARLINGTON	1957
4	SAN SAVAINE CREEK AND BANANA STREET STORM DRAIN	TWO MILES SOUTH OF ETIWANDA AND ONE MILE EAST OF ETIWANDA AVENUE	SBCFCD	BANANA AVENUE	1944
5	CACTUS AVENUE STORM DRAIN	THREE MILES WEST OF SAN BERNARDINO	SBCFCD	CACTUS	NO RECORD
6	CHURCH STREET STORM DRAIN	ONE MILE NORTH-EAST OF CUCAMONGA	SBCFCD	CHURCH	ABOUT 1958
7	NATURAL RUNOFF	ONE MILE EAST OF CLAREMONT	SBCFCD	COLLEGE HEIGHTS	1932
8	CUCAMONGA CREEK, SAN ANTONIO CR., FRANKISH AND STAMM CANYONS	ONE MILE NORTH OF UPLAND UP TO MOUTH OF CUCAMONGA CANYON	SAN ANTONIO WATER COMPANY	CUCAMONGA	1900
9	DAY CREEK AND SURFACE RUNOFF	NORTH OF ETIWANDA AT MOUTH OF DAY CANYON	ETIWANDA WATER COMPANY	DAY CANYON	1912
10	DAY CREEK	ONE MILE NORTH OF HIGHLAND AVENUE AND ONE MILE WEST OF ETIWANDA AVENUE	SBCFCD	DAY CREEK	1923
11	DEER CREEK	FIVE MILES NORTHEAST OF CUCAMONGA AT NORTH END OF HERMOSA AVENUE	SBCFCD	DEER CREEK	1935
12	EAST ETIWANDA CREEK	NORTHWEST INTERSECTION OF U.S. RT. 66 AND ETIWANDA CREEK	ETIWANDA WATER COMPANY	EAST AVENUE	1908
13	EIGHTH STREET STORM DRAIN AND CUCAMONGA CR., IF HEAVY FLOW	TWO MILES NORTHEAST OF ONTARIO AND ONE MILE EAST OF EUCLID AVENUE	SBCFCD	EIGHTH STREET	1938
14	STATE STREET STORM DRAIN	TWO MILES SOUTHEAST OF ONTARIO, NORTH SIDE OF EAST ELY STREET	SBCFCD	ELY STREET	1950
15	EAST ETIWANDA CREEK	MOUTH OF ETIWANDA CANYON SOUTH TO BASE LINE ROAD	SBCFCD	ETIWANDA	ABOUT 1960
16	IMPERVIOUS AREA NEAR CALIFORNIA EDISON STEAM PLANT	FIVE MILES WEST, TWO MILES SOUTH OF FONTANA	SBCFCD	ETIWANDA CONSERVATION BASIN	1954
17	FIFTEENTH STREET STORM DRAIN AND WEST CUCAMONGA CREEK	ONE AND ONE-QUARTER MILES NORTHEAST OF UPLAND AND ONE AND ONE-HALF MILES EAST OF EUCLID AVENUE	SBCFCD	FIFTEENTH STREET	1935
18	CONTROLLED FLOW FROM LIVE OAK DAM	NW OF CLAREMONT AT MOUTH OF LIVE OAK WASH, 1960-63. EAST SIDE OF LIVE OAK WASH, NORTH OF BASE LINE ROAD, 1963 TO PRESENT	LACFCD	LIVE OAK	1960
19	EAST FONTANA STORM DRAIN	ONE AND ONE-HALF MILES EAST OF FONTANA AT MERRILL AND LINDEN AVENUES	SBCFCD	MERRILL AND LINDEN	ABOUT 1960
20	EAST RIALTO STORM DRAIN	ONE MILE NORTHWEST OF COLTON AT MERRILL AND MERIDIAN AVENUES	SBCFCD	MILL	1957
21	SAN ANTONIO CREEK AND, AS OF 1964, MWD WATER	2 MILES NORTH WEST OF ONTARIO BETWEEN MONTE VISTA AVENUE AND SAN ANTONIO CR.	SBCFCD	MONTCLAIR	1954
22	NINETEENTH STREET STORM DRAIN	ONE AND ONE-HALF MILES NORTHEAST OF UPLAND AND ONE MILE EAST OF EUCLID AVE.	SBCFCD	NINETEENTH STREET	ABOUT 1942
23	EAST RIALTO STORM DRAIN	ONE MILE NORTHWEST OF COLTON AT MERRILL AND PEPPER AVENUES	SBCFCD	PEPPER	1958
24	TURBID WATER FROM SAN ANTONIO AND EVEY CANYONS PURCHASED FROM CANON W. CO. (1934-55), RUNOFF FROM INTERSECTION OF MILLS AVE.+BASE-LINE RD., WASHWATER FROM FILTRATION PLANT (STARTED 1958)	ONE-HALF MILE NORTH OF FOOTHILL BLVD. AND ONE-EIGHTH MILE WEST OF MILLS AVE.	CITY OF POMONA	POMONA	ABOUT 1900, NEW PIT COMPLETED 1955
25	EAST RIALTO STORM DRAIN	ONE MILE N. W. OF COLTON AT RANDALL AND MERIDIAN AVE.	SBCFCD	RANDALL	1961
26	BERYL AVENUE STORM DRAIN AND CORNELIAN AVE. STORM DRAIN	ONE MILE WEST OF UPLAND ON SOUTHSIDE OF BASELINE AVENUE	SBCFCD	RED HILL	1938
27	CONTROLLED RELEASE FROM SAN ANTONIO FLOOD CONTROL DAM	NORTHEAST OF CLAREMONT BELOW SAN ANTONIO DAM	PVPA	SAN ANTONIO	ABOUT 1921
28	SAN SAVAINE CREEK	NW OF FONTANA AT MOUTH OF SAN SAVAINE CREEK	SBCFCD	SAN SAVAINE	1960
29	TEMESCAL WASH	ONE MILE SOUTH OF HOME GARDENS, 1000 FEET EAST OF ATCHISON TOPEKA AND SANTA FE R. R.	RCFCD	TEMESCAL	1958
30	COBAL, WILLIAMS, PALMER, AND PADUA CREEKS, ALSO THOMPSON CREEK WHEN RESERVOIR ELEV. ABOVE 1625	ABOUT 3 MILES NORTH OF CLAREMONT AT MOUTH OF CANYON	PVPA	THOMPSON	ABOUT 1928
31	DAY CREEK	4-1/2 MILES SOUTHEAST OF ONTARIO	SBCFCD	WINEVILLE AND RIVERSIDE	NO RECORD

(A) PROJECT NUMBER ASSIGNED BY DEPT. OF WATER RESOURCES FOR THIS INVESTIGATION.
(B) SAN BERNARDINO FLOOD CONTROL DISTRICT ABBREVIATED SBCFCD, RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT ABBR. RCFC AND WCS, POMONA VALLEY PROTECTIVE ASSOCIATION ABBR. PVPA., AND LOS ANGELES COUNTY FLOOD CONTROL DISTRICT ABBR. LACFCD.

TABLE 5

QUANTITIES OF WATER ARTIFICIALLY RECHARGED
BY SPREADING GROUND
IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN ACRE FEET

SEASON (A)	8 CUCAMONGA	9 and 10 DAY CANYON AND DAY CREEK	11 DEER CREEK	27 SAN ANTONIO	TOTAL
1934-35	6,700 B	4,550 C	2,130 C	6,830	20,210
1935-36	5,040 B	3,060 C	1,440 C	1,650	11,190
1936-37	7,950 B	9,020 C	4,870 C	22,550	44,390
1937-38	12,340 B	13,390 C	8,130 C	15,000	48,860
1938-39	4,340 B	4,100 C	1,790 C	1,430	11,660
1939-40	6,400 B	3,110 C	1,740 C	2,670	13,920
1940-41	10,300 B	8,560 C	6,740 C	28,090	53,690
1941-42	3,280 B	2,670 C	1,240 C	80	7,270
1942-43	8,770 B	7,160 C	5,310 C	26,000	47,240
1943-44	8,320 B	5,070 C	3,700 C	10,270	27,360
1944-45	5,310 B	5,270 C	3,410 C	4,960	18,950
1945-46	7,170 B	3,500 C	2,240 C	3,270	16,180
1946-47	3,480 B	3,150 C	2,950 C	5,800	15,380
1947-48	1,090 B	1,510 C	370 C	0	2,970
1948-49	1,680 B	1,140 C	200 C	0	3,020
1949-50	1,590 C	1,010 C	460 C	60	3,120
1950-51	1,500	390 C	0 C	0	1,890
1951-52	880	5,030 C	2,740 C	10,470	19,120
1952-53	540	1,160 C	700 C	1,010	3,410
1953-54	1,060	1,870 C	1,870 C	3,150	7,950
1954-55	2,270	1,090 C	810 C	0	4,170
1955-56	2,100	800	810 C	930	4,640
1956-57	1,840	980	650 C	0	3,470
1957-58	12,370	2,830	6,070 C	12,880	34,150
1958-59	3,450	1,150	1,620 C	0	6,220
1959-60	1,600	780	590 C	0	2,970
26-YEAR TOTAL	121,370	92,350	62,580	157,100	433,400
26-YEAR AVERAGE	4,668	3,552	2,407	6,042	16,669

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. CALENDAR YEAR.
C. ESTIMATED BY DEPARTMENT OF WATER RESOURCES.

minimum of 9,400 acre-feet in 1950-51. The seasonal estimates of percolation of precipitation are shown in Table 2.

Percolation of precipitation in the Chino-Riverside area was considered to include both percolation of precipitation on the land surface and in the stream channels. This assumption was made because most of the storm runoff from the San Gabriel Mountains is diverted to artificial recharge and amounts of flow in the stream channels of the Chino-Riverside area reaching the Santa Ana River are small. Percolation of precipitation is equal to the sum of precipitation, surface inflow, and rising water, less the sum of consumptive use of precipitation, internal diversions of storm flow, and surface outflow.

Percolation of Delivered Water. Average seasonal percolation of delivered water in the Chino-Riverside area during the base period was about 152,200 acre-feet and varied from a maximum of 225,100 acre-feet in 1957-58 to a minimum of 116,300 acre-feet in 1934-35. The seasonal amounts of percolation of delivered water are shown in Table 2.

Delivered water is defined as applied water plus conveyance losses. Applied water is defined as the total amount of water, including ground water, actually delivered to a consumer for any domestic, agricultural, commercial, or industrial use, except water used for spreading.

Percolation of delivered water was separated into two components: (1) percolation of irrigation water and (2) percolation of waste water. Irrigation water, which is water used for agriculture and for lawns and shrubs in urban and suburban areas, was computed by subtracting total waste water production and commercial and industrial consumptive use from delivered water. Percolation of irrigation water was computed by subtracting consumptive use of irrigation water from irrigation water. Percolation of waste water was estimated by adding waste water disposed to cesspools, waste water discharged to spreading grounds, and waste-water percolated in streams. For the water-bearing portion of the Chino-Riverside area, it was found that percolation of irrigation water was 40.0 percent (60.0 percent irrigation efficiency) of irrigation water. Percolation of waste water was estimated to be about 17 percent of the percolation of delivered water.

Extractions from the Zone of Saturation

Extractions from the zone of saturation are withdrawals from the ground water reservoir by man or by nature. The components of these withdrawals in the Chino-Riverside area are: ground water pumpage, extractions by phreatophytes, and so-called "rising water". The average seasonal extractions from the zone of saturation, during the base period, were about 314,300 acre-feet . The maximum was 385,800 acre-feet in 1955-56; the minimum was 233,700 acre-feet in 1940-41. Table 6 presents the seasonal extractions from the zone of saturation.

Pumpage. The estimated average seasonal ground water pumpage for the base period was about 251,000 acre-feet, or about 80 percent of the total extractions from the zone of saturation. Ground water pumpage supplied about 70 percent of the total delivered water in the Chino-Riverside area. The seasonal ground water pumpage varied from a minimum of 164,600 acre-feet in 1940-41 to a maximum of 329,500 in 1958-59. This increase was due primarily to the continuing drought and to the increased demand for water resulting from an expansion of the population. The pattern of ground water pumpage in 1960 is shown on Figure 4.

The estimates of seasonal ground water pumpage shown in Table 6 are based on

TABLE 6

ESTIMATED HISTORICAL ANNUAL EXTRACTIONS FROM THE ZONE OF SATURATION IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE-FEET

SEASON(A)	GROUND WATER PUMPAGE(B)	EXTRACTIONS BY PHREATOPHYTES	RISING WATER(C)	TOTAL
1934-35	191.6	14.1	46.7	252.4
1935-36	250.7	17.4	41.7	309.8
36-37	202.2	11.6	44.8	258.6
37-38	214.4	13.8	50.7	278.9
38-39	187.8	16.1	52.6	256.5
39-40	225.6	17.7	52.1	295.4
1940-41	164.6	9.5	59.6	233.7
41-42	199.7	17.5	62.8	280.0
42-43	209.2	14.5	62.3	286.0
43-44	194.3	14.6	66.0	274.9
44-45	221.8	16.1	65.6	303.5
1945-46	226.0	18.6	60.2	304.8
46-47	268.7	17.9	53.6	340.2
47-48	251.8	19.3	50.3	321.4
48-49	275.7	18.4	44.3	338.4
49-50	251.6	18.5	43.3	313.4
1950-51	278.3	20.2	38.0	336.5
51-52	255.9	13.2	37.9	307.0
52-53	303.0	18.8	37.7	359.5
53-54	284.6	17.7	39.4	341.7
54-55	305.5	18.5	34.8	358.8
1955-56	332.7	18.5	34.6	385.8
56-57	298.8	19.3	34.3	352.4
57-58	295.1	12.6	37.1	344.8
58-59	329.5	21.0	32.6	383.1
59-60	305.7	19.8	27.5	353.0
TOTAL	6,524.8	435.2	1,210.5	8,170.5
26-YEAR AVERAGE	251.0	16.7	46.6	314.3

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES GALLERY DIVERSIONS WITHIN WATER-BEARING AREA.
C. INCLUDES IRRIGATION WATER(WASTE WATER) RETURN FLOW FROM HIDDEN VALLEY RANCH.

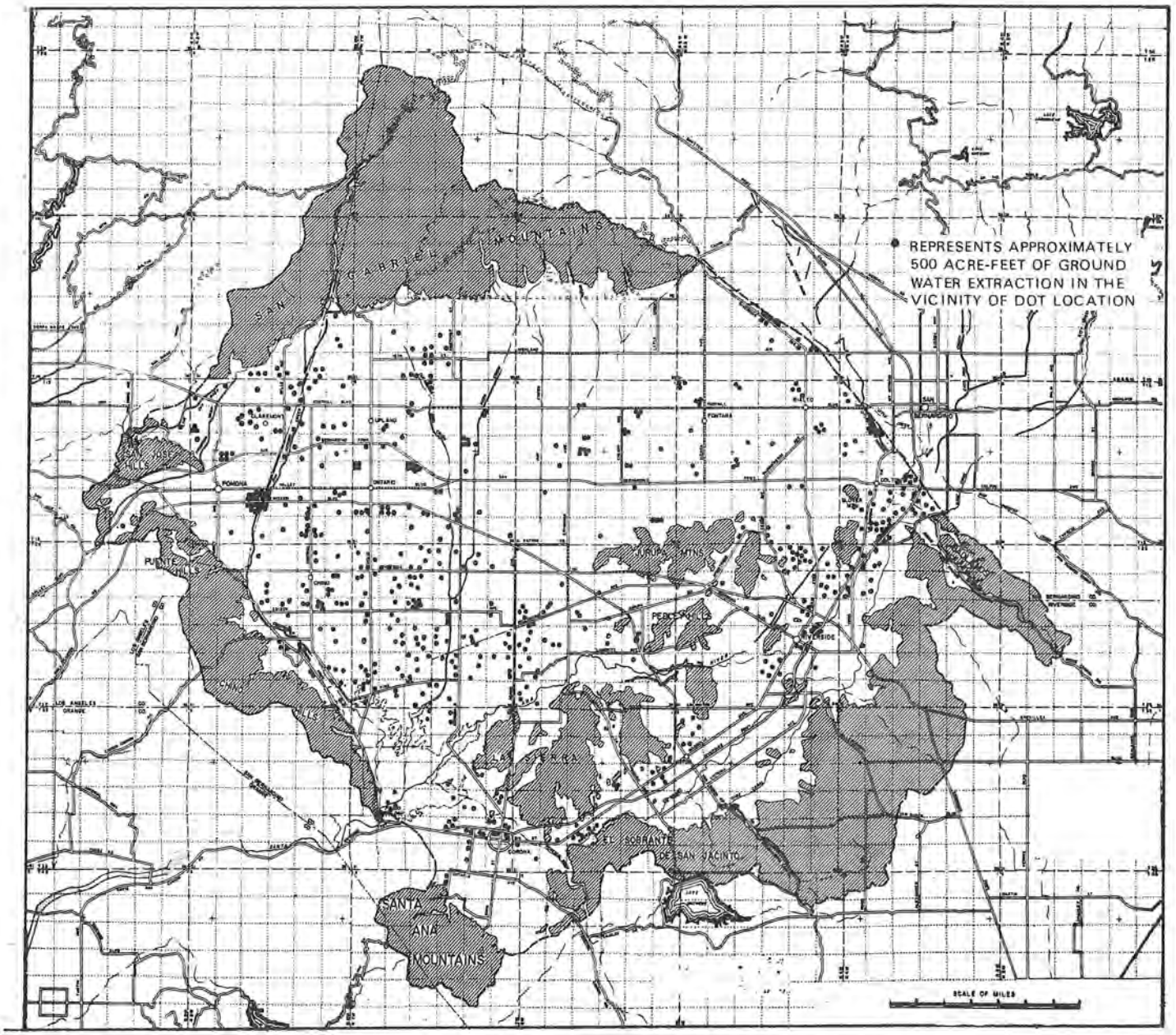


FIGURE 4 – PATTERN OF GROUND WATER PUMPAGE IN 1960

estimated amounts for the years 1933-34 through 1948-49 and recorded amounts for the years 1949-50 through 1959-60. Unfortunately, ground water pumpage data prior to 1950 were either unavailable or incomplete for most of the ground water extracting agencies in the Chino-Riverside area. Reliable extraction data became available in the later years as a result of the Recordation of Water Extractions and Diversions Act (Sections 4999 through 5008 of the California Water Code). Estimates of ground water pumpage for the years 1933-34 through 1948-49 were based on the assumption that the average irrigation efficiency has not changed since 1933.

Water is diverted by the San Antonio Water Company through Frankish and Stam Tunnels, a mile long gallery paralelling the west bank of Cucamonga Wash. The water is used for domestic purposes and spreading in the Cucamonga Spreading Grounds. The average diversion through these tunnels is 300 acre-feet per year.

The Etiwanda Water Company taps the subsurface water in Day Canyon by means of Smith and Bee Tunnels that act as gallery diversions. The average annual diversion in Smith Tunnel is 800 acre-feet per year. That for Bee Tunnel is 300 acre-feet per year. Because this water is obtained from the zone of saturation, these gallery diversions are considered to be extractions.

Extractions by Phreatophytes. Average seasonal extractions by phreatophytes in the Chino-Riverside Ground Water Basin for the base period were about 16,700 acre-feet, or about 5 percent of the total extractions from the zone of saturation. Extractions by phreatophytes, as shown in Table 6, ranged from a maximum of about 21,000 acre-feet in 1958-59 to about 9,500 acre-feet in 1940-41.

Phreatophytes grow in the vicinity of Prado Flood Control Basin and upstream, along the Santa Ana River, to a point above the Riverside Narrows. The amount of water they consume was estimated by use of the Blaney-Criddle method.

Rising Water. Rising water is ground water from the zone of saturation which rises to the surface, usually in a streambed, when the surface is at a lower elevation than the ground water table. Rising water within the Chino-Riverside area occurs at the Prado Flood Control Basin and along the Santa Ana River from Prado to a point above the Riverside Narrows. The amounts of rising water in the Santa Ana River were estimated for the stream gages near Riverside Narrows and at Prado Flood Control Dam. Because of intense local interest in this hydrologic item, meetings were held with representatives of water agencies in the Chino-Riverside area to resolve the minor differences between locally accepted values of rising water and preliminary estimates made for this investigation. Table 7 contains the results of this intensive review. These figures are believed to be the best estimate currently available of rising water in the Chino-Riverside area.

The stream gage on the Santa Ana River near Prado was not in continuous operation for the period 1934-35 through 1939-40, therefore, the flow gaged 2.5 miles downstream at the Orange-Riverside County line, was used for the missing months.

During the base period, "rising water" at the Riverside Narrows varied from a high of 27,000 acre-feet in 1943-44 to a low of 16,000 acre-feet in 1959-60; at Prado it varied from a high of 66,000 acre-feet in 1943-44 to a low of 27,500 acre-feet in 1959-60. Average seasonal rising water for the base period was about 22,000 acre-feet at Riverside Narrows and 47,000 acre-feet at Prado.

Vadose Water in the Zone of Aeration

Precipitation and applied water enter the zone of aeration from the surface and are drawn down toward the zone of

saturation by gravity. The rate at which this water reaches the zone of saturation depends upon: the amount of precipitation or applied water available, the infiltration rate and moisture content of the soil belt, and the vertical permeability of the intermediate zone. If only a small amount of water is applied or is available through precipitation, it may be used up by evaporation and transpiration in the soil belt, even though the infiltration rate of the soil belt is high. Water that passes the soil belt moves downward through the intermediate zone, in which water is usually not affected by evaporation and transpiration. Water that reaches the zone of saturation is an increment to the ground water supply. To determine the time required for water applied at the ground surface to reach the zone of saturation, varying amounts of water in transit were imposed upon a mathematical model. The model indicated that, in general, the effects of water in transit are felt at the zone of saturation in about one year, where the zone of saturation is 100 feet or more below the ground.

Studies on the rate of flow of vadose water through the zone of aeration are currently being carried on by several agencies, including the Department of Water Resources. No such studies were made in the Chino-Riverside area in this investigation, because data and facilities needed for directly measuring unsaturated flow are beyond the scope of this investigation. As mentioned before, it was partially for this reason that the study period was chosen so as to contain a dry period of precipitation directly preceding the beginning and end of the study period. It was then assumed that the amount of water in transit in the zone of aeration was essentially the same at the beginning and end of the study period.

Ground Water in Storage

Wells draw their water from the saturated zone below the water table. In this report, the discussion of subsurface water storage will be restricted to ground water in the saturated zone.

The volume of water in a saturated aquifer is essentially equal to the volume of the pore spaces, disregarding chemically combined water in minerals and trapped gases in the voids. Ground water in storage is the water that will drain freely from the satu-

TABLE 7

ESTIMATED HISTORICAL ANNUAL AMOUNTS OF RISING WATER IN THE CHINO-RIVERSIDE AREA

IN ACRE FEET

SEASON(A)	RIVERSIDE NARROWS	PRADO DAM(B)
1934-35	20,600	46,700
1935-36	20,600	41,700
36-37	21,300	44,800
37-38	22,600	50,700
38-39	23,600	52,600
39-40	23,700	52,100
1940-41	24,500	59,600
41-42	25,800	62,800
42-43	27,100	62,300
43-44	27,100	66,000
44-45	27,000	65,600
1945-46	26,800	60,200
46-47	24,400	53,600
47-48	24,600	50,300
48-49	24,500	44,300
49-50	24,400	43,300
1950-51	22,000	38,000
51-52	21,900	37,900
52-53	20,100	37,700
53-54	19,600	39,400
54-55	16,400	34,800
1955-56	17,500	34,600
56-57	18,200	34,300
57-58	19,500	37,100
58-59	17,100	32,600
59-60	16,000	27,500
26-YEAR AVERAGE	22,200	46,600

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

B. INCLUDES IRRIGATION WATER(WASTE WATER) RETURN FLOW FROM HIDDEN VALLEY RANCH.

TABLE 8

SPECIFIC YIELD VALUES ASSIGNED TO SEDIMENTS
IN THE CHINO-RIVERSIDE AREA

Drillers term	Specific yield,* in percent
Clay	3
Silt	10
Sandy silt	15
Silty sand	20
Sandy clay	5
Fine sand	26
Medium sand	35
Coarse sand	33
Sand (undifferentiated)	32
Cemented sand	12

Gravels** (By Township, Range and Section)

Location	Specific yield, in percent
1N/5W - All sections	13
1N/6W - Sect. 19-30	13
31-36	15
1N/7W - All sections	13
1N/8W - " "	13
1N/9W - " "	17
1S/4W - Sect. 6-18	16
19-34	18
1S/5W - Sect. 1-12	14
13-24	16
25-36	14
1S/6W - Sect. 1-12	16
13-24	18
25-36	20
1S/7W - Sect. 1-12	15
13-24	16
25-36	18
1S/8W - Sect. 1-12	15
13-24	16
25-36	18

Location	Specific yield, in percent
1S/9W - All sections	18
2S/4W - " "	16
2S/5W - Sect. 1-12	14
13-24	19
25-36	20
2S/6W - Sect. 1-18	21
19-36	20
2S/7W - Sect. 1-6	21
7-12	22
13-24	23
25-36	20
2S/8W - Sect. 1-12	21
13-26	22
3S/5W - All sections	18
3S/6W - Sect. 1-12	14
13-36	19
3S/7W - Sect. 1-24	19
25-36	16
3S/8-9W None	
4S/6W - All sections	14
4S/7W - " "	14

*Specific yield values were based on values determined in a cooperative study between the United States Geological Service Hydrology Laboratory and the Department (see Reference No. 200 in Bibliography).

**For a clay and gravel mixture use appropriate gravel value, add clay value and divide sum by two.

rated aquifer. The total water content includes water that will be retained in the aquifer under capillary and molecular tension or trapped in closed pores.

The storage potential of a water-bearing body is calculated by mutiplying the total volume of the water-bearing material by its specific yield. The amount of water in storage is calculated in the same way, using the volume of saturated material only.[1/] Table 8 lists the specific yields of various materials in the basin.

The effective base of the ground water reservoir (Plate 4) is the fixed lower boundary of the saturated water-bearing materials of the Chino-Riverside ground water basin. The upper surface of the saturated zone—the water table—fluctuates in response to supply and withdrawal of ground water and thereby reflects changes in the amount of ground water in storage.

Volume in Storage. The potential storage capacity of the Chino-Riverside ground water basin was calculated to be about 18,300,000 acre-feet, mostly in the central part of the basin. At the beginning of the base period (water year 1934-35), ground water in storage was 12,650,000 acre-feet and at the end (water year 1959-60), 12,000,000 acre-feet, the net decline being about 650,000 acre-feet and the average about 25,000 acre-feet per year.

Change in Storage. The changes in ground water storage are indicated by the fluctuations of water levels of the basin. The fluctuations show the effects of variations in natural and man made occurrences on the surface, such as precipitation, temperature, artificial recharging, and pumping. Typical fluctuations in the Chino-Riverside area are shown in hydrographs of 18 selected wells, on Figures 5 through 22. (These figures are bound at the end of this chapter.)

Wells 1, 2, 12, 14, and 18 are close to the recharge source of the San Gabriel Mountains watershed and their hydrographs reflect relatively wet and dry periods that can also be seen in the underflow in San Antonio Canyon (Table 9). Farther from the watershed recharge points, or insulated from recharge pulses by ground water impediments, wells 6, 7, 8, 9, 13, 15, and 16 receive a steady recharge and are most affected by seasonal variations in pumping and evaporation rate, although wells 12, 15 and 18 show the summertime low of curves influenced by climatic conditions.

Wells 3, 4, 5, 10, and 11 show a much lower variability in water level.

Wells 3, 4, and 5 show, in a lessened form, delayed annual high water levels seen in earlier years in wells near the mountain front. Well 17 is in an area of low transmissibility, where water is recharged and withdrawn at a correspondingly slow rate; its nearly-straight-line decline suggests that the general reduction of water in storage over the years is the controlling factor, all cycles of lesser frequency having been damped out.

By using the averages by square mile areas of these and many other water level measurements, the annual changes in the configuration of the water table have been plotted and the resultant changes in ground water storage computed annually for the base period, 1934-35 through 1959-60.

1/ This may be expressed mathematically by Porosity = specific retention + specific yield; where porosity = percent by volume of voids in the saturated zone; specific retention = percent by volume of retained water; specific yield = percent by volume of free-draining water. The latter two terms are, of course, complementary.

TABLE 9

SUBSURFACE INFLOW TO THE
CHINO-RIVERSIDE AREA

In acre-feet

Season[a]	Lytle Creek	San Jacinto Fault	Colton Narrows[b]	Temascal Creek	San Antonio Canyon	Frontal flow	Total inflow
		3,000	16,900	170	6,920	7,150	38,040
1935-36	4,000	3,000	19,700	150	4,670	7,150	38,670
36-37	4,000	3,000	16,900	150	8,970	7,150	40,170
37-38	4,000	3,000	12,100	170	6,500	7,150	32,920
38-39	4,000	3,000	13,600	260	6,500	7,150	34,510
39-40	3,700	3,000	15,000	260	6,920	7,150	36,030
1940-41	3,700	3,000	13,800	270	10,420	7,150	38,340
41-42	4,200	3,000	13,700	220	4,330	7,150	32,600
42-43	3,600	3,000	12,200	150	10,420	7,150	36,520
43-44	4,200	3,000	13,800	230	7,670	7,150	36,050
44-45	4,200	3,000	13,700	190	7,670	7,150	35,910
1945-46	4,000	3,000	13,700	130	8,170	7,150	36,150
46-47	4,000	3,000	12,000	110	6,500	7,150	32,760
47-48	3,600	3,000	11,900	90	2,500	7,150	28,240
48-49	3,500	3,000	13,000	70	4,170	7,150	30,890
49-50	3,500	3,000	8,700	60	3,830	7,150	26,240
1950-51	2,800	3,000	9,400	50	3,700	7,150	26,100
51-52	2,700	3,000	8,700	50	2,700	7,150	28,100
52-53	4,000	3,000	4,600	50	4,000	7,150	22,000
53-54	3,600	3,000	5,500	50	5,000	7,150	24,300
54-55	3,800	3,000	4,700	50	4,670	7,150	23,370
1955-56	3,600	3,000	4,600	40	5,500	7,150	23,890
56-57	3,300	3,000	4,400	40	3,830	7,150	21,720
57-58	4,200	3,000	4,200	40	10,120	7,150	28,110
58-59	4,100	3,000	4,100	50	3,830	7,150	22,230
59-60	3,600	3,000	3,900	40	2,670	7,150	20,360
26 year average	3,800	3,000	10,570	121	5,856	7,150	30,404

a. 12-month period from October 1 through September 30
b. Underflow (1935-49) revised and extrapolated (1934-35, 1949-60) from Dutcher and Garrett (1963, p. 105)

In 1945, the hydrographs reflected a basinwide increase in storage up to a maximum of 13,100,000 acre-feet and a steady decline thereafter. The lowest point came in 1960, the last year of the base period. The greatest yearly increase was 145,000 acre-feet in the water year 1937-38 and the greatest yearly decline was 188,000 acre-feet in the water year 1949-50 (Table 3).

Plates 12 and 13 , which show lines of equal elevation of the water table at the beginning and end of the base period, are generally similar, but a close comparison shows the decline in storage. Plate 14, which shows changes in water level from 1934 to 1960, indicates that the most extensive changes in water levels have been in the Pomona-Claremont area, where static water levels have been lowered more than 75 feet.

Two methods are widely accepted in computing change in the amount of stored water in a ground water basin. They are the water supply inventory method and the specific yield method.

The equation of hydrologic equilibrium can be applied to the study area with the zone of saturation as a free body to determine the change in storage. This is shown schematically in Figure 23. The equation of hydrologic equilibrium for this free body is expressed as:

> Deep Percolation + Subsurface Inflow - Extraction from the Zone of Saturation - Subsurface Outflow = Change in Storage.

By using this equation, the seasonal amount of change in storage was indirectly determined.

The components in the above equation are related to the residual amounts of water supply that infiltrate into the zone of aeration after the area's water supply has been used and disposed of. Table 3 presents the seasonal amounts of each component of deep percolation and of extraction, subsurface flow, and change in storage as computed by use of the above equation. Change in the amount of ground water

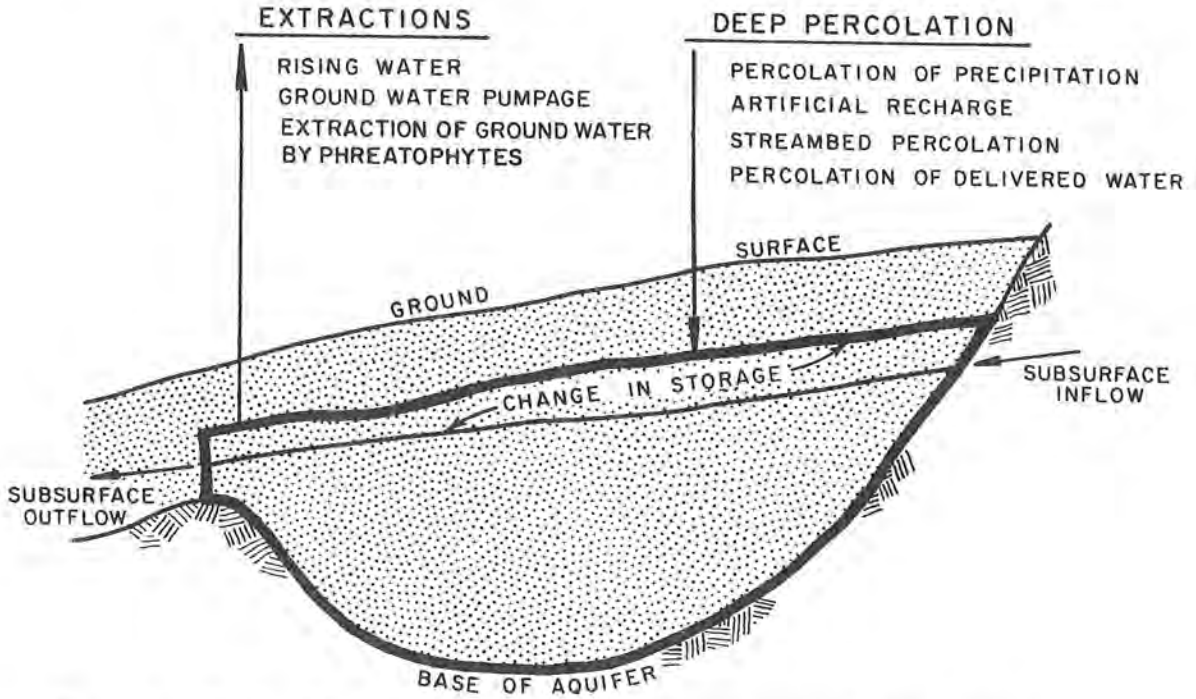


Fig. 23—THE ZONE OF SATURATION AS A FREE BODY

in storage by the Specific Yield Method is also shown in this table for comparison.

Seasonal amounts of change in ground water storage were directly determined by the Specific Yield Method:

1. Ground water in storage was computed in the fall of each year by the following equation:

Specific Yield X Thickness of Saturated Water-Bearing Material X Area = Ground Water in Storage.

2. Change in storage for each year of the base period was computed by subtracting the ground water in storage in the fall of each year from the ground water in storage in the fall of the following year.

Specific yield is relatively small in sediments with low porosity, such as poorly sorted, compacted, or highly cemented strata, and likewise in fine-grained or relatively impermeable material with high specific retention. In consolidated or highly clayey beds, therefore, the specific yield may be as low as three percent and in unfractured crystalline bedrock it is essentially zero. On the other hand, unconsolidated, highly permeable, clean sands and gravels, as in the recent alluvium of the Chino-Riverside area, may have specific yield values up to 35 percent. Specific yield values used in this investigation are shown in Table 8.

In this study, the storage capacity (in terms of specific yield) was determined for the water-bearing materials in each section. All well logs of known locations, about 1,800 in all, were analyzed and appropriate specific yield values were assigned to each stratum of different lithologic characteristics identified in the logs. A weighted average specific yield was computed for each 20-foot increment of depth in each log. All individual well logs in a given section were then combined into a composite log, representing the average specific yield for each 20-foot increment below the average ground surface of the section. Composite logs which did not extend to the base of the ground water reservoir were extrapolated, either by correlation with those in adjoining sections or by extending downward the average specific yield of the known interval. In sections with no well log data, idealized logs were constructed by comparing them with those in adjacent areas having similar geology.

Ground Water Movement

Ground water moves generally south and southwestward under the Chino Plain from the inflow sources toward the outlet at Prado Dam. The structure of the underlying nonwater-bearing rock and the fault zones that cut the aquifer deflect or retard flow, and influence water levels, as shown by the hydrographs on Figures 5 through 22.

Location of the wells used for the hydrographs is shown on Plate 5. The shape of the water table indicates the direction of flow and the effectiveness of the subsurface impediments. To show this shape, lines of equal elevation on the water table have been plotted for each year of the study period and those for the beginning and end of the study period are reproduced on Plates 12 and 13.

The southward gradient below the San Gabriel Mountain front reflects the underflow from the watershed. Below the Santa Ana Mountains and west-side hills, even though the amount of ground water contributed by these watersheds is relatively small, the hydraulic gradients are steep because of the low permeability.

Lytle Creek Fan. Subsurface flow from Lytle Creek Fan at the

eastern end of the San Gabriel Mountains cascades over "Barrier J", a buried fault scarp marking the front of an alluvium-mantled bedrock ledge. The hydrograph of well No. 1 (Figure 5) shows the strong influence of precipitation on the shallow water-bearing zone north of "Barrier J"; hydrographs of wells nos. 10 and 14 show the much smaller variability of water levels at the foot of the cascade where supply is maintained by constant overflow and the volume of water-bearing materials is much greater.

Rialto-Colton Barrier. In the Rialto vicinity, ground water is shunted southeasterly along the obstacle formed by the Rialto-Colton Fault, and turns westward into the central portion of the ground water reservoir through the gap in the fault north of Slover Mountain. At the north end of the barrier, the water level disparity is more than 350 feet. Near the gap the disparity decreases to less than 50 feet. Hydrographs of wells Nos. 4 and 5, which are for wells about five miles south of the San Gabriel Mountain front, show a maximum elevation in the period 1945-50 that appears to correspond with the wet trend 1939-44. This correspondence suggests that water that percolates at the mountain front affects the water level elevations in the wells six years later. Thus the rate of pressure front movement in the area appears to be about one mile per year.

Bloomington Area. A flattened mound occurs in the water table in the Bloomington area northeast from the Jurupa Mountain to the Rialto-Colton Fault (Plates 12 and 13) along a line more or less coinciding with Bloomington Avenue. The mound is evidently created by underflow through the gap in the Rialto-Colton Fault. The mound divides across a bedrock channel leading from the Santa Ana River floodplain into the central ground water basin (Plate 4). Water quality analyses indicate that the mound blocks the heavily mineralized Santa Ana River channel water from flowing northward into the central basin. The difference in head on the flanks of the divide suggests that most of the water from the mound flows westward along the north side of the Jurupa Mountains and that the remaining amount moves south to mix with the Santa Ana River channel ground water.

Riverside-Arlington Area. In the Riverside-Arlington region, south of the Jurupa Mountains, ground water moves toward the Santa Ana River channel. West of Arlington, however, flow is southwestward to Temescal Valley through the narrows between La Sierra and El Sobrante de San Jacinto. The water-bearing deposits throughout the region in and south of the Santa Ana River channel are thin and the amount of water involved in the movements described above is relatively small. Regular, strong seasonal variations in water levels, as shown by Hydrographs of wells 6, 7, 8, and 9, reflect the demands made by summer pumpage and evapotranspiration on this shallow water supply.

Pomona. The water table maps (Plates 12 and 13) indicate a ground water mound south of Pomona, where water moves south from the subsurface "spillway" at the lowest point in the San Jose Fault barrier. The crest of the mound appears to shift from year to year, probably in response to variations in withdrawal on the flanks of the mound. The mound trends generally southward from Pomona to the Puente Hills. A portion of the ground water from this mound moves westward into San Jose Wash and thence into San Gabriel Valley. The remainder moves southeastward along the front of the Puente Hills to Prado Dam.

San Jose Fault. Most of the ground water stemming from the San Antonio Creek channel and mountain front in the northwestern portion of the area is initially confined by

the San Jose Fault. At the Indian Hill Fault, part of the south-flowing ground water within the enclosed area is diverted westward into the San Gabriel Valley through San Dimas gap and the rest cascades over the buried escarpment of the Indian Hill Fault and moves on southward to overflow the San Jose Fault at the east end of the San Jose Hills. Strongly marked discontinuities in water levels across the San Jose Fault (Plates 12 and 13) indicate that the fault plane itself is nearly water-tight. The lack of direct hydraulic connection across the fault is further demonstrated by the difference between hydrographs of wells Nos. 14, 15 and 18. Water levels in these wells are influenced by recharge variations caused by climatic conditions in the watershed. The hydrograph of well 16 shows the water level record of a well in the area fed by overflow across the fault in which these variations are absent.

Red Hill Fault. Water moves almost unimpeded from the mountain front toward Red Hill Fault, north of Upland, where a plateau in the water table is created. Northwest and northeast of Red Hill the water level contours show little relief (Plate 4). The water level contours are based on limited data. Comparison of the hydrographs of wells Nos. 11 and 12 suggests that ground water that passes across the fault may be overflowing from a relatively large impounded body. Well No. 11 is downslope from the fault; well No. 12 is upslope from the fault, hence is more markedly influenced by recharge than well No. 11.

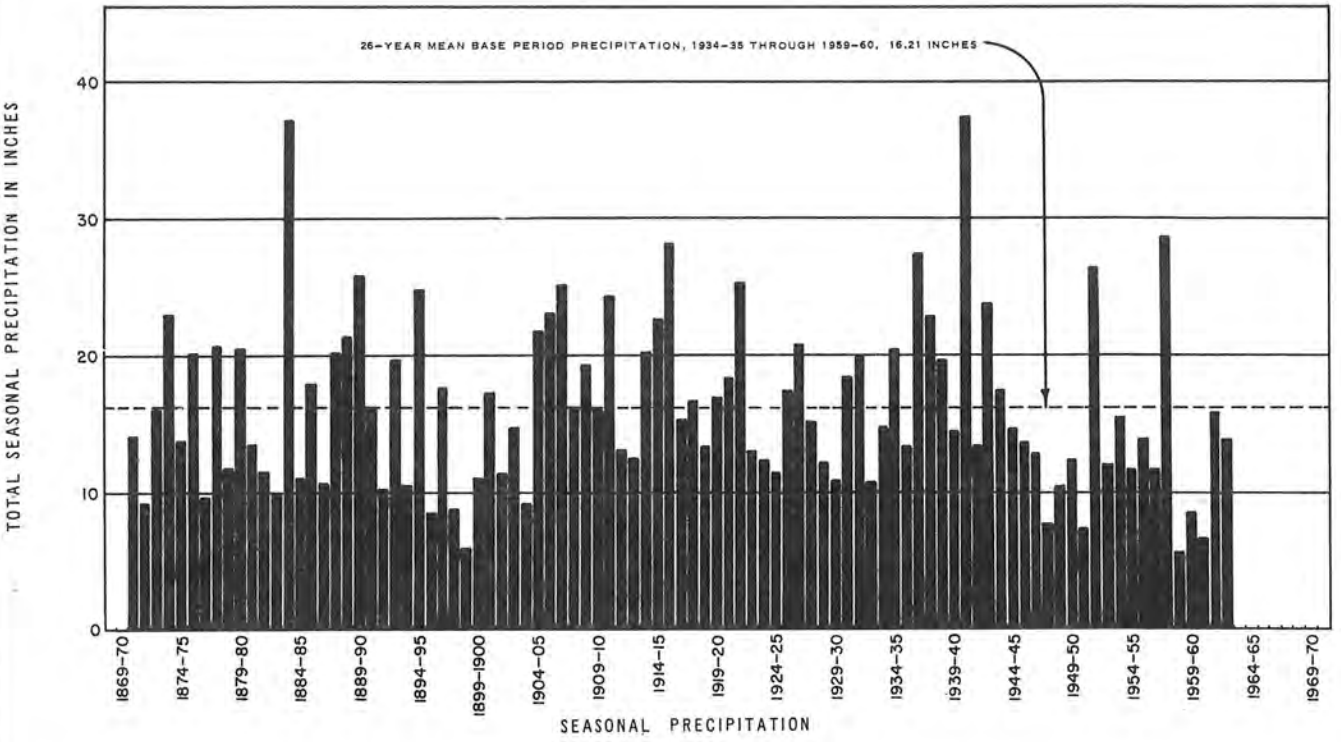
Study Period

In most watersheds, the original source of local water is precipitation. Therefore, the amount of precipitation falling on a ground water basin and its tributary areas serves as an index to the local water supply available to that basin. By analyzing long-time precipitation records, a base period--a relatively short, recent span of time--can be selected for study as representative of the long-time period.

Hydrologic conditions during a base period should represent long-time hydrologic conditions. The base period should be within the period of available records and recent cultural conditions. Both the beginning and end of the base period should be preceded by a series of dry years, so as to minimize the difference between the amount of water in transit at the beginning and end of the base period.

Overall Length. The precipitation period for this study was determined from a graph of the accumulated deviation from the period of record of the precipitation at Ontario, California. This graph, Figure 24, shows three pairs of wet and dry trends covering the periods 1883-84 through 1903-04, 1904-05 through 1933-34, and 1934-35 through 1962-63. The water years 1883-84 through 1962-63 cover three recorded wet and dry trends.

The water years 1934-35 through 1959-60 were chosen as a base period on the basis of the criteria presented above. This 26-year period includes the most recent pair of wet and dry trends, begins and ends after a series of dry years, lies within the period of available data, and encompasses recent cultural conditions. The mean annual precipitation during the base period at Ontario, 16.21 inches, corresponds closely to that of the long-time period--16.43 inches. Because of similar below-normal precipitation that preceded the water years 1934-35 and 1959-60, the assumption could be made that there was no significant difference in the amount of vadose water in the zone of aeration at the beginning and end of the base period. The amount of water percolating to the zone of saturation was negligible for both peri



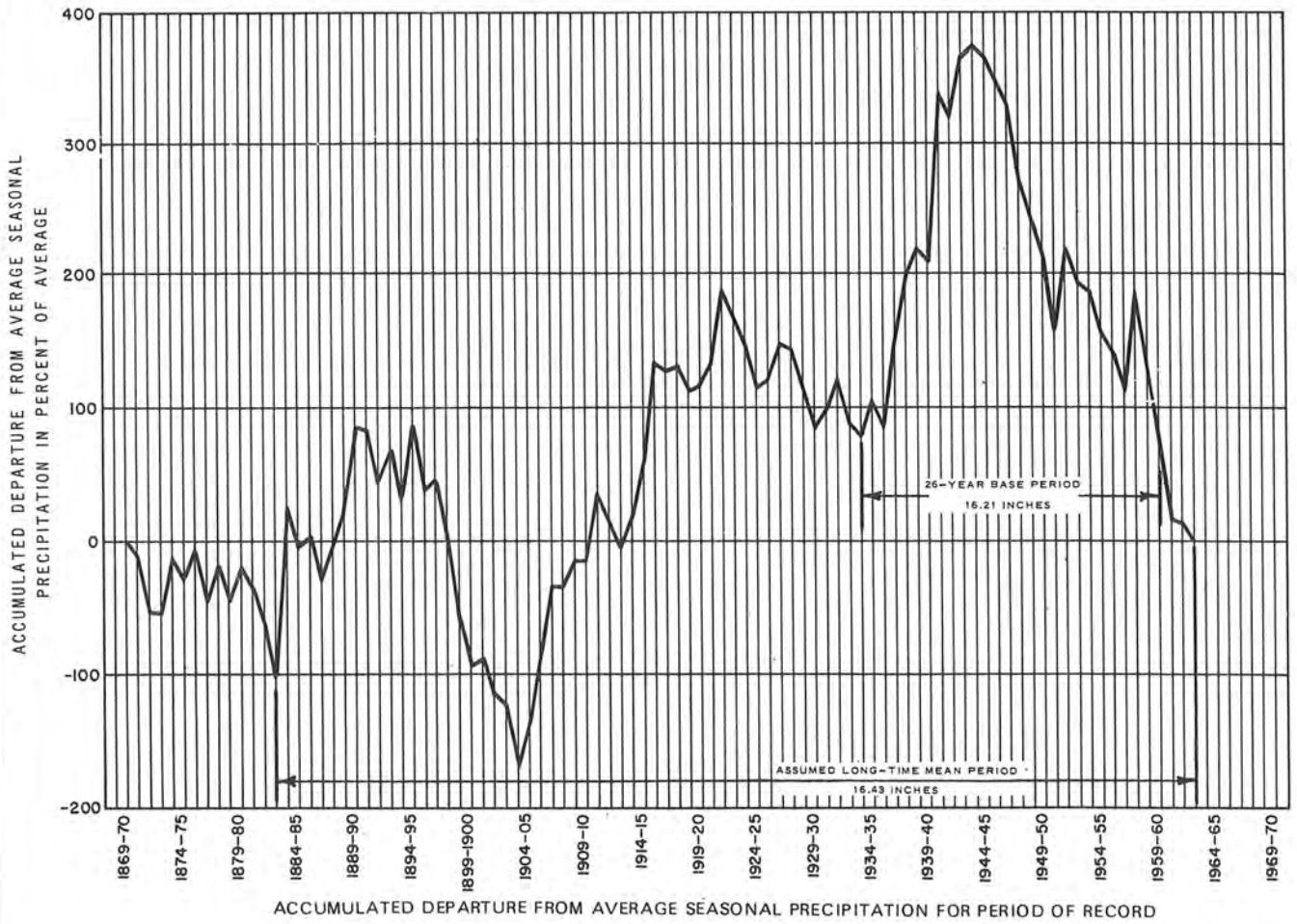


Figure 24 - PRECIPITATION CHARACTERISTICS AT ONTARIO

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1970

ods. This assumption facilitated change in storage computations for the base period.

A considerable portion of the water supply to the valley land of the Chino-Riverside area comes from surface streamflow. Although this supply is from precipitation on areas tributary to the ground water basin, a study of streamflow records is desirable to ascertain that the selected base period is representative with respect to long-time streamflow, as well as to long-time precipitation.

Gaps in the Record. The period of record of stream gaging stations in the Chino-Riverside area does not completely cover the period 1883-84 through 1962-63. Therefore, a shorter period, composed of the two most recent wet and dry trends, was assumed to represent the long-time mean for streamflow. Figure 25 shows that these two most recent wet and dry trends extended from 1904-05 through 1962-63. The base average streamflow of San Antonio Creek is 16,243 acre-feet. Hydrologic conditions during the base period were assumed to be representative of the conditions of the long-time mean with respect to both streamflow and precipitation.

Inventory

In the following sections of this Chapter, the components of supply and disposal, as determined by the inventory of past data, are discussed in detail.

Supply. Water supply as used in inventory work is water added to the water-bearing portion of the area of investigation from outside the ground water basin. The components of water supply are precipitation, surface inflow, fresh water import, waste water import, and subsurface inflow. The average seasonal water supply to the Chino-Riverside area during the 26-year base period, 1934-35 through 1959-60, was about 590,000 acre-feet. The seasonal amounts of historical surface water supply during the base period are summarized in Table 10 and the subsurface inflow in Table 9.

Although pumped ground water could be considered an item of inflow for the surface water supply, it is discussed in the next chapter as an item of outflow from the zone of saturation. However, when surface and ground water supplies are simultaneously considered for an area, pumped ground water will cancel out as a factor in the overall hydrologic equation.

Estimates of the seasonal volume of precipitation on the water-bearing area were based on records of the Flood Control Districts of Los Angeles, Orange, Riverside and San Bernardino Counties. After these records were evaluated for length and location, the records of 43 rain gage stations were used to estimate the seasonal volume of precipitation. To estimate missing records and adjust data errors, the records of these stations were correlated with the average of 10 stations with complete, reliable records. The locations of the rainfall stations used in this study are shown on Plate 15 and Table 11. Seasonal depth of rainfall at each station is shown in Table 12.

The Thiessen method was used to compute the volume of seasonal precipitation by constructing a polygon of influence around each rain gage station and multiplying the seasonal depth of rainfall by the area of the polygon. The total volume of precipitation in the water-bearing area was obtained by totalling the volume of rainfall for all polygons.

The average seasonal precipitation on the Chino-Riverside area varies with location, ranging from 10 inches near Lake Mathews to 25 inches along the base of the San Gabriel Mountains and increasing to about 45 inches at their crests. Plate 15, which shows the average seasonal isohyets for the 26-year

TABLE 10

ESTIMATED HISTORICAL ANNUAL SURFACE WATER SUPPLY
TO THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE-FEET

SEASON(A)	PRECIPI-TATION	SURFACE INFLOW(B)	FRESH WATER IMPORT(C)		WASTE WATER IMPORT	TOTAL SURFACE SUPPLY
			USED IN BASIN	MWD WATER CONVEYED THROUGH AREA(D)		
1934-35	438.1	43.8	90.1		4.1	576.1
1935-36	286.5	27.3	100.7		3.2	417.7
36-37	635.2	156.0	94.9		3.5	889.6
37-38	523.9	348.4	101.0		3.3	976.6
38-39	387.9	56.0	102.3		3.8	550.0
39-40	307.8	45.4	108.3		3.5	465.0
1940-41	742.3	200.9	95.7		3.8	1,042.7
41-42	286.6	49.8	106.4		4.1	446.9
42-43	520.9	176.1	111.1		4.7	812.8
43-44	447.2	103.9	115.9		5.6	672.6
44-45	364.8	82.0	114.9		6.8	568.5
1945-46	279.9	64.9	128.5		6.8	480.1
46-47	303.0	65.4	120.9		7.1	496.4
47-48	198.3	29.1	116.3		7.0	350.7
48-49	249.2	24.9	105.1	4.7	7.6	391.5
49-50	263.2	22.5	99.7	25.3	8.2	418.9
1950-51	189.3	9.6	97.1	28.5	8.2	332.7
51-52	583.2	83.4	99.2	38.2	8.7	812.7
52-53	265.2	16.6	100.8	29.4	8.6	420.6
53-54	336.5	31.8	101.6	91.1	8.7	569.7
54-55	280.7	13.1	98.3	77.9	9.0	479.0
1955-56	309.9	17.6	101.6	77.8	9.5	516.4
56-57	266.7	13.0	94.2	54.0	9.7	437.6
57-58	606.6	102.6	103.1	0	10.0	822.3
58-59	135.0	10.6	116.4	0	10.5	272.5
59-60	208.2	8.5	99.1	0.5	12.0	328.3
TOTAL	9,416.1	1,803.2	2,723.2	427.4	178.0	14,547.9
26-YEAR AVERAGE	362.2	69.3	104.7	16.5	6.8	559.5

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. EXCLUDES SURFACE DIVERSIONS IMPORTED FROM THE SAN GABRIEL MOUNTAINS.
C. INCLUDES SURFACE DIVERSIONS IMPORTED FROM THE SAN GABRIEL MOUNTAINS.
D. COLORADO RIVER WATER RELEASED INTO SANTA ANA RIVER, LIVE OAK WASH AND PUDDINGSTONE DIVERSION CHANNEL.

TABLE 11 LOCATION OF SELECTED PRECIPITATION STATIONS IN AND ADJACENT TO THE CHINO-RIVERSIDE AREA

Station number[a]	Station name	Location[b]
Los Angeles County Flood Control District Precipitation Stations[c]		
85G	Mt. Baldy Guard Station	U.S.F.S. Guard Station, Mt. Baldy
87	San Dimas Guard Station	9292 N. Mainfork, San Dimas Canyon Road
96B-E	Puddingstone Dam	Puddingstone Dam at caretaker's house
230D	Claremont-Elder	899 Maryhurst Drive, Claremont
255C	Mount San Antonio College-Spadra	San Jose Hills near Spadra, Mt. San Antonio College
256B	Pomona-Fire Station	216 West Fifth Street, Pomona
263F	Pomona-Rivera	1 mile west of Park Avenue, and 2 miles south of Fifth Street, Pomona
356C	Spadra-Pacific Colony	State Hospital, south of Pomona Boulevard, Spadra
617B	Pomona-Adamson[d]	931 North Weber Street, Pomona
691B	San Antonio Spreading Grounds	San Antonio Spreading Grounds, mouth of San Antonio Canyon
740B	San Dimas Canyon - Fern No. 2	San Dimas Canyon, Fern Canyon
Orange County Flood Control District Precipitation Station		
23A	Santa Ana Canyon	Prado Dam at caretaker's house
Riverside County Flood Control and Water Conservation District Precipitation Stations		
3S/5W-21P1	Arlington (Gage Canal Company)	Jackson Street and Gage Canal, Riverside
3S/5W-30P1	Arlington Heights	Northeast corner of Dufferin and Prade Streets, and 600 feet southwest of Stewart Street, Arlington Heights, Riverside
3S/6W- 6P1	Norco (Orange Heights Water Company)	Near intersection of Tart Street and Adams Avenue, Norco
3S/7W-25P2	Corona (Temescal Water Company Office)[d]	100 feet south of 7th Street, and 100 feet east of Main Street, Corona
4S/7W-12P1	Corona (Foothill Lemon Company No. 2)[d]	Halfway between Taylor Street and Buena Vista Street, and 200 feet south of Hill Street, Corona
San Bernardino County Flood Control District Precipitation Stations[e]		
5B	Declez-Fontana Fire Station No. 2	Near intersection of San Bernardino Avenue and Fontana Avenue, Fontana
7A	Pine Avenue No. 2, Chino	2,500 feet south and 3,000 feet east of intersection of Pine Avenue and Euclid Avenue, Chino
8C	Crestmore	0.1 miles west of Bloomington Boulevard and 0.3 miles south of San Bernardino-Riverside County Line, Riverside
17	Fontana 5N (Crawford-Getchell)	0.6 miles southwest from intersection of Riverside Avenue and Lytle Creek Road, and 300 feet south of Lytle Creek Road

Station number[a]	Station name	Location[b]
San Bernardino County Flood Control District Precipitation Stations[e] (continued)		
18	Fontana (B & B)	8117 Palmetto Avenue, Fontana
20A	Carbon, California Jr. Republic[f]	Near intersection of Edison Avenue and Corona Freeway, Chino
21A	Mira Loma Air Force Base	At Mira Loma Quartermaster Depot near intersection of Mission Boulevard and Etiwanda Avenue, Mira Loma
26	Ontario Fire Station	119 South Euclid Avenue, Ontario
27	Colton Police Department[d]	251 West F Street, Colton
28	Day Creek	In triangle formed by roadways to and from Day Canyon Forestry Lookout, and the Day Canyon Road; 100 feet north of the lookout, San Bernardino
34	Claremont-Pomona College[d]	0.4 miles east northeast of Claremont Post Office, Claremont
69	Cucamonga	Garret and Co. - Virginia Dare. Corner of Foothill Boulevard and Haven Avenue (east of town of Cucamonga), Cucamonga
73	Fontana Power House No. 2	1.3 miles north of Highland Avenue, and 30 feet east of Riverside Avenue
75	Guasti Wine Company[d]	0.38 miles east of Archibald Avenue, and 200 feet south of the San Bernardino Freeway, Guasti
79	Chino-Imbach[d]	15108 Archibald Avenue, Chino
85	San Antonio Heights	24th Street and Euclid Avenue, San Antonio Heights
117	Upland-Jordan[d]	125 South 9th Street, Upland
119	Etiwanda-California Department of Forestry	1,250 feet south of Highland Avenue, and 150 feet west of Etiwanda Avenue, Etiwanda
124	Rubidoux Lab USDA	4500 Glenwood Drive, Riverside
125	West Riverside	California Department of Forestry, 7545 Mission Boulevard, Riverside
137	Monte Vista Fire Department Station 13	10585 Central Avenue, Montclair
142	Lytle Creek Power House No. 1	One mile north of Devore Cutoff on Lytle Creek Canyon Road
145	Riverside Fire Station No. 3	Near intersection of Magnolia Avenue, and Central Avenue, Riverside
182	Chino American Beet Sugar Company	520 G Street, Chino
191	Rialto, Adams	652 South Cactus Avenue, Rialto
198	Lytle Creek San Bernardino Water Department Plant[d]	Near intersection of Baseline Road and Meridan Avenue, Rialto

a. Station designation used by the agency operating the precipitation station.
b. Station locations delineated on Plate 1.
c. Detailed information on precipitation stations is presented in annual and biennial Hydrologic Reports of the Los Angeles County Flood Control District.
d. Base stations. RCFCAWCD station number 4S/7W-1P1 (Corona-Foothill Lemon Company No. 1) was used as a base station but not as a polygon station because it was within one mile of station R 4S/7W-12P1; therefore, it is not included in this table.
e. Detailed information on precipitation stations is presented in annual and biennial Hydrologic Reports of the San Bernardino County Flood Control District.
f. Formerly called "Casa Colina, Chino."

TABLE 12 ANNUAL DEPTH OF PRECIPITATION AT SELECTED STATIONS

SEASON (A)	STATION NUMBER(B) LACFCD 85G	LACFCD 87	LACFCD 96B-E	LACFCD 230D	LACFCD 255C	LACFCD 256B	LACFCD 263F	LACFCD 356C	LACFCD 617B	LACFCD 691B	LACFCD 740B	OCFCD 23A
1934-35	44.67	30.62	22.68	23.07C	23.69D	20.95	21.19	19.52C	21.70	26.70C	39.00C	18.50D
1935-36	27.96	21.42	14.55	15.47	14.04D	14.59	13.09	12.89C	14.18	17.63C	26.00C	10.63D
36-37	52.67	31.76	27.21	33.38	27.29D	29.26	29.27	29.10C	29.44	39.81C	46.00C	25.63D
37-38	57.35	35.67	27.34	29.90	26.86D	25.97	24.77	23.95C	27.68	32.77C	55.00C	20.89D
38-39	34.47	26.15	18.39	20.06	19.50D	19.56	19.62	17.42C	19.51	21.18	28.94	15.65D
39-40	24.20	20.87	14.58	15.62	15.69D	13.29	13.64	13.59C	14.61	18.40	22.26	11.52D
1940-41	57.32	41.46	36.96	39.46	38.72D	33.97	37.13	33.48C	37.63	40.69	54.49	31.54D
41-42	23.05	15.15	12.31	13.46	12.89D	12.83	12.87	12.74C	12.86	14.28	18.08	10.35D
42-43	57.22	37.12	23.87	28.33	24.43D	24.12	24.69	23.53C	25.07	35.62	49.71	19.79D
43-44	43.26	26.83	18.78	21.37	20.79D	17.90	18.60	19.51C	20.36	25.62	39.32	13.43D
44-45	36.67	27.83	17.01	17.93	16.57D	15.08	15.00	15.77	17.87	24.55	31.48	15.76
1945-46	34.75	22.18	14.98	15.88	14.58D	13.01	13.51	13.05	14.67	20.97	29.20	11.60
46-47	35.69	22.57	14.30	15.44	14.41D	12.73	13.34	12.81	15.56	22.82	33.56C	12.03
47-48	19.30	12.86	10.31	11.03	10.16	8.68	8.59	8.61	9.78	12.79	19.96	6.48
48-49	20.38	16.08	12.80	13.73	10.88	9.90	10.25	9.80	11.95	15.10	20.52	9.02
49-50	22.34	19.22	14.08	14.59	13.36	12.44	11.12	11.57	14.22	17.59	24.09	10.21
1950-51	11.73	11.04	9.53	10.30	9.65	8.67	9.51	8.89	9.78	11.04	13.84	8.46
51-52	50.07	37.23	27.45	28.99	27.93	28.23	27.36	26.93	28.31	35.07	49.78	22.67
52-53	17.95	15.52	11.87	13.69	12.28	12.54	12.05	11.78	12.51	15.21	19.29	9.16
53-54	30.93	22.17	16.45	18.63	15.70	15.75	14.69	16.10	16.80	21.34	31.10	13.62
54-55	21.06	16.35	12.17	13.42	12.70	12.05	12.15	13.02	13.52	14.75	23.18	12.10
1955-56	20.32	20.07	15.84	16.63	14.75	13.47	14.08	14.53	15.20	18.63C	23.04	13.28
56-57	20.99	17.81	12.62	14.45	11.45	11.10	10.68	10.98	11.50	15.55	23.74	11.06
57-58	57.31	43.33	31.92	33.85	32.40	31.22	33.09	28.92	32.78	41.00	59.96	25.13
58-59	20.04	11.85	8.04	7.90	8.15	7.33	7.55	8.23	7.88	10.52	17.71	5.59
59-60	17.40	11.22	10.17	10.83	10.98	9.61	9.45	10.11	10.26	12.00	16.66	8.52
26-YEAR AVERAGE	33.04	23.63	17.57	19.13	17.67	16.70	16.82	16.42	17.91	22.37	31.38	14.52

SEASON (A)	STATION NUMBER(B) SBCFCD 26	SBCFCD 27	SBCFCD 28	SBCFCD 34	SBCFCD 69	SBCFCD 73	SBCFCD 75	SBCFCD 79	SBCFCD 85	SBCFCD 117	SBCFCD 119	SBCFCD 124	SBCFCD 125
1934-35	20.35D	16.89	29.40C	22.85	20.47D	21.63	18.12	14.46	25.26	24.71	24.74	15.38	16.02C
1935-36	13.43D	13.41	19.42C	14.27	13.77D	15.75	11.57	8.53	17.07	17.03	16.18	8.56	10.58C
36-37	27.54D	24.96	43.83C	29.97	30.32D	30.33	26.94	20.86	34.61	35.10	35.91	20.98	23.89C
37-38	22.92D	19.82	36.08C	26.98	25.59D	26.15	20.92	16.32	32.90	30.01	32.04	12.97	19.66C
38-39	19.83D	14.71	26.25C	19.87	19.10D	20.18	16.32	11.96	22.42	21.96	23.06	11.74	14.30C
39-40	14.41D	12.81	20.48C	15.50	15.17D	18.10	12.87	9.75	18.45	16.54	18.23	9.38	11.16C
1940-41	37.35D	29.19	50.43C	38.27	36.32D	35.26	31.86	27.66	42.40	37.74	39.40	24.00	27.48C
41-42	13.41D	10.61	19.19C	12.73	15.31D	15.95	13.90	9.21	17.30C	14.89	16.89	9.31	10.45C
42-43	23.71D	20.23	35.45C	25.42	25.21	30.06	24.13	16.11	31.98C	28.20	31.50	14.35	19.32C
43-44	17.51D	16.83	29.39C	20.38	21.53	24.73	21.06	15.11	29.14	23.39	26.69	14.74	16.01C
44-45	14.56D	12.92	23.56D	17.84	16.70	24.40	14.94	10.92	27.50	18.77	21.56	10.65	13.41C
1945-46	13.51D	7.68	18.98D	14.63	17.27	15.71	13.36	8.93	19.92	16.96	18.93	7.22	10.23C
46-47	12.71D	10.73	21.21D	15.91	14.92	17.69	12.97	9.33	22.54	18.55	18.65	9.07	11.07C
47-48	7.61D	7.11	12.53D	10.03	10.04	12.63	8.86	5.53	12.36	11.10C	12.85	5.80	7.21C
48-49	10.24D	10.98	15.36D	10.79	10.82	18.29	9.76	7.78	15.52	13.71	14.85	7.49	8.00
49-50	12.16D	9.07	18.15D	13.86	13.82	15.89	11.31	8.33	17.60	15.81	16.57	7.83	8.37
1950-51	7.37D	7.39	9.87D	9.69	8.71	11.25	7.53	5.41	10.38	10.70	10.81	6.57	7.28
51-52	26.14D	21.31	47.80	29.78	29.95	30.26	25.98	21.25	33.39	32.52	32.98	19.15	18.17
52-53	12.03D	10.96	17.95C	12.65	12.89	14.79	11.54	7.91	14.02	17.21	15.01	9.14	8.89
53-54	15.25D	11.48	20.29	17.41	17.15	19.43	14.01	11.78	20.03	19.50	17.49	10.35	11.54
54-55	11.37D	10.86	17.32	12.64	12.50	17.22	11.67	10.90	13.89	12.17	14.58C	9.46	10.27
1955-56	13.78D	12.77	20.62	15.99	14.55	18.00	13.33	10.90	19.73	17.36	17.75C	9.23	11.45
56-57	11.56D	10.82	20.98	13.34	13.32	14.76	11.37	9.68	14.82	14.61	15.57C	8.86	10.75
57-58	28.62D	23.42	44.92	34.60	33.02	31.39	27.05	22.89	36.22	38.31	35.69C	15.73	19.08
58-59	5.60D	5.36	6.66	7.37	6.70	7.95	5.08	3.89C	8.52	7.62	7.72C	8.36	4.48
59-60	8.48D	8.49	15.06	9.35	9.49	12.14	9.03	8.47C	9.36	10.37	10.74C	3.41	8.28
26-YEAR AVERAGE	16.21	13.88	24.66	18.16	17.87	20.00	15.60	12.07	21.82	20.19	21.02	11.14	12.98

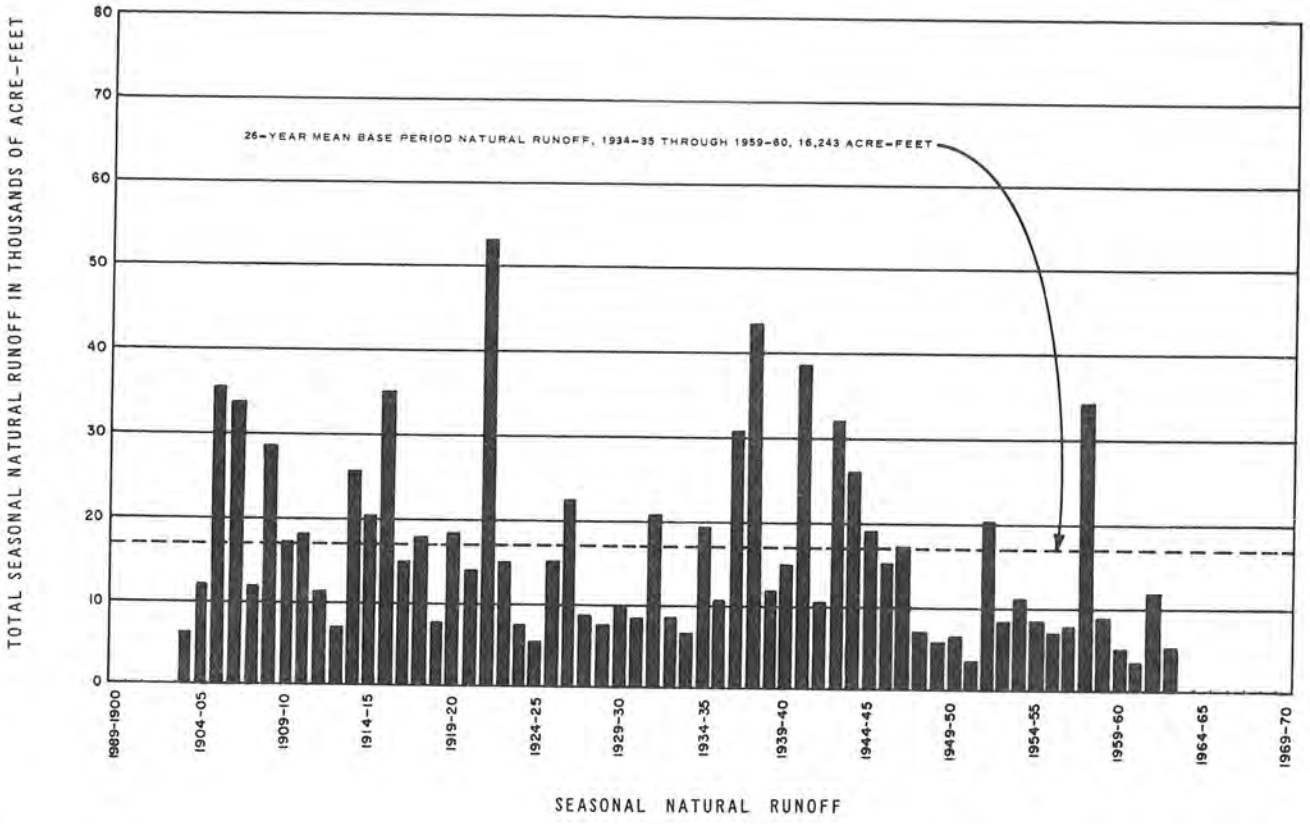
IN AND ADJACENT TO THE CHINO-RIVERSIDE AREA

IN INCHES

STATION NUMBER(B)												SEASON (A)
RCFCAWCD 3S/5W-21P1	RCFCAWCD 3S/5W-30P1	RCFCAWCD 3S/6W-6P1	RCFCAWCD 3S/7W-25P2	RCFCAWCD 4S/7W-12P1	SBCFCD 5B	SBCFCD 7A	SBCFCD 8C	SBCFCD 17	SBCFCD 18	SBCFCD 20A	SBCFCD 21A	
12.54C	11.77	14.90D	15.34	19.67	18.58C	17.77C	15.86C	30.79	21.90D	19.18C	16.96C	1934-35
8.28C	6.39	7.07D	8.70	13.05	12.27C	11.74C	10.47C	22.02	15.76D	12.66C	11.20C	1935-36
18.69C	18.39	20.00D	23.96	33.34	27.70C	26.50C	23.65C	40.46	33.85D	28.59C	25.29C	36-37
15.39C	11.52	14.79D	18.78	25.23	22.80C	21.81C	19.46C	40.83	26.82D	23.53C	20.81C	37-38
9.76	12.08	10.39D	13.63	19.87	16.59C	15.87C	14.16C	26.84	18.62D	17.12C	15.14C	38-39
8.76	8.64	9.17D	10.12	13.61	12.94C	12.38C	11.05C	24.08	17.45D	13.36C	11.81C	39-40
22.09	20.53	25.72	27.15	34.19	31.87C	30.49C	27.23C	47.26	35.54	32.90C	29.09C	1940-41
8.66	8.41	10.16	10.35	13.90	12.12C	11.60C	10.35C	19.90	14.02	12.51C	11.06C	41-42
13.96	13.29	14.61	18.86	25.72	22.40C	21.43C	19.12C	41.23	25.05	23.12C	20.45C	42-43
14.78	14.03	14.49	14.87	19.42	19.95	17.76C	17.97	31.62	23.96	18.56	17.49	43-44
9.84	9.21	11.63	13.35	18.18	14.80	14.88C	12.78	33.05	22.76	15.74	12.58	44-45
7.55	6.03	8.54	7.41	13.94	10.31	11.35C	9.15	21.54	12.83	12.73	9.97	1945-46
8.81	7.90	7.83	10.03	13.47	13.32	11.40C	10.97C	24.39	14.74	13.45	11.75	46-47
5.24	4.48	4.99	5.88	9.95	9.78	9.39	7.14C	16.55	10.58	8.62	8.17	47-48
7.53	6.42	7.01	7.54	11.25	11.54	8.80	8.99C	22.29	14.65	9.55	9.88	48-49
6.99	4.89	7.50	8.45	12.16	10.82	9.95	8.65C	21.90C	13.78	13.71	10.04	49-50
5.81	4.07	6.78	7.77	8.52	8.80	6.73C	7.61	14.91	9.99	9.43	7.77	1950-51
18.02	15.76	18.21	19.52	27.44	23.81	24.05	22.08	39.87	27.56	26.92	25.42	51-52
8.87	5.41	8.16	9.37	11.44	11.56C	10.39	10.23	19.61	13.01	12.32C	10.28	52-53
8.28	5.25	9.32	13.05	18.62	15.04C	13.73	13.30	26.57	17.38	14.55C	13.10	53-54
9.01	7.87C	8.08	9.42	13.48	13.63C	13.04	10.59	21.32	14.97	12.85C	12.65	54-55
7.21	8.08C	9.70	10.28	13.70	14.24C	12.97	9.58C	24.73	15.30	13.19	11.29	1955-56
8.44	6.38	8.57C	9.06	12.75	11.17C	11.06	9.98C	19.44	12.81	8.83	10.58	56-57
17.21	14.22C	18.87C	20.75	28.75	24.28	26.76	19.50C	41.53	27.08	28.19	21.25	57-58
3.87	3.62C	4.12C	4.61	6.69	5.82	3.36	4.49C	10.33	6.85	5.95	4.45	58-59
7.68	5.49C	6.26C	7.25	9.53	9.62	7.62	8.38	14.24	10.45	9.49	6.82	59-60
10.51	9.24	11.03	12.52	17.23	15.61	14.73	13.18	26.82	18.38	16.03	14.05	26-YEAR AVERAGE

SEASON (A)	STATION NUMBER(B)					
	SBCFCD 137	SBCFCD 142	SBCFCD 145	SBCFCD 182	SBCFCD 191	SBCFCD 198
1934-35	20.44D	40.34	14.70	20.93	21.35C	18.83
1935-36	14.39D	28.09	9.18	12.10	14.10C	14.48
36-37	27.25D	50.18	21.78	27.41	31.83C	30.14
37-38	23.41D	54.86	16.09	21.79	26.20C	26.14
38-39	18.98D	32.67	12.00	18.85	19.72	16.18
39-40	13.25D	29.15	9.64	13.03	16.46	15.14
1940-41	32.77D	54.65	23.02	36.79	33.66	32.63
41-42	13.29D	24.76	9.64	12.31	14.63	13.77
42-43	24.96D	45.63	15.16	22.07	24.64	24.37
43-44	21.13	38.68	15.79	17.78	23.29	21.42
44-45	15.06	39.08	10.95	14.12	18.65	19.23
1945-46	13.98	27.85	8.58	12.99	11.69	12.20
46-47	14.19	29.59	8.25	12.20	15.09	14.12
47-48	8.84	20.87	6.13	7.89	9.47	10.25
48-49	11.76	25.17	8.29	9.31	14.88	14.33
49-50	13.10	28.39	7.56	11.40	12.47	12.13
1950-51	8.83	18.19	4.20	8.67	9.25	9.53
51-52	28.07	42.79	17.71	24.84	24.53	25.57
52-53	12.97	24.01	8.93	11.84	13.36	13.22
53-54	15.28	31.72	9.64	15.88	18.24	16.41
54-55	11.43	24.87	8.68	12.77	15.14	13.55
1955-56	13.74	26.76	9.09	14.78	15.60	13.98
56-57	11.30	22.00	8.51	9.08	14.69	12.59
57-58	30.92	46.50	15.67	27.03	26.29	25.83
58-59	5.87	13.30	3.66	6.08	5.79	6.27
59-60	8.53	17.59	7.06	15.06	10.26	10.73
26-YEAR AVERAGE	16.68	32.22	11.15	16.04	17.74	17.04

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. AGENCY DESIGNATION. LACFCD-LOS ANGELES COUNTY FLOOD CONTROL DISTRICT, OCFCD-ORANGE COUNTY FLOOD CONTROL DISTRICT, RCFCAWCD-RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, SBCFCD-SAN BERNARDINO COUNTY FLOOD CONTROL DISTRICT.
C. ESTIMATED BY THE DEPARTMENT OF WATER RESOURCES.
D. ADJUSTED BY THE DEPARTMENT OF WATER RESOURCES PRINCIPALLY FOR CHANGES IN GAGE LOCATION.



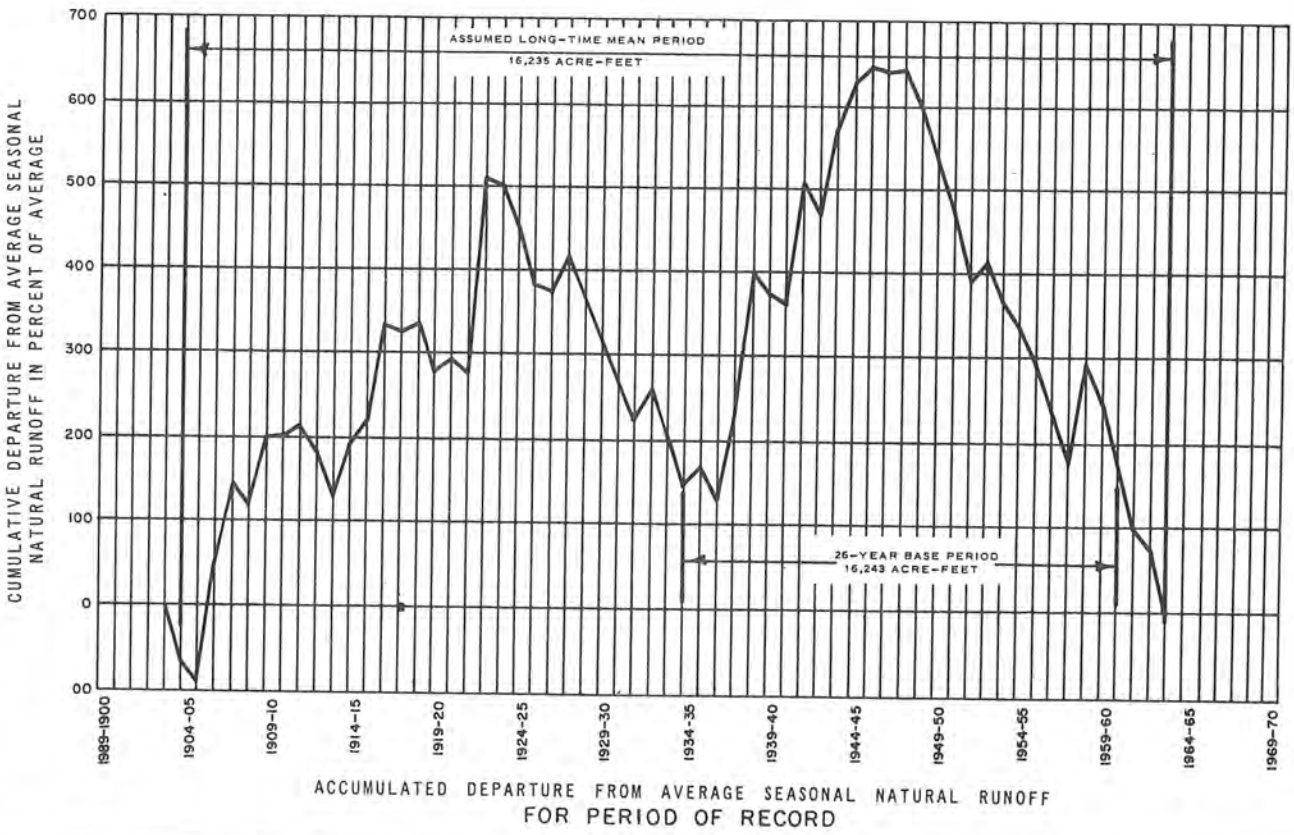


Figure 25-RUNOFF CHARACTERISTICS AT SAN ANTONIO CREEK

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1970

base period, depicts the areal variation of precipitation over the Chino-Riverside area. The average seasonal precipitation over the water-bearing area for the 26-year base period was 15.7 inches, or 362,200 acre-feet. This rainfall provided about 61 percent of the average seasonal total water supply. Table 10 shows that the highest seasonal precipitation occurred in 1940-41, with a volume of 742,300 acre-feet, while the lowest, 135,000 acre-feet, occurred in 1958-59. In general, precipitation was above average from 1934-35 to 1944-45 and below average from 1945-46 to 1959-60.

Surface inflow consists of surface water that crosses the boundaries of the water-bearing portions of the Chino-Riverside area. Natural runoff is included in this category, but diversions and imports are categorized differently. The major source of water coming into the area is the Santa Ana River-Warm Creek stream system that crosses the San Jacinto Fault. Other surface inflows are: inflow to Puddingstone Reservoir from the San Gabriel Valley; inflow from the San Jacinto Valley through Temescal Creek and runoff from the contiguous nonwater-bearing areas. Inflow from the San Gabriel Valley, Bunker Hill area, and San Jacinto Valley is gaged, as is most of the inflow from the San Gabriel Mountains. Inflow from the impervious hills within and along the southern periphery of the basin is mainly ungaged and is estimated by rainfall-runoff relationships. Runoff from the ungaged portions of the San Gabriel Mountains was estimated either from a correlation with an adjacent gaged area or from a rainfall-runoff relationship. Station locations are shown on Plate 15, and in Table 13. Records of these stations are presented in Table 14.

The average seasonal surface inflow to the water-bearing portion during the base period was about 70,000 acre-feet, of which about 35,000 acre-feet

TABLE 13

LOCATION OF SELECTED STREAM GAGING STATIONS IN AND ADJACENT TO THE CHINO-RIVERSIDE AREA

Station number[a]	Station name	Period of record
	Los Angeles County Flood Control District	
F 31-R	Live Oak Creek near Mouth of Canyon	1928 to present[b]
F 32B-R	Thompson Creek below Thompson Creek Dam	1943 to present
F 40-R	Puddingstone Creek below Puddingstone Dam	1928 to present
F 151-R	San Antonio Creek at Mouth of Canyon	1931 to 1955
F 276-R	Thompson Creek Spreading Grounds Intake	1940 to present
F 307-R	Puddingstone Diversion Channel	1953 to present
F 311-R	Live Oak Wash below Seventh Street	1953 to present
	San Bernardino County Flood Control District	
1.11hA	Carbon Creek at Ramona Avenue	1942 to present
	United States Geological Survey	
11-560.00	Santa Ana River near San Bernardino	1954 to present
11-575.00	San Timoteo Creek near Loma Linda	1954 to present
11-580.00	Santa Ana River at E Street Bridge	1939 to 1954
11-660.00	Warm Creek near Colton	1920 to present
11-665.00	Santa Ana River near Riverside Narrows	1927 to present
11-670.00	Day Creek near Etiwanda	1927 to present
11-685.00	Cucamonga Creek near Upland	1927 to present
11-720.00	Temescal Creek near Corona	1927 to present
11-740.00	Santa Ana River below Prado Dam	1930 to present
11-745.00	Santa Ana River at County Line	1919 to present

a. Station designation used by the agency operating the stream gaging station.
b. Present refers to conclusion of base period--September 30, 1960.

were contributed by the Santa Ana River and Warm Creek and about 26,000 acre-feet from the San Gabriel Mountains. Water that is diverted from streams in the San Gabriel Mountains and enters the basin through ditches and pipes for domestic and agricultural uses and for spreading in artificial recharge projects was considered to be a fresh-water import.

The average seasonal surface inflow amounted to about 12 percent of the average seasonal total supply to the basin. Seasonal surface inflow varied from a low of 8,500 acre-feet in 1959-60 to a high of 348,400 acre-feet in 1937-38. The seasonal amount of surface inflow for the period 1934-35 through 1959-60 is shown in Table 10.

Fresh water import to the basin is any transportation of water effected by man into the area, such as water conveyed in a ditch or pipeline. Water

TABLE 14

ANNUAL RUNOFF AT SELECTED GAGING STATIONS IN AND

SEASON (A)	CARBON CREEK AT RAMONA AVENUE 1.114A	CUCAMONGA CREEK NEAR UPLAND 11-685.00	DAY CREEK NEAR ETIWANDA 11-670.00	LIVE OAK CREEK NEAR MOUTH OF CANYON F 31-R	LIVE OAK WASH BELOW SEVENTH STREET F 311-R	PUDDINGSTONE CREEK BELOW PUDDINGSTONE DAM F 40-R	PUDDINGSTONE DIVERSION CHANNEL F 307-R	SAN ANTONIO CREEK AT MOUTH OF CANYON F 151-R	SANTA ANA RIVER AT COUNTY LINE 11-745.00
1934-35		5,070	2,820	0		44		6,840	56,420
1935-36		3,590	2,160	0		36		1,640	51,590
36-37		10,860	6,360	429		198		22,570	120,000
37-38		18,150	12,130	794		4,810		42,300	229,120
38-39		4,560	3,120	1		1,330		1,430	63,130
39-40		4,480	2,390	10		145		2,820	61,300
1940-41		14,640	8,260	763		1,790		28,570	--B
41-42		3,650	1,810	0		1,640		83	--B
42-43	811	12,220	6,820	822		3,060		29,990	--B
43-44	364	9,140	5,070	215		1,120		10,280	
44-45	123	8,160	4,270	150		394		4,960	--B
1945-46	80	5,780	2,680	76		2,840		3,270	--B
46-47	92	6,970	2,960	38		131		5,800	--B
47-48	1	2,220	526	0		49		6	--B
48-49	1	1,860	536	0		45		0	--B
49-50	19	2,170	615	0		28		55	--B
1950-51	0	1,130	193	0		11		3	--B
51-52	900	7,100	3,500	397		108		9,870	--B
52-53	21	2,330	536	0		135	--B	24	74,490
53-54	279	4,490	1,270	57	29,604	30,650	432	4,140	114,300
54-55	--B	2,270	488	0	24,080	23,300	1,368	--B	96,650
1955-56	670	2,100	577	67	56,039	50,800	74		71,310
56-57	18	1,840	724	0	50,010	53,780	27		45,390
57-58	469	12,370	4,770	594	0	314	0		79,700
58-59	23	3,450	783	2	0	60	--B		38,010
59-60	0	1,600	228	0	464	42	0		35,210

conveyed through the area without contributing to the basin's water supply, such as in MWD feeders, is not an import. However, Colorado River water released into the study area for transportation to spreading grounds in the Coastal Plain of Los Angeles and Orange Counties is considered to be an import, since in passing through the area some of the water may percolate and flow out of the basin as rising water.

Average seasonal fresh water imports to the area during the base period were about 121,200 acre-feet, about 21 percent of the average seasonal supply to the basin. Fresh water imports increased from 90,100 acre-feet in 1934-35 to a maximum of 192,700 acre-feet in 1953-54. Estimates of seasonal fresh water imports during the base period are shown in Table 10.

During the study period, an average seasonal amount of 15,400 acre-feet of surface water diverted from streams in the San Gabriel Mountains was considered to be a water import. Of this amount, 4,400 acre-feet were spread in artificial recharge projects and 11,000 acre-feet were used for domestic and irrigation purposes. Although diversions were considered as imports, they were merely transported from the frontal area of the mountains into the water-bearing area. The seasonal amounts of water diverted from the San Gabriel Mountains are shown in Table 15. Quantities of diverted water inflow used for various purposes are shown in Table 16.

Colorado River water was first imported into the study area in 1949 when it was released into the Santa Ana River near Riverside Narrows for conveyance to spreading grounds in the Coastal Plain of Orange County. Beginning in 1954, similar releases of Colorado River water were made in the Live Oak Wash and Puddingstone Diversion Channel for conveyance through Puddingstone Reservoir and ultimate recharge in the Coastal Plain of Los Angeles County. Table 17 shows imports of Colorado River water discharged into streams in the water-bearing area of the area of investigation.

The major portion of fresh water imports, close to 70 percent, comes from above the San Jacinto Fault. The remainder is made up of fresh water imports from Temescal Canyon, diversions

ADJACENT TO THE CHINO-RIVERSIDE AREA — IN ACRE-FEET

SANTA ANA RIVER AT E STREET BRIDGE 11-580.00	SANTA ANA RIVER BELOW PRADO DAM 11-740.00	SANTA ANA RIVER NEAR RIVERSIDE NARROWS 11-665.00	SANTA ANA RIVER NEAR SAN BERNARDINO 11-560.00	SAN TIMOTEO CREEK NEAR LOMA LINDA 11-575.00	TEMESCAL CREEK NEAR CORONA 11-720.00	THOMPSON CREEK BELOW THOMPSON CREEK DAM F 328-R	THOMPSON CREEK SPREADING GROUNDS INTAKE F 276-R	WARM CREEK NEAR COLTON 11-660.00	SEASON (A)
	--B	24,230			0			15,860	1934-35
	--B	25,650			0			9,840	1935-36
	--B	75,080			3,350			23,460	36-37
	--B	196,500			26,980			69,710	37-38
--B	--B	29,590			5,200			32,290	38-39
5,980	--B	28,450			1,380			28,820	39-40
41,000	174,400	101,000			12,830		545	52,730	1940-41
2,950	77,920	39,200			2,520		0	41,250	41-42
25,530	144,700	93,380			13,350		317	55,220	42-43
4,980	109,700	61,210			6,460	0	37	56,200	43-44
8,700	102,200	57,150			2,100	0	18	51,250	44-45
9,570	86,900	51,490			803	0	5	45,490	1945-46
7,260	84,200	49,640			31	0	0	44,060	46-47
2,100	59,110	32,520			3	0	0	33,030	47-48
1,910	57,900	34,420			1	0	0	27,910	48-49
2,240	74,570	52,590			2	0	0	23,400	49-50
566	70,340	51,520			0	0	0	16,000	1950-51
16,350	123,300	74,380			765	33	163	26,520	51-52
2,910	73,390	52,120			9	0	0	15,460	52-53
3,880	113,300	88,860			26	0	0	15,850	53-54
	96,380	74,900	1,330	569	23	0	0	12,500	54-55
	70,590	48,130	2,950	1,170	35	0	0	11,590	1955-56
	44,190	24,800	1,580	698	6	0	0	12,230	56-57
	75,700	34,030	15,430	2,080	218	219	163	19,820	57-58
	35,480	17,820	723	702	10	0	0	9,350	58-59
	32,830	18,050	969	888	6	0	0	6,300	59-60

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCOMPLETE RECORD, NOT SHOWN.

from the San Gabriel Mountains and imports of Colorado River water. Table 18 lists water service agencies and amounts of water imported by each agency into the Chino-Riverside area.

The ground water reservoir under the Chino Plain receives subsurface inflow both from the watersheds around the valley and from adjacent ground water reservoirs.

Most of the precipitation in the Chino-Riverside area falls on the mountains and highlands; much of the rain and meltwater runs off the surface of the impervious rocks into canyons that drain towards the valley, but a portion finds its way into fractures and joints, and eventually percolates into the valley-filling alluvium as frontal flow from bedrock. In addition, some of the surface runoff in the larger canyons is absorbed into the alluvial bed and migrates in the subsurface to the central ground water body.

The greatest part of watershed-derived underflow in the Chino-Riverside ground water reservoir comes from the San Gabriel Mountains and only very minor amounts from the semi-arid uplands west and south of the reservoir. The difference is exemplified in the subsurface inflow calculations (Table 9) for San Antonio Canyon, the main canyon draining the San Gabriel Mountains, and for Reche Canyon near Riverside. Frontal flow is almost completely limited to the northern side of the Chino Plain, where ground water passes from the high San Gabriel Mountain block into the alluvium in the valley.

Subsurface inflow across the boundary of the Chino-Riverside area takes place in permeable materials that are in hydrologic continuity with ground water in the San Bernardino Valley to the northeast and Temescal Valley to the south.

Because of recent geologic activity, zones of clayey fault gouge and mineralized, cemented rock along the Cucamonga Fault zone extend upward through the alluvium to form a continuous, nearly impermeable ground water impediment at the base of the San Gabriel Mountains. The water impounded behind the barrier overflows through surface seeps or through the alluvium and soil layers overlying the faults.

The effect of the Cucamonga Fault zone is seen at the mouth of Day Canyon, north of Etiwanda, where impounded ground water forms a boggy meadow on the upthrown side of a 10-foot high, south-facing escarpment in the bouldery alluvium. At the scarp line, rising ground water seeps from the face, flows across the fault line, and sinks in the dry soil beyond. A tunnel drilled in the early 1950's through a three-foot thick zone of red clayey gouge near the mouth of San Sevine Canyon north of Fontana, let out a "flood" of impounded water that gradually diminished to less than 20 gpm (Lee F. Dutcher, verbal communication, 1965).

Although lateral wells drawing from water impounded behind the Sierra Madre Fault have been an important source of water in the San Gabriel Valley for years, early attempts to develop similar w ells through the Cucamonga Fault zone failed for lack of sustained flow (Mendenhall, 1908, pps. 34-35). Frontal flow from the San Gabriel Mountains passes through or across the Cucamonga Fault zone, excluding San Antonio Canyon, at an estimated average rate of 7,000 acre-feet per year. Frontal flow from other watersheds in the area appears to be very small and is assumed to be zero.

TABLE 15 DIVERTED WATER INFLOW TO THE CHINO-RIVERSIDE GROUND WATER BASIN IN ACRE FEET

SEASON (A)	SAN ANTONIO CANYON			DEER CANYON	DAY CANYON	EAST ETIWANDA CANYON	TOTAL
	STREAM DIVERSIONS BY CANON WATER CO.	STREAM DIVERSIONS BY SAN ANTONIO WATER CO.	GALLERY DIVERSIONS BY SAN ANTONIO WATER CO.	GALLERY DIVERSIONS BY HERMOSA WATER CO.	STREAM DIVERSIONS BY ETIWANDA WATER CO. WEST CANYON	STREAM DIVERSIONS BY ETIWANDA WATER CO.	
1934-35	4,130	9,570	1,190	560	2,590 B	1,310	19,350
1935-36	3,670	7,350	860	460	2,130 B	1,030	15,500
1936-37	4,250	10,380	2,150	870	3,140 B	1,830	22,620
1937-38	3,960	8,900	2,900	1,460	3,370 B	1,700	22,290
1938-39	3,890	6,620	1,540	630	2,250 B	1,480	16,410
1939-40	4,260	9,040	1,710	630	1,200 C	1,410	18,250
1940-41	4,250	10,660	2,270	1,010	1,650 C	1,080	20,920
1941-42	4,230	7,860	1,520	710	1,880 C	1,440	17,640
1942-43	3,550	8,600	2,700	1,120	1,390 C	1,170	18,530
1943-44	4,390	10,660	2,990	1,100	1,510 C	1,180	21,830
1944-45	4,490	9,540	2,730	910	1,900 C	1,380	20,950
1945-46	4,060	8,430	1,750	830	1,900 C	900	17,870
1946-47	4,090	9,000	1,930	740	1,400 C	640	17,800
1947-48	2,610	4,660	840	790	1,490 C	990	11,380
1948-49	2,100	4,070	530	800	1,280 C	890	9,670
1949-50	2,570	4,210	550	700	1,270 C	650	9,950
1950-51	1,330	2,510	300	590	890 D	520	6,140
1951-52	3,660	8,950	1,260	1,000	1,610 D	1,400	17,880
1952-53	2,830	4,870	610	510	1,500 D	810	11,130
1953-54	3,250	7,000	720	500	920 D	830	13,220
1954-55	3,280	5,260	790	400	930 D	660	11,320
1955-56	2,540	4,390	710	310	720 D	540	9,210
1956-57	2,700	4,200	710	300	550 D	540	9,000
1957-58	4,110	10,250	2,470	460	1,460 D	1,580	20,330
1958-59	3,400	5,750	1,110	220	1,600 D	900	12,980
1959-60	1,970	3,690	480	250	1,000 D	530	7,920
26-YEAR TOTAL	89,570	186,420	37,320	17,860	41,530	27,390	400,090
26-YEAR AVERAGE	3,445	7,170	1,435	687	1,597	1,053	15,388

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. ESTIMATED FROM ETIWANDA WATER CO. RECORDS
C. FROM USGS-WSP BASED ON PERIODIC MEASUREMENTS.
D. FROM USGS-WSP MEASURED VALUES.

TABLE 16

TOTAL DIVERTED WATER INFLOW AND OUTFLOW IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN ACRE FEET

SEASON (A)	INFLOW			OUTFLOW
	DOMESTIC AND IRRIGATION	ARTIFICIAL RECHARGE	TOTAL	DOMESTIC AND IRRIGATION (B)
1934-35	12,460	6,890	19,350	8,200
1935-36	10,710	4,790	15,500	8,290
1936-37	14,340	8,280	22,620	8,370
1937-38	16,310	5,980	22,290	8,440
1938-39	11,430	4,980	16,410	8,530
1939-40	12,040	6,210	18,250	8,590
1940-41	13,130	7,790	20,920	8,700
1941-42	13,550	4,090	17,640	8,780
1942-43	13,570	4,960	18,530	9,060
1943-44	14,730	7,100	21,830	9,310
1944-45	16,010	4,940	20,950	9,580
1945-46	11,840	6,030	17,870	9,880
1946-47	14,350	3,450	17,800	10,140
1947-48	9,360	2,020	11,380	10,430
1948-49	7,610	2,060	9,670	10,540
1949-50	7,740	2,210	9,950	10,670
1950-51	5,330	810	6,140	10,780
1951-52	14,980	2,900	17,880	10,910
1952-53	9,790	1,340	11,130	11,050
1953-54	11,100	2,120	13,220	11,180
1954-55	8,650	2,670	11,320	11,290
1955-56	7,100	2,110	9,210	11,390
1956-57	5,930	3,070	9,000	11,250
1957-58	10,010	10,320	20,330	11,970
1958-59	9,200	3,780	12,980	12,240
1959-60	5,610	2,310	7,920	12,490
26-YEAR TOTAL	286,880	113,210	400,090	262,060
26-YEAR AVERAGE	11,034	4,354	15,388	10,079

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

B. TOTAL WATER DELIVERED TO THE NONWATER-BEARING AREA OF THE BASIN. THIS WATER WAS OBTAINED FROM PUMPAGE IN THE GROUND WATER BASIN AND COMPUTED BY KNOWN LAND USE.

TABLE 17

IMPORTS OF COLORADO RIVER WATER DISCHARGED INTO STREAMS IN THE WATER-BEARING AREA

(VALUES IN ACRE FEET)

SEASON (A)	LIVE OAK WASH LACFCD F311-R (B)	PUDDINGSTONE DIVERSION CHANNEL LACFCD F307-R (C)	SANTA ANA RIVER AT THE RIVERSIDE NARROWS (D)	TOTAL
1934-35				
1935-36				
1936-37				
1937-38				
1938-39				
1939-40				
1940-41				
1941-42				
1942-43				
1943-44				
1944-45				
1945-46				
1946-47				
1947-48				
1948-49			4,670	4,670
1949-50			25,270	25,270
1950-51			28,470	28,470
1951-52			38,160	38,160
1952-53		480	28,890	29,370
1953-54	30,030	0	61,050	91,080
1954-55	24,760	680	52,440	77,880
1955-56	56,040	70	21,700	77,810
1956-57	50,030	0	3,930	53,960
1957-58	0	0		0
1958-59	0	0		0
1959-60	460	0		460
26-YEAR TOTAL	161,320	1,230	264,580	427,130
26-YEAR AVERAGE	6,205	47	10,176	16,428

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. DELIVERY BEGAN JULY 1954.
C. DELIVERY BEGAN APRIL 1954.
D. DELIVERY BEGAN AUGUST 1949 AND ENDED OCTOBER 1956.

Yearly underflow at the mouth of San Antonio Canyon (Table 9), where the bedrock channel is 3,000 feet wide and is filled with alluvium to a maximum depth of 192 feet, has been calculated using a flow equation based on Darcy's Law. The average of these underflow figures is about 6,000 acre-feet per year. Large variations in underflow from year to year reflect this low-storage, high-permeability system's sensitivity to variations in annual water supply.

Underflow, in the alluvium that fills smaller canyons draining from the San Gabriel Mountains, is intercepted at the Cucamonga Fault barrier where the water either seeps through the fault zone to contribute to frontal flow or rises to the surface. The total subsurface inflow from the San Gabriel Mountains is a combination of frontal flow from bedrock into alluvium and underflow from San Antonio Canyon, amounting to approximately 13,000 acre-feet per year.

In Reche Canyon, one of the largest and deepest of the alluviated washes that lead from the highlands behind Riverside, underflow is apparently negligible, even in wet years. No hydrologic evidence suggests that conditions are different elsewhere around the southern and western margin of the basin. The Chino-Riverside area ground water inflow from these watersheds, including frontal flow, is considered negligible in the planned utilization study.

At the northeastern boundary of the valley, which follows the partly-buried trace of the San Jacinto Fault zone, ground water flows into the Chino-Riverside area through relatively thick bodies of younger alluvium that

lie across the impermeable fault planes at the mouth of Lytle Creek Canyon and in the Santa Ana River channel at Colton Narrows.

The geometry of subsurface water barriers under the alluvial fan deposits at the mouth of Lytle Creek Canyon can only be inferred from widely spaced water level data. The position of "Barrier E", northward from its intersection with "Barrier J", is based upon limited information (Plate 2). However, it is clearly apparent from the gradient of the water table in the northeastern corner of the area that ground water flows across this segment of "Barrier E", into the Chino-Riverside area. Southward from the intersection of "Barrier E" with "Barrier J", however, the boundary of the area follows buried fault planes that greatly retard the flow of ground water.

Where inflow from the Lytle Creek fan crosses the north end of "Barrier E", the width of the permeable material in a section normal to the path of flow is approximately 1.5 miles. Dutcher

TABLE 18

FRESH WATER IMPORT

SEASON (A)	BARNHILL MUTUAL WATER CO.	U.OF CALIF. RIVERSIDE CITRUS STA. (C)	CITIZENS LAND AND WATER CO	CITY OF COLTON
1934-35	400	301	3,230	2,240
1935-36	440	417	4,280	2,550
1936-37	480	245	4,150	2,620
1937-38	500	231	3,680	2,400
1938-39	500	336	3,960	2,690
1939-40	460	581	5,290	2,800
1940-41	400	81	4,010	2,740
1941-42	500	450	5,874	2,650
1942-43	500	167	7,006	3,140
1943-44	500	221	7,603	3,070
1944-45	500	223	7,488	3,260
1945-46	500	422	8,978	4,070
1946-47	570	187	7,320	4,060
1947-48	580	94	7,060	4,160
1948-49	580	304	7,079	4,170
1949-50	560	263	5,967	4,230
1950-51	550	330	5,618	4,330
1951-52	260	192	4,595	3,880
1952-53	130	441	5,955	3,500
1953-54	130	213	6,129	3,550
1954-55	110	652	5,117	4,120
1955-56	160	244	6,140	4,440
1956-57	80	324	4,210	3,970
1957-58	40	402	4,748	3,010
1958-59	10	481	5,989	2,990
1959-60	90 B	591	6,350	3,200
26-YEAR TOTAL	9,530	8,393	147,826	87,840
26-YEAR AVERAGE	367	323	5,686	3,378

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. COMPANY ABSORBED BY CITY OF COLTON.
C. WATER TRANSPORTED IN THE GAGE CANAL.

SEASON (A)	FONTANA-UNION WATER CO. (B)	GAGE CANAL COMPANY	LYTLE CREEK WATER AND IMPROVEMENT CO.	MEEKS AND DALEY WATER CO.
1934-35	12,370	21,560	3,742	7,210
1935-36	13,630	27,430	5,090	9,860
1936-37	16,730	20,020	3,392	7,300
1937-38	17,650	26,080	3,625	7,990
1938-39	15,800	26,190	4,597	6,980
1939-40	15,800	26,780	5,285	10,040
1940-41	15,450	22,510	2,717	7,120
1941-42	15,690	27,420	5,183	8,340
1942-43	21,230	24,830	5,752	7,940
1943-44	23,100	23,020	5,779	7,060
1944-45	19,160	24,790	5,684	9,120
1945-46	23,270	28,540	7,509	10,150
1946-47	21,800	26,470	7,259	9,950
1947-48	16,320	29,190	7,025	11,020
1948-49	13,540	26,640	6,772	10,660
1949-50	11,270	27,790	5,967	9,500
1950-51	8,600	30,150	5,618	10,760
1951-52	11,750	23,010	4,595	9,230
1952-53	12,650	25,620	5,955	10,480
1953-54	12,270	25,380	6,129	9,470
1954-55	12,160	25,600	5,117	7,900
1955-56	10,630	28,420	6,140	8,040
1956-57	9,240	26,740	4,210	6,430
1957-58	13,250	22,410	4,748	5,880
1958-59	16,680	29,690	7,122	7,450
1959-60	12,310	25,680	6,362	7,990
26-YEAR TOTAL	392,150	671,960	143,374	224,970
26-YEAR AVERAGE	15,083	25,845	5,514	8,653

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES BOTH SURFACE DIVERSION AND IMPORTED EXTRACTED WATER.

SEASON (A)	TOTAL MWD IMPORT	RANCHERIA WATER COMPANY	CITY OF RIALTO	RIALTO MUTUAL WATER CO
1934-35	0	323	B	927
1935-36	0	428	B	861
1936-37	0	415	580	995
1937-38	0	368	540	751
1938-39	0	396	600	798
1939-40	0	529	640	715
1940-41	0	401	650	844
1941-42	0	587	690	853
1942-43	0	701	740	818
1943-44	0	760	770	1,046
1944-45	0	749	800	1,155
1945-46	0	898	830	932
1946-47	0	732	910	1,056
1947-48	0	706	1,020	1,239
1948-49	4,670	616	970	1,540
1949-50	25,270	650	820	1,080
1950-51	29,430	776	620	1,280
1951-52	39,320	652	600	1,000
1952-53	31,040	613	620	1,370
1953-54	97,540	469	620	960
1954-55	84,880	421	790	830
1955-56	84,110	488	850	470
1956-57	62,740	290	710	780
1957-58	6,300	284	1,000	780
1958-59	7,050	374	1,450	580
1959-60	6,430	52	1,010	780
26-YEAR TOTAL	478,780	13,678	18,830	24,440
26-YEAR AVERAGE	18,415	526	724	940

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDED WITH LYTLE CREEK WATER AND IMPROV. CO.

IN ACRE FEET

TO THE CHINO-RIVERSIDE GROUND WATER BASIN

SEASON (A)	CITY OF RIVERSIDE DOMESTIC	CITY OF RIVERSIDE IRRIGATION (B)	RIVERSIDE HIGHLAND WATER CO.	CITY OF SAN BERNARDINO
1934-35	5,330	2,740	4,920	40
1935-36	5,950	3,740	4,740	40
1936-37	6,000	1,560	3,730	40
1937-38	5,530	1,460	4,470	40
1938-39	6,510	3,630	4,970	60
1939-40	6,600	6,300	4,330	50
1940-41	5,660	4,100	3,960	50
1941-42	6,780	5,160	5,250	50
1942-43	7,560	3,250	4,640	60
1943-44	7,790	3,980	4,550	50
1944-45	8,200	4,900	5,310	110
1945-46	9,180	5,870	4,610	110
1946-47	9,260	5,610	4,960	100
1947-48	9,870	5,580	7,630	100
1948-49	10,010	3,870	5,630	100
1949-50	10,280	4,170	5,900	100
1950-51	10,390	5,920	5,360	110
1951-52	10,380	5,200	4,100	110
1952-53	11,410	7,450	5,960	120
1953-54	12,720	5,710	4,070	220
1954-55	13,170	6,870	5,150	290
1955-56	14,990	8,260	5,280	320
1956-57	17,080	5,270	4,280	410
1957-58	16,690	7,320 C	3,890	340
1958-59	19,330	5,210 C	5,610	460
1959-60	18,450	4,230 C	5,030	500
26-YEAR TOTAL	265,120	127,360	128,330	3,980
26-YEAR AVERAGE	10,197	4,898	4,936	153

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES ONLY RICE THORN FLUME AND ANTIL REGION WATER DESTINED FOR RIVERSIDE FROM BUNKER HILL.
C. CALENDAR YEAR.

SEASON (A)	TOTAL TEMESCAL WASH IMPORT BY TEMESCAL WATER CO. (B)	TERRACE WATER CO.	TOTAL
1934-35	3,580	750	69,663
1935-36	5,740	750	85,946
1936-37	7,340	750	76,347
1937-38	9,150	750	84,315
1938-39	10,470	750	93,237
1939-40	8,160	750	95,110
1940-41	7,260	750	78,803
1941-42	9,320	750	95,447
1942-43	8,630	750	97,714
1943-44	9,350	1,000	99,649
1944-45	7,740	1,250	100,439
1945-46	8,370	1,230	115,469
1946-47	6,330	1,330	107,904
1947-48	4,180	1,110	106,884
1948-49	2,720	1,000	100,871
1949-50	2,620	1,340	117,777
1950-51	2,170	1,150	123,062
1951-52	3,090	1,180	123,144
1952-53	2,470	980	126,584
1953-54	3,660	950	190,190
1954-55	3,560	1,090	177,827
1955-56	3,140	1,110	183,232
1956-57	2,750	1,220	150,734
1957-58	5,080	1,140	97,312
1958-59	4,010	1,300	115,786
1959-60	3,260	1,030	103,345
26-YEAR TOTAL	144,150	26,080	2,916,791
26-YEAR AVERAGE	5,544	1,003	112,184

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. REPRESENTS ALL IMPORT IN TEMESCAL WASH.

and Garrett (p. 108, 1963) estimated this underflow to average 4,000 acre-feet per year assuming a gradient of 175 feet per mile and a permeability of 100 gallons per day per square foot (gpd/ft^2) for a gradient of one foot per foot in a saturated section about 130 feet thick. Later water level data were used to extend their computations through the year 1959-60. The underflow values computed on the basis of the additional data (Table 9) lowers the average to about 3,700 acre-feet per year.

In the Colton Narrows, north of Riverside, the Santa Ana River and its tributary, Warm Creek, flow into the Chino-Riverside area in an alluviated channel about one mile wide, in which the alluvium has a permeability of about 2,700 gpd/ft^2. Using an equation that takes advantage of simultaneous water level measurements in two observation wells along the line of ground water flow, Dutcher and Garrett(1963, p. 105) calculated annual underflow in this channel for the period 1935-1949. These figures were revised downward (Table 9) after a subsequent (1964) investigation by the Department of Water Resources established that the alluvium was less thick than had been assumed in the former study. Underflow values for 1950-60, the remainder of the base period, were extrapolated on the basis of water level records from the same wells used by Dutcher and Garrett and from correlative wells when the original observation wells ceased to be measured after 1954. A marked decline in subsurface flow is clearly evident over the base period, due principally to withdrawal of the normal underflow in the channel upstream from the San Jacinto Fault. The remaining flow consists of treated waste water effluent undiluted, or nearly so, by natural ground water. (Department of Water Resources, 1964).

The boundary of the study area in the Temescal Valley is south of Corona

and permits some ground water flow into the Chino-Riverside Area. Underflow from this region is effectively limited to the recent alluvial fill of Temescal Creek channel and very little ground water passes northward in the older alluvium underlying the rest of the Temescal Valley. The 600 foot wide creek channel contains alluvium with an estimated permeability of 1,500 gpd/ft,^{2} in which ground water flows under a hydraulic head of about 40 feet/mile. The annual inflow averaged about 100 acre-feet over the base period. At the end of the base period, the inflow was only about one-fifth what it had been at the beginning. This may have been due to increased consumptive use and evaporation losses in the Lake Elsinore district, at the upper end of the Temescal Valley.

Waste water imported into the study area originates from San Bernardino's two waste water treatment plants. The treated effluent is released to the Santa Ana River and to Warm Creek, where it flows across the San Jacinto Fault into the Chino-Riverside area. Historically, some of this waste water import has been diverted for irrigation use and the remaining effluent percolated in the Santa Ana River before reaching Riverside Narrows. Seasonal amounts of waste water import are shown in Table 10. Table 19 lists the amounts of waste water diverted for irrigation and percolation in the Santa Ana River.

Disposal. Water disposal, which includes use, is considered to be the removal of water from the water-bearing portion of the study area. The components of disposal include consumptive use, surface outflow, fresh water export, waste water export, and subsurface outflow. The average seasonal amount of water use and disposal during the 26-year base period 1934-35 through 1959-60 was about 614,600 acre-feet. Table 20 summarizes the historical surface water use and disposal for this 26-year base period. Table 21 lists the exports of Colorado River water from the Chino-Riverside area from 1934-35 to 1959-60. Table 22 lists the subsurface outflow.

Consumptive use is water consumed by vegetative growth in transpiration and building plant tissue; evaporation from adjacent soil; from water surfaces; and from foliage. It also includes water consumed and evaporated by nonvegetative use.

In general, consumptive use decreased during the base period, reflecting the change from agricultural to urban land use. The average seasonal consumptive

TABLE 19

WASTE WATER IMPORT
TO THE CHINO-RIVERSIDE GROUND WATER BASIN
IN ACRE FEET

SEASON (A)	DIVERTED FOR IRRIGATION	PERCOLATION IN SANTA ANA RIVER	TOTAL IMPORT
1934-35	1,020	3,090	4,110
1935-36	1,970	1,180	3,150
1936-37	1,330	2,220	3,550
1937-38	780	2,570	3,350
1938-39	710	3,040	3,750
1939-40	380	3,100	3,480
1940-41	0	3,840	3,840
1941-42	190	3,950	4,140
1942-43	580	4,130	4,710
1943-44	240	5,350	5,590
1944-45	0	6,790	6,790
1945-46	990	5,810	6,800
1946-47	2,000	5,060	7,060
1947-48	1,830	5,160	6,990
1948-49	2,680	4,940	7,620
1949-50	2,920	5,300	8,220
1950-51	3,900	4,340	8,240
1951-52	2,510	6,210	8,720
1952-53	2,590	6,000	8,590
1953-54	2,310	6,380	8,690
1954-55	590	8,420	9,010
1955-56	400	9,070	9,470
1956-57	10	9,690	9,700
1957-58		9,880	9,880
1958-59		10,080	10,080
1959-60		11,810	11,810
26-YEAR TOTAL	29,930	147,410	177,340
26-YEAR AVERAGE	1,151	5,670	6,821

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

TABLE 20

ESTIMATED HISTORICAL ANNUAL SURFACE WATER USE AND DISPOSAL
IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE-FEET

SEASON(A)	CONSUMPTIVE USE(B)	SURFACE OUTFLOW(C)	FRESH WATER EXPORT		WASTE WATER EXPORT	TOTAL SURFACE USE AND DISPOSAL
			LOCAL WATER(D)	MWD WATER CONVEYED THROUGH AREA(E)		
1934-35	535.8	61.7	10.4		1.3	609.2
1935-36	446.6	55.0	11.5		1.3	514.4
36-37	565.2	133.6	10.6		1.5	710.9
37-38	541.9	244.4	10.7		1.5	798.5
38-39	504.8	68.4	10.5		1.5	585.2
39-40	465.4	63.8	10.2		1.5	540.9
1940-41	595.4	198.8	10.2		1.6	806.0
41-42	467.8	78.8	10.7		1.9	559.2
42-43	535.6	160.1	11.6		2.2	709.5
43-44	530.3	116.0	11.4		2.4	660.1
44-45	511.6	105.7	11.8		2.4	631.5
1945-46	461.5	89.4	11.6		2.5	565.0
46-47	486.4	85.4	13.1		4.0	588.9
47-48	414.2	57.7	13.1		4.6	489.6
48-49	460.7	53.5	13.2	4.6	3.4	535.4
49-50	463.2	50.8	13.0	24.8	3.0	554.8
1950-51	428.7	42.6	13.0	27.9	3.0	515.2
51-52	566.9	97.0	12.6	37.4	3.9	717.8
52-53	478.4	46.0	13.5	28.8	3.8	570.5
53-54	480.7	56.6	13.4	89.8	5.0	645.5
54-55	480.4	42.1	14.5	76.8	9.5	623.3
1955-56	466.9	48.9	15.0	77.4	9.1	617.3
56-57	454.9	41.3	15.2	53.9	7.7	573.0
57-58	595.2	91.7	14.3	0	8.0	709.2
58-59	389.3	35.9	16.7	0	9.1	451.0
59-60	437.2	33.1	17.6	.5	10.1	498.5
TOTAL	12,765.0	2,158.3	329.4	421.9	105.8	15,780.4
26-YEAR AVERAGE	490.9	83.0	12.7	16.2	4.1	606.9

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES EXTRACTION BY PHREATOPHYTES.
C. INCLUDES RISING WATER OUTFLOW AT PRADO DAM.
D. INCLUDES WATER DELIVERED TO THE NONWATER-BEARING AREA WITHIN THE BASIN.
E. COLORADO RIVER WATER RELEASED TO LIVE OAK WASH, PUDDINGSTONE DIVERSION CHANNEL AND SANTA ANA RIVER.

TABLE 21

CHINO - RIVERSIDE AREA
EXPORTS OF COLORADO RIVER WATER
FROM THE WATER-BEARING AREA
In acre feet

Season[a]	Live Oak Wash LACFCD F311-R[b]	Puddingstone Diversion Channel LACFCD F307-R[c]	Santa Ana River at the Riverside Narrows[d]	Total
1934-35				
1935-36				
1936-37				
1937-38				
1938-39				
1939-40				
1940-41				
1941-42				
1942-43				
1943-44				
1944-45				
1945-46				
1946-47				
1947-48				
1948-49			4,580	4,580
1949-50			24,760	24,760
1950-51			27,900	27,900
1951-52			37,400	37,400
1952-53		480	28,310	28,790
1953-54	30,030	0	59,830	89,860
1954-55	24,760	680	51,390	76,830
1955-56	56,040	70	21,270	77,380
1956-57	50,030	0	3,850	53,880
1957-58	0	0		0
1958-59	0	0		0
1959-60	460	0		460
26-year total	161,320	1,230	259,290	421,840
26-year average	6,205	47	9,973	16,225

[a] 12-month period from October 1 through September 30.
[b] For artificial recharge in Montebello Forebay.
[c] To maintain water level in Puddingstone Reservoir.
[d] For artificial recharge in Orange County.

use of applied water and precipitation during the base period was about 490,900 acre-feet, which represented about 80 percent of the average seasonal total water use and disposal. As shown in Table 20, consumptive use varied from a low of 389,300 acre-feet in 1958-59 to a high of 595,400 acre-feet in 1940-41.

Land use surveys conducted by the Department of Water Resources (or its predecessor agencies) in 1932, 1942, 1948, 1957, and 1963 were used to establish the nature and extent of land use for the 26-year base period. The small portion of the study area located within Los Angeles County had a different schedule of land use surveys, the last three being in 1950, 1955, and 1960.

Land use was estimated for each year of the base period by a straight line interpolation between years of land use surveys. Studies of population trends and other factors indicated that the accuracy of this method was within the limits of accuracy of the land use data. As shown in Table 23, urban and suburban land use in the Chino-Riverside area increased from 27,000 acres in 1932 to 121,800 acres in 1963. On the other hand, irrigated agricultural areas decreased from 113,900 acres in 1932 to 87,100 acres in 1963 and nonwater service areas decreased from 136,200 acres in 1932 to 68,200 acres in 1963.

The seasonal amounts of consumptive use of precipitation and applied water were estimated by using the "Blaney-Criddle" method. The monthly consumptive use of irrigated crops and native vegetation is the product of an empirical consumptive use crop coefficient, average monthly temperature, and monthly ratio of daylight hours. To account for that portion of rain-

TABLE 22

SUBSURFACE OUTFLOW FROM THE
CHINO-RIVERSIDE AREA

In Acre-Feet

Season[a]	North Side San Jose Hills (San Dimas Gap)	South Side San Jose Hills (San Jose Wash)	Prado Dam[b]	Total
1934-35	4,290	160	2,400	6,850
1935-36	4,290	150	2,400	6,840
36-37	4,030	120	2,400	6,550
37-38	5,640	100	2,400	8,140
38-39	6,900	100	2,400	9,400
39-40	5,640	110	2,400	8,150
1940-41	6,160	150		6,310
41-42	7,700	240		7,940
42-43	7,700	220		7,920
43-44	8,220	240		8,460
44-45	8,220	260		8,480
1945-46	8,220	270		8,490
46-47	8,220	240		8,460
47-48	8,220	200		8,420
48-49	7,700	170		7,870
49-50	7,700	150		7,850
1950-51	7,500	150		7,650
51-52	6,160	140		6,300
52-53	6,900	170		7,070
53-54	7,500	170		7,670
54-55	6,900	200		7,100
1955-56	7,500	200		7,700
56-57	6,900	220		7,120
57-58	7,500	210		7,710
58-59	7,700	260		7,960
59-60	7,600	260		7,860
26-year Average	6,960	187		

[a] 12-month period from October 1 through September 30.
[b] Prado Dam in operation 1940; natural underflow ceased.

TABLE 23

ESTIMATES OF LAND USE IN THE CHINO-RIVERSIDE AREA FOR SURVEY YEARS WATER-BEARING AREA (in acres)

Nature and class of land use	1932	1942	1948	1957	1963
Water service areas					
Urban and suburban					
Residential, single	10,400	10,500	15,200	22,600	34,700
Residential, multiple	200	200	300	500	1,200
Residential, rural	3,200	3,100	3,300	2,700	1,700
Commercial	900	1,000	1,300	2,000	4,200
Industrial	1,700	1,700	2,600	2,700	4,400
Unclassified	900	900	1,400	4,300	7,000
Street	7,200	7,200	11,000	14,000	22,300
Included nonwater service areas	2,500	2,500	3,500	5,600	46,300
Gross urban and suburban areas	27,000	27,100	38,600	54,400	121,800
Irrigated agriculture					
Alfalfa	4,200	4,700	5,400	6,400	7,900
Pasture	6,400	7,900	12,100	13,000	15,000
Deciduous orchard, walnuts	24,400	17,800	12,200	3,600	500
Citrus	53,400	55,600	53,700	35,300	24,300
Truck crops	19,800	20,900	22,000	29,400	17,100
Vineyards	0	0	2,700	15,100	18,000
Street	5,700	5,600	5,700	5,400	4,300
Gross irrigated agricultural areas	113,900	112,500	113,800	108,200	87,100
Nonwater service areas					
Native vegetation, barren	2,600	2,700	2,300	2,100	1,300
Native vegetation, light	55,000	55,900	46,900	43,100	34,000
Native vegetation, medium	64,400	64,500	61,800	56,000	24,500
Native vegetation, heavy	4,700	4,700	4,200	4,100	1,700
Riparian vegetation	4,700	4,900	5,100	5,100	4,600
Street	4,800	4,800	4,400	4,100	2,100
Gross nonwater service areas	136,200	137,500	124,700	114,500	68,200
Grand Totals	277,100	277,100	277,100	277,100	277,100

DEFINITION OF NATURE AND CLASS OF LAND USE IN THE CHINO-RIVERSIDE AREA

WATER SERVICE AREAS

Urban and Suburban

Residential, single	One and two family urban units, and recreational residence.
Residential, multiple	Three family, and larger units, hospitals and institutions, one and two story hotels and motels, and recreational camp and trailer sites.
Residential, rural	Small rural units and farmsteads.
Commercial	Three and more story hotels, commercial office and retail buildings, theaters, arenas, churches, and recreational commercial.
Industrial	Manufacturing, assembling and processing establishments, all refineries, paper mills, meat packing, steel plants, and canneries.
Unclassified	Schools, dairies, and livestock and poultry feed lots.
Street	Streets, all paved and oiled surfaces, lined stream channels.
Included nonwater service area	Vacant unpaved or graveled areas, quarries, and dumps.

Irrigated Agriculture

Alfalfa	Alfalfa raised for hay, seed or pasture.
Pasture	Clover, pasture, lawns, parks, cemeteries, and sudan.
Deciduous, walnuts	Deciduous fruits and nuts.
Citrus	Citrus fruit, avocado, and subtropical fruits.
Truck Crops	Fresh vegetables, melons, flower seed, hay and grain, rice, and field crops.
Vineyards	All varieties of grapes.
Streets	Streets in agricultural areas.

NONWATER SERVICE AREAS

Native vegetation, barren	Bare ground and river washes.
Native vegetation, light	Idle land, grass land, and light brush.
Native vegetation, medium	Medium brush, native classes unsegregated, and nonirrigated agriculture.
Native vegetation, heavy	Heavy brush, brush and timber, forest.
Riparian vegetation	Swamps and marshes, meadow land, brush, trees and water surface.
Street	Streets in native areas.

TABLE 24

ESTIMATES OF AVERAGE SEASONAL UNIT VALUES OF CONSUMPTIVE USE IN THE CHINO-RIVERSIDE AREA FOR THE BASE PERIOD 1934-35 THROUGH 1959-60

In feet

Nature and class of land use	Applied water	Precipitation	Total
WATER SERVICE AREAS			
Urban and Suburban			
Residential, single	1.4	0.8	2.2
Residential, multiple	0.3	0.5	0.8
Residential, rural	0.8	0.7	1.5
Commercial	0.4	0.5	0.9
Industrial	1.4	0.5	1.9
Unclassified	0.5	0.6	1.1
Street	--	0.5	0.5
Included nonwater service area	--	0.6	0.6
Irrigated Agriculture			
Alfalfa	2.5	1.1	3.6
Pasture	2.6	1.0	3.6
Deciduous orchard, walnuts	1.6	1.1	2.7
Citrus	1.6	0.9	2.5
Truck crops	1.3	0.9	2.2
Vineyards	1.2	1.1	2.3
Street	--	0.5	0.5
NONWATER SERVICE AREAS			
Barren	--	0.6	0.6
Native vegetation	--	1.2	1.2
Riparian vegetation	--	1.3	4.8*
Street	--	0.5	0.5

*Includes consumptive use of ground water.

fall not used by plants, runoff due to rainfall was first estimated and then subtracted from the total rainfall. This yielded the rainfall supply available to plants.

Consumptive use of applied water during the growing and nongrowing season was calculated as the amount of water needed over and above the available precipitation. The average unit values of consumptive use of applied water and of precipitation developed in the above manner are contained in Table 24. The monthly consumptive use of irrigated crops, during the four to five months of the nongrowing season, was considered to equal the potential consumptive use or the available precipitation, whichever was smaller. To account for the moisture holding capacity of the soil, it was assumed that soil moisture would be depleted at the beginning of the water year and would be replenished, depending upon the monthly precipitation available in excess of runoff and consumptive use by plants, during the winter months; by the end of the water year soil moisture would be depleted again. When the root zone or the belt of soil water became saturated, it was assumed that the excess would percolate and eventually reach the zone of saturation.

Surface outflow occurs as water leaves the water-bearing portion of the study area through the natural stream system. The average seasonal surface outflow for the 26-year base period was about 83,000 acre-feet, or about 13 percent of the average seasonal total water use and disposal. Of the surface outflow, about 95 percent occurs through Prado Dam; the remaining five percent is through San Jose Wash 1/ and to Puddingstone Reservoir. As can be seen in Table 20, the seasonal outflow varied from a low of 33,100 acre-feet in 1959-60 to a high of 244,400 acre-feet in 1937-38.

To eliminate the need for accounting for the change of storage within Puddingstone Reservoir and evaporation from the stored water, Puddingstone Reservoir was assumed to lie outside the water-bearing portion of the study area. The surface outflow to Puddingstone Reservoir was then computed by taking the measured amounts of inflow to the Reservoir and subtracting the Colorado River water which was released into the Live Oak Wash and flowed into the Reservoir.

The gaged values of outflow at Prado include storm or local water, rising water, Colorado River water, and waste water. Colorado River water and waste water had to be deducted from the gaged values as they are considered fresh water export and waste water export, respectively. It was assumed that two percent of the Colorado River water is lost between its point of discharge

1/ Department of Water Resources, Bulletin No. 104-2, "Planned Utilization of Ground Water Basins — San Gabriel Valley, Appendix A, "Geohydrology".

and Prado, therefore, 98 percent of the measured releases to the Santa Ana River were subtracted from the gaged flow at Prado. The waste water that was released from the two waste water treatment plants in Riverside directly to the Santa Ana River was also subtracted from the gaged flow at Prado. Table 25 shows the composition of the gaged outflow at Prado.

As shown in Table 20, the average seasonal fresh water export from the Chino-Riverside area for the base period was about 28,900 acre-feet, or five percent of the total water use and disposal. Most of the fresh water export is Colorado River water passing through Prado, but other exports are: pumped ground water from the Prado Flood Control Basin, which is conveyed by pipeline through the dam and released to the river downstream; water conveyed from the water-bearing area for use in the nonwater-bearing portions of the study area; and water conveyed to the San Gabriel Valley. These quantities amount to a 26-year annual average of about 16,200 acre-feet of Colorado River water, 500 acre-feet of pumped ground water through Prado, 10,100 acre-feet to the nonwater-bearing areas, and 2,100 acre-feet to the San Gabriel Valley. Table 21 shows the details of the export of Colorado River water from the water-bearing area.

Water table gradients, except in the Pomona area, are generally towards the lowest point in the Chino-Riverside area, at Prado Dam (Plates 12 and 13). At Prado, the water-bearing alluvium is cut off by the dam and the ground water table intersects the ground surface. Consequently, ground water runs out of the area and becomes surface water in the Santa Ana River (Table 25). Prior to construction of Prado Dam (1940), some ground water escaped from the area at this point, but there is no longer any underflow where the river crosses the area boundary at Prado Dam.

TABLE 25
ESTIMATED COMPONENTS
OF THE GAGED FLOW AT PRADO
IN THOUSANDS OF ACRE-FEET

SEASON(A)	GAGED OUTFLOW	RISING WATER(B)	STORM FLOW	MWD WATER	WASTE WATER(C)
1934-35	56.9	46.7	10.2		
1935-36	53.3	41.7	11.6		
36-37	122.1	44.8	77.3		
37-38	229.7	50.7	179.0		
38-39	63.7	52.6	11.1		
39-40	62.2	52.1	10.1		
1940-41	174.4	59.6	114.8		
41-42	77.9	62.8	15.1		
42-43	144.7	62.3	82.4		
43-44	109.8	66.0	43.8		
44-45	102.2	65.6	36.6		
1945-46	86.9	60.2	26.7		
46-47	84.2	53.6	29.3		1.3
47-48	59.1	50.3	7.0		1.8
48-49	57.9	44.3	8.5	4.6	0.5
49-50	74.6	43.3	6.5	24.8	0
1950-51	70.3	38.0	4.4	27.9	0
51-52	123.3	37.9	47.5	37.4	0.5
52-53	73.4	37.7	7.3	28.3	0.1
53-54	113.3	39.4	14.1	59.8	0
54-55	96.4	34.8	6.1	51.4	4.1
1955-56	70.6	34.6	11.8	21.3	2.9
56-57	44.2	34.3	6.1	3.8	0
57-58	75.7	37.1	38.6		0
58-59	35.5	32.6	2.9		0
59-60	32.8	27.5	5.2		0.1
26-YEAR AVERAGE	88.3	46.6	31.3	10.0	0.4

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.
B. INCLUDES IRRIGATION WATER(WASTE WATER) RETURN FLOW FROM HIDDEN VALLEY RANCH.
C. INCLUDES ONLY DIRECT RELEASE TO THE SANTA ANA RIVER

Ground water flows into the upper San Gabriel Valley through the alluviated gaps north and south of the San Jose Hills. Underflow values in these channels, calculated for an earlier report by the Department of Water Resources (1966), are reproduced in Table 22. Average outflow in San Jose Wash is approximately 185 acre-feet per year; in the San Dimas gap north of the San Jose Hills it is approximately 7,000 acre-feet per year. No other points of underflow from the basin are known.

Waste water is exported from the Chino-Riverside area in pipelines to the Bunker Hill area and to the San Gabriel Valley and in the channels of the San Jose Wash and the Santa Ana River. As shown in Table 20, the average annual waste water export from the study area for the 26-year base period was about 4,100 acre-feet.

Waste water is exported to the Bunker Hill area in pipelines by the City of

San Bernardino from that portion of the City of San Bernardino that lies within the Chino-Riverside area. In 1954, the Los Angeles County Sanitation District No. 21 began exporting waste water through the San Gabriel Valley for treatment at the Los Angeles County Sanitation District's joint disposal plant. Waste water from the Pomona Water Reclamation Plant is exported in a pipeline to the San Gabriel Valley for irrigation use. The effluent from the reclamation plant, in excess of that exported for irrigation, is released to San Jose Wash, from where the effluent flows into the San Gabriel Valley. Effluent from the two Riverside waste water treatment plants is usually discharged into the Sheehan Ditch, where it is conveyed downstream for irrigation. It was assumed that none of the waste water in the Sheehan Ditch found its way directly into the Santa Ana River. Occasionally, waste water has been discharged directly into the Santa Ana River from the treatment plants when the Sheehan Ditch has been shut down for repairs. The amount of waste water exported in the Santa Ana River through Prado was considered as effluent discharged directly into the river.

Total waste water production in the Chino-Riverside area equaled the sum of the following: (1) waste water export, (2) waste water discharged to spreading grounds, (3) waste water discharged into cesspools, and (4) treated waste water percolated in stream beds or used for irrigation. The average annual waste water production during the base period was about 24,700 acre-feet. Amounts of components of total waste water production for the base period are shown in Table 26. Amounts of waste water production and disposition, are shown in Table 27.

Evaluation

When the water-bearing area, from the base of the alluvium to and including the ground surface is considered as a free or separate body (shown in Figure 5) the equation of equilibrium can be expressed as:

Water Supply - Water Use and Disposal = Change in Storage

This equation for the change in storage in the ground water basins of the study area was determined for the water-bearing portion of the study area during the base period.

Because of the similarity in hydrologic conditions which existed immediately prior to the beginning and end of the base period, the assumption could be made that there was no significant difference between the amount of water in transit within the zone of aeration at the beginning and at the end of the base period. It was recognized that, because the water table was lower at the end of the base period than at the beginning, some additional water should be in transit at the end of the base period in the zone that was dewatered. However, because of the dry periods preceding the beginning and end of the base period, this amount of water would be small and was therefore not considered.

Since this difference in the amount of water in transit was negligible, as was assumed in this investigation, the total difference between the water supply and disposal is considered to be equal to the change in ground water storage during the same period.

During the base period, the total annual fresh water supply -- that is, the sum of all the amounts of surface and subsurface inflows to the water-bearing portion of the Chino-Riverside area -- was less than the sum of all the items of surface and subsurface outflow (including consumptive use) from the area. This difference amounted to 638,800 acre-feet during the base period and represents the amount of ground water removed from storage.

As shown in Table 28, the total surface water supply during the base period amounted to 14,547,900 acre-feet, the total water surface disposal amounted to 15,780,400 acre-feet and the net subsurface inflow amounted to 593,700 acre-feet for the base period. The same table shows the water supply and disposal, along with the annual difference between the two that existed during the base period.

Water Quality

Water quality is dependent upon both natural and manmade factors. Quantity and quality are interrelated variables that must be taken into account in selecting water management plans. Water quality is an important factor in available water supplies in the Chino-Riverside area. According to Schoeller (1959), "Finding water is not everything. The water has to be fit for use. Hence in many cases the key factor is no longer quantity but quality".

In describing the quality of water, total dissolved solids (TDS) can be used as an indicator because it is the single measurement that most closely describes the quality of water; it reflects the influence of the main dissolved constituents, and is the most significant chemical generalization that can be used in evaluating the suitability of water for different beneficial uses. Most of the data collected and maps in existence are in terms of TDS. While individual mineral constituents may be critical to agricultural, municipal and various industrial uses, TDS is a good indicator in compromise for describing the quality of water in consideration of data availability.

Local Water

The developed water supply of the area is largely derived from underlying ground water resources. However, the limited available flows of surface streams are also utilized to the fullest practicable extent and are supplemented by import of water from the Bunker Hill and from Colorado River water by The Metropolitan Water District of Southern California.

Ground Water. Ground water is the main source of water supply in the Chino-Riverside area. A study of the historical quality of extracted ground water and how the quality changed with time was necessary in the early steps of the study. The study of historical water quality included preparation of iso-salinity (TDS) maps for several time periods: 1930, 1940, 1950, 1960, and 1965. Other contour maps were developed to show water quality changes between some of these historic years. A study of these water quality maps indicates ground water quality has not changed substantially within the basin over a period of 30 years (1930-60). In most of the areas where the ground water was subject to man's activities there was an increase in mineralization with time.

In the Chino-Riverside area the main natural sources of ground water recharge are precipitation, stream percolation, and subsurface flow from bordering areas. The almost saltless rain water (10 ppm TDS) traveling through the soil and the unsaturated zone dissolves soluble minerals from the sediments by simple solution or chemical reaction. This water, upon reaching the saturated zone, will move laterally in response to the hydraulic gradient. Water moving through the aquifer will continue to dissolve minerals with which it comes in contact. The quality of the water will also become modified due to such reactions as ion exchange, reduction, oxidation, and deposition. Therefore, quality changes as water moves from the recharge area through the aquifer. Concentration of minerals tends to increase as water moves down the hydraulic gradient through the basin. The change, however, is not uniform with respect to time or distance. Local variations in soil, geol-

TABLE 26 WASTE WATER EFFLUENT IN THE CHINO-RIVERSIDE GROUND WATER BASIN

SEASON (A)	1 CALIFORNIA INSTITUTE FOR MEN	2 CALIFORNIA INSTITUTE FOR WOMEN	3 CHINO PLANT NO 1	4 CHINO PLANT NO 2	5 COLTON	6 CORONA	7 CUCAMONGA COUNTY WATER DISTRICT	8 EDGEMONT COMMUNITY SERVICES DISTRICT
1934-35						470 B		
1935-36						480 B		
1936-37						490 B		
1937-38			310 B			500 B		
1938-39			320 B		10	520 B		
1939-40			330 B		820	530 B		
1940-41			340 B		1,110	540 B		
1941-42	40 B		360 B		770	540 B		
1942-43	110 B		370 B		810	550 B		
1943-44	120 B		380 B		960	560 B		
1944-45	70 B		390 B		1,020	570 B		
1945-46	90 B		410 B		1,330	580 B		
1946-47	110 B		420 B		1,420	590 B		
1947-48	160 B		430 B		1,310	600 B		
1948-49	190 B		440 B		1,290	600 B		
1949-50	250 B		460 B		1,270	610 B		
1950-51	270 B		490 B		1,210	630 B		
1951-52	300 B	100 B	530 B		1,280	650 B		
1952-53	350 B	100 B	580 B		1,540	670 B		
1953-54	350 B	100 B	640 B		1,620	690 B		
1954-55	350 B	110 B	700 B		1,580	710 B		
1955-56	320 B	110 B	780 B		1,720	760		
1956-57	330 B	110 B	880 B		2,030	800		
1957-58	350 B	110 B	990 B		2,130	840		
1958-59	370 B	110 B	980		1,840	960		
1959-60	410	120 B	1,280	C	1,990	1,050	D	E
26-YEAR TOTAL	4,540	970	12,810	0	29,060	16,490	0	0
26-YEAR AVERAGE	175	37	493	0	1,118	634	0	0

SEASON (A)	13 LACSD NO. 21 JOB ID LINE	14 MIRA LOMA A.F. STA.	15 NAVAL ORDINANCE LABORATORY NORCO	16 ONTARIO-UPLAND	17 RIALTO	18 RIVERSIDE NO 1	19 RIVERSIDE NO 2 (ARLANZA)	20 RUBIDOUX COMMUNITY SERVICES DISTRICT
1934-35				1,470 B		2,510 B		
1935-36				1,490 B		2,550 B		
1936-37				1,510 B		2,590 B		
1937-38				1,520 B	80 B	2,630 B		
1938-39				1,540 B	80 B	2,670 B		
1939-40				1,560 B	90 B	2,710 B		
1940-41				1,650 B	90 B	2,800 B		
1941-42				1,740 B	90 B	2,890 B	110	
1942-43				1,820 B	100 B	2,990 B	380	
1943-44				1,910 B	100 B	3,080 B	570	
1944-45		130 B	220	2,000 B	110 B	3,020	710	
1945-46		130 B	220	2,090 B	110 B	3,340	110	
1946-47		130 B	220	2,170 B	120 B	3,360	60	
1947-48		130 B	220	2,290 B	120 B	3,740	120	
1948-49		130 B	220	2,380 B	130 B	3,760	140	
1949-50		130 B	0	2,550	130 B	3,800	160	
1950-51		130 B	70	2,330	130 B	3,910	180	
1951-52		40 B	70	2,180	140 B	4,220	200	
1952-53		40 B	70	2,990	150 B	4,720	220	
1953-54	830	40 B	70	3,360	150 B	5,290	380	
1954-55	2,740	40 B	70	3,850	170 B	6,080	540	40
1955-56	2,830	30 B	70	4,440	200 B	6,640	700	200
1956-57	2,910	30 B	70	5,490	580	7,380	810	300
1957-58	3,160	30	70	5,100	760	7,910	1,230	440
1958-59	3,970	30	70	5,940	860	8,240	1,340	500
1959-60	4,500	20	70	6,820	960	8,340	1,560	370
26-YEAR TOTAL	20,940	1,210	1,800	72,190	5,450	111,170	9,520	1,850
26-YEAR AVERAGE	805	47	69	2,777	210	4,276	366	71

IN ACRE FEET

9 FONTANA	10 JURUPA COMMUNITY SERVICES DISTRICT	11 LA SIERRA COLLEGE	12 LACSD NO. 21 POMONA WATER RECLAMATION PLANT
			1,300
			1,310
			1,500
			1,480
			1,480
			1,530
			1,630
			1,870
			2,230
			2,360
			2,360
			2,470
			2,690
			2,790
			3,000
			2,960
			2,960
		100	3,380
		100 B	3,770
		110 B	4,110
		110 B	2,630
		120 B	3,280
40		120 B	4,660
470		120 B	4,730
880		130 B	4,910
940	F	130	5,210
2,330	0	1,040	72,600
90	0	40	2,792

ogy, and man's influence, make the rate and degree of change very variable.

Urbanization in the Chino-Riverside area resulted in: (1) changes in the natural drainage and surface water systems by diversions; (2) multiple use and reuse of surface and ground water supplies; (3) discharges of domestic and industrial waste water in which salts had been dissolved; (4) import of waters of higher salt concentration to supplement local supplies; and (5) return to the saturated zone of irrigation water that carried a high concentration of fertilizers.

Areas in which the greatest change was noted are close to waste water discharges or extensive agricultural activity. In some areas, such as Arlington and Riverside, where the basin is shallow, the effects of man's use and reuse are more intensified.

Water is received in wells throughout their saturated thickness. Percolating

21 SAN BERNARDINO NO.1	22 SAN BERNARDINO NO.2	23 WESTERN PACIFIC SANITATION CO. PLANT A	24 WESTERN PACIFIC SANITATION CO. PLANT B	25 ESTIMATED INDUSTRIAL
4,110				4,460
3,150				4,460
3,550				4,460
3,350				4,460
3,750				4,460
3,480				4,460
3,840				4,520
4,140				4,520
4,710				4,520
5,590				4,740
6,790				4,720
6,800				4,930
7,060				4,900
6,990				5,630
7,620				5,600
8,220				5,630
8,240				5,780
8,720				5,840
8,590				6,250
8,690				6,340
9,010				6,450
9,470				6,640
9,700				6,810
9,880				6,970
9,770	310			7,970
7,260	4,550	30	10	7,750
172,480	4,860	30	10	143,270
6,634	187	1	0	5,610

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

B. ESTIMATED BY DEPARTMENT OF WATER RESOURCES.

C. PLANT COMMENCED OPERATION IN MARCH 1961.

D. PLANT COMMENCED OPERATION IN 1962.

E. PLANT COMMENCED OPERATION IN FEBRUARY 1961.

F. PLANT COMMENCED OPERATION IN AUGUST 1961.

TABLE 27

WASTE WATER PRODUCTION
IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN ACRE FEET

SEASON (A)	REUSE IRRIGATION	REUSE-ARTIFICIAL RECHARGE	INTO STREAMS - STREAM FLOW	PIPE LINE	CESSPOOLS	TOTAL
1934-35	3,640	4,430	2,330	200	310	10,910
1935-36	3,660	4,480	2,340	200	550	11,230
1936-37	3,680	4,530	2,530	200	610	11,550
1937-38	4,000	4,660	2,550	160	510	11,880
1938-39	4,040	4,720	2,670	40	750	12,220
1939-40	4,840	4,780	2,620	180	140	12,560
1940-41	5,210	4,940	2,730	190	590	13,660
1941-42	5,020	5,160	2,970	170	1,480	14,800
1942-43	5,180	5,590	3,220	280	1,530	15,800
1943-44	5,430	6,100	3,350	290	1,660	16,830
1944-45	5,570	6,500	3,240	500	2,250	18,060
1945-46	5,970	6,460	3,490	280	2,920	19,120
1946-47	6,170	5,150	5,040	270	3,680	20,210
1947-48	7,410	3,510	6,520	540	3,330	21,310
1948-49	7,510	3,220	6,790	770	4,150	22,440
1949-50	7,080	3,650	6,890	730	5,470	23,820
1950-51	6,930	3,810	6,450	1,350	7,760	26,300
1951-52	7,100	3,820	6,990	1,680	9,530	29,120
1952-53	8,420	3,880	8,290	1,300	9,830	31,720
1953-54	9,210	3,800	9,730	1,690	9,930	34,360
1954-55	9,880	4,060	8,030	4,140	10,940	37,050
1955-56	11,070	4,200	9,150	4,210	11,150	39,780
1956-57	12,350	5,110	11,070	4,560	9,470	42,560
1957-58	12,870	5,340	12,970	4,210	10,410	45,800
1958-59	14,050	6,960	14,370	4,770	8,530	48,680
1959-60	15,280	7,190	15,160	5,100	8,890	51,620
26-YEAR TOTAL	191,570	126,050	161,490	38,010	126,270	643,390
26-YEAR AVERAGE	7,368	4,848	6,211	1,462	4,857	24,746

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

water returns to these same strata carrying a higher concentration of TDS than during its last cycle. The return waters mix downward very slowly, making the topmost layers more saline than the waters below. Thus, well depth has an important effect on water quality, especially in the Chino-Riverside area, where most of the water used is pumped ground water. Extractions from a shallow well will show the effects of water returns more

than those from a deeper well. This variation of well depths in the Chino-Riverside area from one locale to the other, and the resultant extracted water quality pattern, may exaggerate or minimize man's local effects on ground water quality.

In the following pages historic and present ground water quality, in terms of TDS distribution and changes observed with time, are discussed.

The mineral quality of extracted ground water in the Chino-Riverside area varies from one area to the other. The local depth of wells, thickness of the saturated zone, water level gradient, and the proximity of the well to waste water discharges or to areas under extensive irrigation, are primary causes of these variations.

In the study area, the change in water quality in the last 35 years has been considerable in a few locales, but generally small in most of the area. By examining the 1930, 1950, 1960 and 1965 isosalinity-contour maps, it is apparent that in the lower Chino, Corona, and Arlington areas change was particularly measurable (Plates 16 through 19).

Due to the insufficiency of data, comparison of change of water quality of

TABLE 28

ESTIMATED PAST ANNUAL AMOUNTS OF DIFFERENCE BETWEEN SUPPLY AND DISPOSAL IN THE CHINO-RIVERSIDE GROUND WATER BASIN

IN THOUSANDS OF ACRE FEET

1	2	3	4	5	6	7	8	
SEASON(A)	SURFACE WATER SUPPLY	SUBSURFACE INFLOW	(2+3) TOTAL SUPPLY	SURFACE WATER USE AND DISPOSAL	SUBSURFACE OUTFLOW	(5+6) TOTAL USE AND DISPOSAL	(4-7) WATER SUPPLY SURPLUS OR DEFICIENCY SEASONAL	ACCUMULATED
1934-35	576.1	38.0	614.1	609.2	6.9	616.1	- 2.0	- 2.0
1935-36	417.7	38.7	456.4	514.4	6.9	521.3	- 64.9	- 66.9
36-37	889.6	40.2	929.8	710.9	6.5	717.4	+212.4	+145.5
37-38	976.6	32.9	1,009.5	798.5	8.1	806.6	+202.9	+348.4
38-39	550.0	34.5	584.5	585.2	9.4	594.6	- 10.1	+338.3
39-40	465.0	36.0	501.0	540.9	8.1	549.0	- 48.0	+290.3
1940-41	1,042.7	38.3	1,081.0	806.0	6.4	812.4	+268.6	+558.9
41-42	446.9	32.6	479.5	559.2	7.9	567.1	- 87.6	+471.3
42-43	812.8	36.5	849.3	709.5	7.9	717.4	+131.9	+603.2
43-44	672.6	36.0	708.6	660.1	8.4	668.5	+ 40.1	+643.3
44-45	568.5	35.9	604.4	631.5	8.5	640.0	- 35.6	+607.7
1945-46	480.1	36.2	516.3	565.0	8.5	573.5	- 57.2	+550.5
46-47	496.4	32.8	529.2	588.9	8.4	597.3	- 68.1	+482.4
47-48	350.7	28.2	378.9	489.6	8.4	498.0	-119.1	+363.3
48-49	391.5	30.9	422.4	535.4	7.9	543.3	-120.9	+242.4
49-50	418.9	26.2	445.1	554.8	7.9	562.7	-117.6	+124.8
1950-51	332.7	26.1	358.8	515.2	7.7	522.9	-164.1	- 39.3
51-52	812.7	28.1	840.8	717.8	6.3	724.1	+116.7	+ 77.4
52-53	420.6	22.0	442.6	570.5	7.1	577.6	-135.0	- 57.6
53-54	569.7	24.3	594.0	645.5	7.7	653.2	- 59.2	-116.8
54-55	479.0	23.4	502.4	623.3	7.1	630.4	-128.0	-244.8
1955-56	516.4	23.9	540.3	617.3	7.7	625.0	- 84.7	-329.5
56-57	437.6	21.7	459.3	573.0	7.1	580.1	-120.8	-450.3
57-58	822.3	28.1	850.4	709.2	7.7	716.9	+133.5	-316.8
58-59	272.5	22.2	294.7	451.0	8.0	459.0	-164.3	-481.1
59-60	328.3	20.4	348.7	498.5	7.9	506.4	-157.7	-638.8
TOTAL	14,547.9	794.1	15,342.0	15,780.4	200.4	15,980.8	-638.8	
26-YEAR AVERAGE	559.5	30.5	590.0	606.9	7.7	614.6	-24.6	

A. 12-MONTH PERIOD FROM OCTOBER 1 THROUGH SEPTEMBER 30.

representative wells from one year to the next is difficult. Water quality distribution based on historical available analyses of well water was the best method of comparison. The 1930 contour map was prepared on the basis of 58 TDS values; the 1950 map was based on 168 values; the 1960 map was based on 430 values; and the 1965 map was based on 269 TDS values. Figure 26 is a frequency diagram showing distribution and change of water quality (TDS) from 1930 to 1965. Data used in plotting the frequency diagram (Table 29) show that in 1930, 46.5 percent of the sampled wells produced water of less than 200 ppm, but only 6.5 percent in 1965.

In 1930, 3.5 percent of the wells produced water with a TDS concentration above 1,000 ppm. On the other hand, in 1965 eight percent of the wells supplied water with TDS values above 1,000 ppm. Figure 26 also shows that the frequency trend was quite similar from 1950 to 1965.

Present Quality—In the Chino-Riverside area, 1965 TDS values of well waters varied from 122 ppm in well No. 1S/5W-11E1, southwest of Rialto, to 1,450 ppm in well No. 3S/7W-15Q1, northwest of Corona and east of Prado Dam. Figure 26 shows that about 60 percent of the wells, with available quality information, produced water with TDS concentrations between 100 and 500 ppm.

The graph also shows that more than 90 percent of the wells produced water with less than 1,000 ppm TDS. Five hundred to 1,000 ppm TDS is permitted for domestic use and up to 1,500 ppm is temporarily permitted by the State of California Board of Public Health.

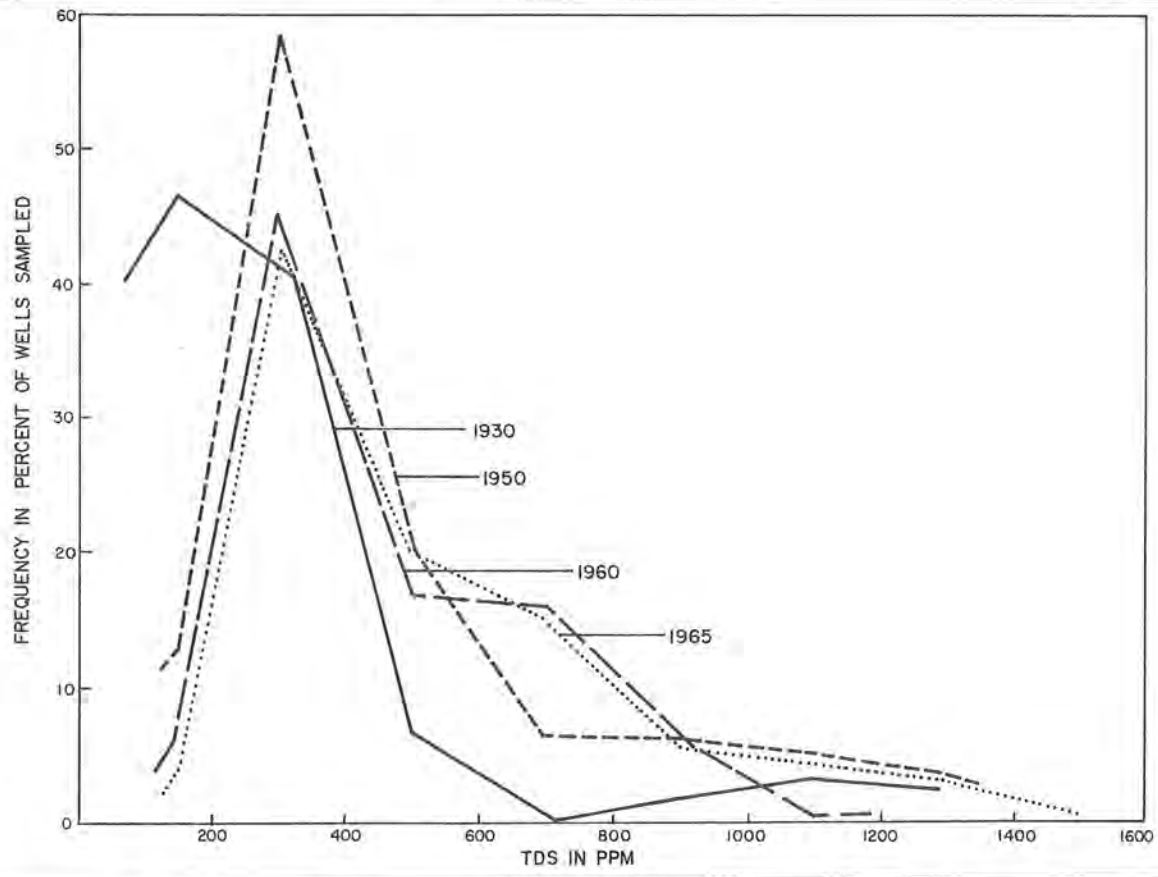


Figure 26 - FREQUENCY DISTRIBUTION OF DISSOLVED-SOLIDS CONTENT OF GROUND WATER IN CHINO BASIN IN 1930, 1950, 1960, AND 1965

Water quality is lower in the southern part of the Chino Plain; northwest and north of Corona; the Arlington area; south and southeast of Riverside; Colton; and the area east of Pomona and west of Ontario than in the other parts of the basin (Plates 16 through 19). In most of these areas, ground water from shallow wells is generally of poorer quality than water from deep wells. Most of these well waters are affected by local discharges of domestic and industrial waste waters, or by agricultural waste water returns. In some of these areas, such as Riverside, Arlington, and Corona, and the southern portion of the Chino Basin, the ground water basin is shallow, and only shallow wells exist.

Table 30 presents upper and lower limits of concentrations of the major ionic constituents in the Chino-Riverside area. This table indicates that ground water supply of the area is generally suitable for domestic use, except in a few locations where nitrate levels are higher than 45 ppm. 1/ The water is also class 1 or class 2 irrigation water (Table 31).

Nitrate concentrations are highest in ground water sampled from wells in the Riverside, Arlington, Corona, and lower Chino basins, north of Claremont, Pomona, Ontario, and east and southeast of Chino.

Sixty-four of the 278 wells, or 23 percent of those sampled in 1965, produced water containing nitrate at concentrations above 45 ppm. Twelve wells (four percent), in the Riverside-Arlington, Temescal, lower Chino Basins, and in the vicinity of Limonite, contained nitrate concentrations above 90 ppm. The highest nitrate concentration (144 ppm) was in water sampled from well No. 3S/5W-8B1 east of Arlington.

1/ Recommended by the U. S. Public Health Service Drinking Water Standards, 1962.

TABLE 29

SUMMARY OF DATA USED IN FIGURE 26

TDS (ppm)	Percentage Occurrences Among Sampled Wells			
	1930	1950	1960	1965
100-200	46.5	7.5	4.0	6.5
200-400	41.5	58.5	45.0	44.0
400-600	7.0	20.0	17.0	20.5
600-800	0.0	6.5	16.0	15.0
800-1000	1.5	6.0	6.5	6.0
1000-1200	3.5	0.8	5.0	4.5
1200-1400		0.0	3.5	3.0
1400-1600		0.7	1.5	0.5
1600-1800			1.5	
	100.0	100.0	100.0	100.0

The chemical character of ground water in the northern portion of the study area is predominantly calcium bicarbonate. In the Riverside-Arlington area, the Temescal area, and in the lower portion of the Chino Plain, the character of ground water is variable. Predominant cations are calcium and sodium. Chloride and bicarbonate are the predominant anions; however, sulfate is also found in high concentrations in some wells. Close to the Santa Ana River, below the Riverside Narrows, ground water, particularly that from shallow wells, has high TDS concentrations. The character of this water is sodium calcium-bicarbonate sulfate. This water reflects the effect of wastes discharged into the river.

Surface Water. Runoff in surface streams is part of the natural water supply available to the valley floor area of the Chino-Riverside area. Surface runoff is an important source of water for direct diversion and use and is the largest contributor to ground water storage in the basin. The largest of the streams is the Santa Ana River. Smaller streams in the area include San Antonio Creek, Lytle Creek, Day Creek, Cucamonga Creek, Deer Creek, Chino Creek, and Temescal Wash.

TABLE 30

GROUND WATER MINERAL QUALITY

(1965 Range of Values)

ITEM	HIGHEST CONCENTRATION		LOWEST CONCENTRATION	
	ppm	Source	ppm	Source
Calcium	244	Well 1S/6W-20Q1 (Node 32)	17	2S/7W-32K3 (Node 8)
Magnesium	135	Well 3S/7W-24Q3 (Node 4)	1	1S/8W-10N1 (Node 55)
Sodium	220	Well 3S/7W-23D1 (Node 5)	6	1N/7W-29E1 (Node 66)
Potassium	18	Well 3S/7W-23D2 (Node 5)	1	in many wells
Bicarbonate	500	Well 3S/7W-15Q1 (Node 5)	73	3S/7W-27H2 (Node 4)
		Well 2S/7W-27A1 (Node 16)		
Sulfate	403	Well 2S/5W-11K2 (Node 115)	6	1S/6W-31M1 (Node 33)
				1S/7W-23D1 (Node 48)
				1S/6W-17F1 (Node 79)
Chloride	376	Well 3S/7W-23D1 (Node 5)	2	2S/7W-30G1 (Node 18)
Nitrate	144	Well 3S/5W-8B1 (Node 122)	1	1S/7W-P1 (Node 34)
Boron	2.7	Well 3S/7W-14D1 (Node 5)	0	in many wells
TDS	1450	Well 3S/7W-15Q1 (Node 5)	122	1S/5W-11E1 (Node 106)
Total hardness	689	Well 3S/7W-22A1 (Node 5)	59	2S/7W-31B1 (Node 8)

TABLE 31

CRITERIA FOR IRRIGATION WATERS*

FACTORS	CLASS 1 EXCELLENT TO GOOD	CLASS 2 GOOD TO INJURIOUS	CLASS 3 INJURIOUS TO UNSATISFACTORY
Specific electrical Conductance EC x 10^6 at 25°C	Less than 1,000	1,000 -- 3,000	More than 3,000
Boron, ppm	Less than 0.5	0.5 -- 2.0	More than 2.0
Chloride, ppm	Less than 175	175 -- 350	More than 350
Percent sodium	Less than 60	60 -- 75	More than 75

* California State Water Resources Board, "Water Resources of California", Bulletin No. 1, 1951.

Natural flow in these streams emanates from drainage from the mountains that occurs almost exclusively in winter months. The Santa Ana River receives, besides natural runoff, waste water and effluent ground water (rising water) below the Riverside Narrows. The contribution of effluent flow from ground water storage varies, depending on the fluctuations of the ground water levels on both sides of the stream. During the course of its meanders, the quality of the water in the Santa Ana River changes, due to inflows of waste and ground water and extractions by phreatophytes. Evaporation diminishes the flow of water in amounts that depend upon temperature, wind, depth, and other factors.

During the summer the concentration of minerals in the water above Prado Dam becomes greater because of lack of dilution by storm water and evaporation and transpiration.

Data for quality of surface water, other than the major streams, are discontinuous. Plate 20 shows locations of sampling points referred to in the tables of analyses (Table 32, 37, and 38) of surface water in the area. The water entering the Riverside area is either calcium sodium-bicarbonate or sodium-chloride bicarbonate in character, depending on the area of origin of the major portion of the flow -- the Santa Ana River or its tributary Warm Creek, respectively.

Analysis of water samples from the Santa Ana River at Colton (1S/4W-28) shows that minimum and maximum TDS concentrations in 1966, an average water supply year, were 337 and 625 ppm. Table 32 also shows the concentrations of the other mineral constituents of the water. A weighted average TDS value (based on quantity of flow and TDS monthly values) for the year 1966 was 423 ppm. The character of the water is calcium-sodium bicarbonate with high chlorides. The quality of water flowing in the Santa Ana River near Arlington (2S/6W-25) varied between 288 and 805 ppm in 1966; the weighted average TDS was 453 ppm. The character of the water is calcium-sodium bicarbonate with high chloride.

The quality of water near Norco (2S/7W-36) varied between 328 and 815 ppm TDS in 1966, the weighted average TDS was 576 ppm. The character of flow is calcium-sodium bicarbonate with high chlorides.

The quality of water at Prado Dam (3S/7W-29) is complex. It is calcium-sodium bicarbonate-chloride. TDS concentrations varied between 122 and 436 ppm in 1966. The weighted average TDS was 397 ppm.

It is noticeable from analyses of water samples from the upper reaches to the lower reaches of the stream that quality changes gradually except in the Prado Dam area, where surface flows from the Temescal area and surface and subsurface flows from the Chino plain cause considerable change in the quality of the water.

In the year 1965, because of high precipitation and runoff, the weighted average TDS at Prado was unusually low (397 ppm TDS).

Water flowing in the Santa Ana River is considered within the prescribed standard limits for domestic use and has been classified as Class 1 to 2 irrigation water.

The 1954 analysis of water flowing in San Antonio Creek showed a concentration of 280 ppm TDS with a calcium-bicarbonate character. No data were available to calculate a weighted average TDS.

The Chino Creek flow (2S/8W-36) had TDS values ranging from 208 to 768 ppm in 1966, with an average weighted value of 316 ppm.

Warm Creek water (1S/4W-21) contained TDS concentrations varying from 179 to 641 ppm TDS in 1966. The weighted

TABLE 32

SELECTED MINERAL ANALYSES OF SURFACE WATERS
CHINO – RIVERSIDE AREA

Location	Date sampled	pH	Specific conductance (micromhos at 25° C)	Chemical constituents in parts per million / equivalents per million									Chemical constituents in parts per million				Weighted average TDS
				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	Total dissolved solids	Total hardness Ca CO_3	
Santa Ana River – 1S/4W–28	2–04–66	7.6	624	55 / 2.74	10 / 0.82	48 / 2.09	7 / 0.18	0	199 / 3.26	46 / 0.96	52 / 1.47	33 / 0.53	0.6	0.26	337	178	423
	9–07–66	7.6	1014	57 / 2.84	18 / 1.48	117 / 5.09	14 / 0.36	0	189 / 3.10	80 / 1.66	138 / 3.89	70 / 1.13	0.8	0.6	625	216	
Santa Ana River – 2S/6W–25	1–06–66	8.0	1286	132 / 6.59	29 / 2.38	103 / 4.48	8 / 0.20	0	361 / 5.92	138 / 2.87	147 / 4.14	43 / 0.69	0.9	0.2	805	449	453
	12–08–66	8.0	455	50 / 2.49	9 / 0.74	29 / 1.26	7 / 0.18	0	162 / 2.66	44 / 0.91	30 / 0.85	9.3 / 0.15	0.7	0.08	288	162	
Santa Ana River – 2S/7W–36	1–06–66	7.6	1346	114 / 5.69	27 / 2.22	132 / 5.74	10 / 0.25	0	315 / 5.16	149 / 3.10	169 / 4.76	53 / 0.85	0.9	0.43	815	396	576
	12–08–66	8.2	538	55 / 2.74	10 / 0.82	41 / 1.78	7 / 0.18	0	174 / 2.85	55 / 1.14	43 / 1.21	8.7 / 0.14	0.8	0.13	328	178	
Santa Ana River – 3S/7W–29	1–06–66	8.0	1346	127 / 6.34	29 / 2.38	121 / 5.26	10 / 0.25	0	358 / 5.87	160 / 3.33	157 / 4.43	35 / 0.58	0.9	0.38	830	436	397
	12–08–66	7.8	360	39 / 1.95	6 / 0.49	23 / 1.0	7 / 0.18	0	114 / 1.87	50 / 1.04	18 / 0.51	10.5 / 0.17	0.8	0.10	240	122	
San Antonio Creek – 1N/8W–26	1–27–54*	7.3	395	49 / 2.45	16 / 1.32	9 / 0.89	4 / 0.10	0	156 / 2.56	67 / 1.39	4 / 0.11	4 / 0.06	—	0.1	280	188	
Chino Creek – 2S/8W–36	1–06–66	7.6	1202	114 / 5.69	27 / 2.22	94 / 4.09	26 / 0.66	0	358 / 5.87	148 / 3.08	104 / 2.93	56 / 0.90	1.3	0.24	768	396	316
	12–08–66	8.0	345	40 / 1.99	10 / 0.82	14 / 0.61	8 / 0.20	0	142 / 2.33	31 / 0.64	11 / 0.31	11.8 / 0.19	0.5	0.05	208	141	
Warm Creek – 1S/4W–21	11–04–66	6.9	1051	51 / 2.54	22 / 1.81	122 / 5.31	13 / 0.33	0	173 / 2.84	78 / 1.62	153 / 4.31	68.2 / 1.10	1.1	0.56	641	218	331
	12–07–66	7.3	277	44 / 2.19	5 / 0.41	7 / 0.30	5 / 0.13	0	157 / 2.57	12 / 0.25	2 / 0.06	1.2 / 0.02	0.5	0.05	179	130	
Day Creek – 1N/6W–8M	5–07–68	8.3	303	46 / 2.30	6.6 / 0.54	8.8 / 0.38	1.6 / 0.04	0	169 / 2.77	16 / 0.33	3.4 / 0.10	1.2 / 0.02	0.3	0	162	142	
Cucamonga Creek – 1N/7W–17H	5–08–68	8.5	331	46 / 2.30	10 / 0.82	11 / 0.48	1.7 / 0.04	4 / 0.13	173 / 2.84	20 / 0.42	3.8 / 0.11	1.4 / 0.02	0.5	0	180	156	
East Etwanda – 1N/6W–9D	5–07–68	8.3	248	28 / 1.40	6.8 / 0.56	14 / 0.61	1.8 / 0.05	0	130 / 2.13	16 / 0.33	4.2 / 0.12	1.4 / 0.02	0.2	0	140	88	
Lytle Creek – 1S/4W–15	2–09–54*	8.1	477	13 / 0.65	5 / 0.41	88 / 3.83	3 / 0.07	0	195 / 3.20	24 / 0.50	46 / 1.30	3 / 0.06	0.4	0	295	51	
Temescal Creek – 3S/6W–30	1–27–56*	7.4	797	69 / 3.44	22 / 1.81	54 / 2.35	11 / 0.28	0	205 / 3.36	136 / 2.84	63 / 1.78	2 / 0.04	—	0.32	489	262	

*Most recent data available

average TDS value for the same year was 331 ppm. Quality of flows in the other, smaller, streams varied between 140 ppm TDS in East Etiwanda, and 489 in Temescal Creek. Quality data for other streams are shown in Table 32.

Reclaimable Waste Water. Reclaimable water is derived from waste water resulting from domestic and light industrial use. Reclaimed water can be used for purposes such as irrigation and recharge, thereby releasing water of better quality for domestic consumption. Most of the waste water treatment facilities in the Chino-Riverside area are primary and secondary biological treatment processes, which do not remove any mineral constituents. Municipal waste water discharges (from flow records of the various waste disposal plants) in the fiscal year 1965-66 were about 40,000 acre-feet. About half of this quantity was reclaimed for irrigation and recharge. Most of this water can be used in crop irrigation, watering golf courses and spreading for ground water recharge.

Quality of water supplies and quality of waste water discharges are interdependent. The quality of waste water is largely dependent on the quality of water supplied to the consumer. In turn, the quality of a reclaimable water supply and its possible beneficial uses depend on the quality of waste water discharges.

General mineral quality for waste water reclamation can be based on quality criteria established for waste water reclamation in the Los Angeles Metropolitan area (Table 33).

Because of the addition of minerals through domestic and industrial use, the mineral content of waste water is invariably higher than that of the original supply. The increase in mineralization resulting from domestic use is shown in Table 34.

Based on data of the mineral quality of water supply and of the waste discharges in Southern California collected in 1958, The State Department of Public Health (1958) prepared a graph (Figure 27) showing the relation between TDS of water supply and TDS pickup.

The mineral quality of waste water discharges in the Chino-Riverside area is

TABLE 33

GUIDELINES FOR MINERAL QUALITY OF WASTE WATER FOR RECLAMATION PURPOSES*

Constituent	Limiting Values, in ppm		
	Suitable	Marginal	Unsuitable
Chlorides	Less than 200	200 to 500	More than 500
Chlorides plus Sulfates	Less than 500	500 to 1,000	More than 1,000
Boron	Less than 1	1 to 2	More than 2
TDS	Less than 1,000	1,000 to 2,000	More than 2,000

*California Department of Water Resources, "Feasibility of Reclamation of Water from Wastes in Coastal San Diego County", Bulletin No. 80-2, February 1968.

TABLE 34*

NORMAL RANGE OF MINERAL PICKUP IN WATER USED FOR DOMESTIC PURPOSES

Mineral Constituent	Normal Range, in ppm (except as noted)
TDS	100 - 300
Boron	0.1 - 0.4
Percent Sodium	5 - 15
Sodium	40 - 70
Potassium	7 - 15
Magnesium	15 - 40
Calcium	15 - 40
Total Nitrogen	20 - 40
Phosphate	20 - 40
Sulfate	15 - 30
Chloride**	20 - 50
Total Alkalinity	100 - 150

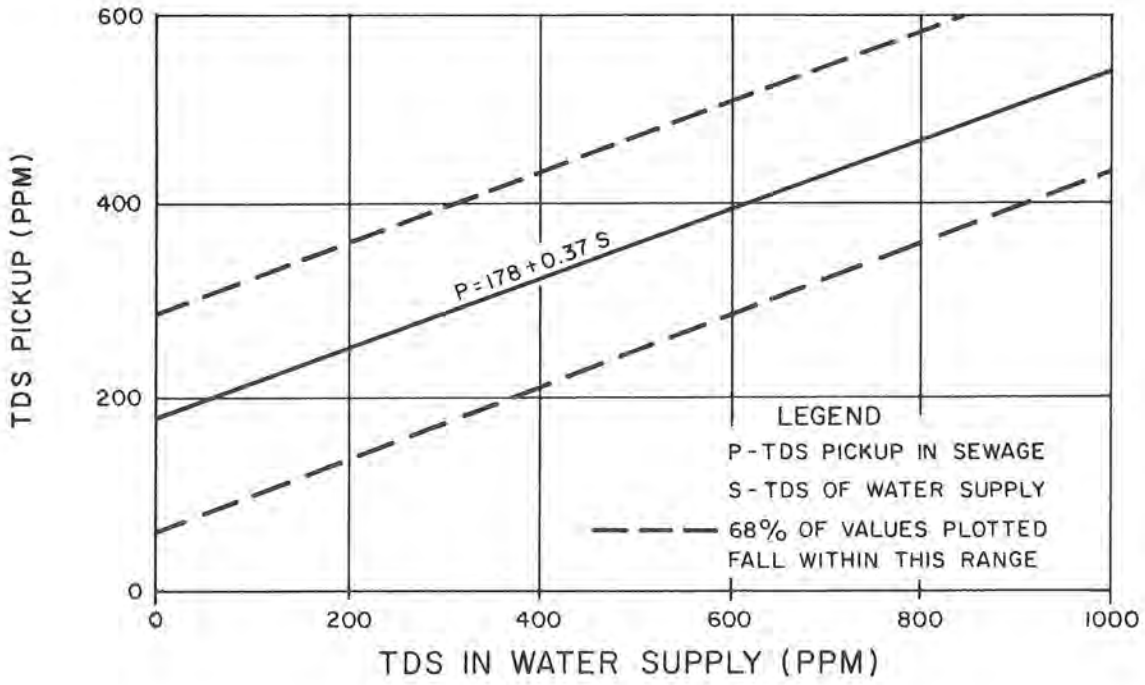
*California Water Pollution Control Board, "Studies of Waste Water Reclamation and Utilization", Publication No. 9, 1954.
**Since 1954, chloride and sodium have undoubtedly increased due to use of ion exchange softeners.

presented in Table 35. These waste waters vary from suitable to marginal for reuse (371 to 1,193 ppm TDS), and "soft" to "very hard" (77 to 415 ppm total hardness as $CaCO_3$).

Imported Water

Water supplied to the Chino-Riverside area from sources outside its boundaries include Colorado River water and surface and ground water extractions conveyed to the Riverside, Arlington, and Corona areas by canals and conduits.

Colorado River Water (MWD). Colorado River water purchased by local water districts from the Metropolitan Water District is supplied to the Chino-Riverside area via the Upper Feeder,



Source: State Department of Health, 1958

FIGURE 27

TOTAL DISSOLVED SOLIDS PICKUP IN SEWAGE IN SOUTHERN CALIFORNIA

TABLE 35

SELECTED MINERAL ANALYSES OF WASTE WATER
CHINO – RIVERSIDE AREA

Location of plant	Date sampled	pH	Specific conductance (micromhos @ 25° C)	Chemical constituents in parts per million / equivalents per million								Chemical constituents in parts per million		
				Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Boron B	Total dissolved solids	Total hardness Ca CO_3
California Institution for Men, Chino	9-22-65	7.0	565	35 1.75	15 1.23	54 2.35	12 0.31	143 2.34	40 0.83	32 0.90	64.0 1.03	0.40	371	149
California Institution for Women, Chino	10-11-66	7.4	662	16 0.80	9 0.74	98 4.26	8 0.20	262 4.30	40 0.83	51 1.44	13.0 0.21	0.46	426	77
City of Chino, No. 2	9-15-65	7.2	845	43 2.14	16 1.31	88 3.88	20 0.51	314 5.15	64 1.33	60 1.69	0.0	0.70	535	173
City of Colton	7-20-65	7.4	979	58 2.89	13 1.07	102 4.44	13 0.33	337 5.53	67 1.39	92 2.59	37.7 0.61	0.58	520	198
City of Corona	7-19-65	7.6	1690	102 5.09	39 3.20	230 10.00	21 0.54	384 6.30	180 3.74	304 8.57	5.0 0.08	1.00	1,193	415
Cucamonga County Water District	11-26-65	7.3	879	19 0.95	18 1.48	121 5.26	19 0.49	350 5.74	43 0.89	72 2.03	17.0 0.27	1.08	593	121
Edgemont Community Service District	7-01-65	7.3	1372	53 2.64	28 2.30	138 6.00	18 0.46	278 4.56	185 3.85	160 4.51	0.0	0.90	802	247
City of Fontana	1-24-65	7.5	1362	57 2.84	29 2.38	121 5.26	14 0.36	391 6.41	178 3.70	102 2.88	15.4 0.25	0.49	745	262
Jurupa Community District	9-01-65	7.2	1290	84 4.19	34 2.79	134 5.83	28 0.72	238 3.90	160 3.33	146 4.12	64.0 1.03	0.30	842	350
City of Ontario	7-19-65	7.7	810	56 2.79	14 1.15	90 3.91	14 0.36	311 5.10	56 1.16	62 1.75	3.0 0.05	0.70	496	197
City of Rialto	9-02-65	7.6	730	32 1.60	14 1.15	68 2.96	21 0.54	311 5.10	44 0.91	53 1.49	0.0	0.80	430	137
Riverside Public Services Department – No. 1	7-20-65	7.0	1020	26 1.30	31 2.55	134 5.83	15 0.38	186 3.05	128 2.66	140 3.95	18.0 0.29	1.60	670	192
Riverside Public Services Department – No. 2	6-23-65	7.3	1880	93 4.64	41 3.37	186 8.09	16 0.41	418 6.85	290 6.03	240 6.77	0.0	1.20	1,121	401
Los Angeles County Sanitation District – Pomona	10-05-65	8.5		58 2.89	15 1.23	105 4.57	12 0.31	174 2.85	119 2.47	108 3.04	40.0 0.64	0.60	615	206

the Lower Feeder and the Orange County Feeder. Most of this water has been used for irrigation.

Analysis of the Upper Feeder water at LaVerne indicates that the mineral concentrations in the water ranged from 759 to 793 ppm TDS in 1966. The average TDS(based on composite monthly values for 1966)was 777 ppm. Colorado River water is of sodium-calcium sulfate character. It is within the prescribed limits for domestic use and Class 2 irrigation water. Chemical analyses, showing concentrations of the mineral constituents in Colorado River water, are shown in Table 36.

Local Imports. Six water systems serve the Riverside-Corona area with water derived from wells and surface diversions from the Bunker Hill Basin and from wells in the Colton and Riverside areas. The six systems include two conduits and four canals. The two conduits are the Riverside conduit which provides municipal water supply for the City of Riverside, and the Riverside Highlands Water Company Conduit which supplies water for both municipal and agricultural uses in the area between the City of Colton and Riverside. The canals that supply agricultural water are the Meeks and Daley, West Riverside, Riverside, and Gage Canals.

The chemical character of water conveyed by these canals and conduits varies from one system to the other, depending on the source of water (surface water diversions or well extractions) discharged into the system. The quality of the water in these canals also varies from upstream to downstream because of local additions of pumped water from the Colton and the Riverside Basins, and local deliveries from the system.

Available data on mineral analyses of these waters (Table 37) show that their chemical character varies between calcium bicarbonate and sodium-calcium bicarbonate. Total dissolved solids concentration in these waters ranged from 250 ppm to 525 ppm. The Riverside conduit's water is suitable for domestic use and is Class 1 irrigation water. The water in the canals is also suitable for domestic use, "moderately hard" to "hard", and is Class 1 irrigation water.

In August 1968, canal and conduit waters were tested for specific conductance. The results are shown in Table 38.

These data,compared with those in Table 37,show that the quality of water con-

TABLE 36

MINERAL ANALYSES OF COLORADO RIVER WATER AT LA VERNE

Date of Analysis	pH	EC x 10^6	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3	Total hardness	TDS
January 1966	8.2	1240	92* / 4.59**	34 / 2.79	119 / 5.18	6 / 0.15	135 / 2.21	348 / 7.24	116 / 3.27	0.9 / 0.01	369	793
September 1966	8.3	1190	88 / 4.39	33 / 2.71	115 / 5.0	5 / 0.13	140 / 2.3	330 / 6.86	108 / 3.05	0.6 / 0.01	355	759

*Concentrations in milligrams per liter or (ppm).
**Concentrations in milligram equivalents per liter or (epm).

TABLE 37

SELECTED MINERAL ANALYSES OF CANALS AND CONDUIT WATER
CHINO – RIVERSIDE AREA

No.[1]	Location	Date sampled	pH	Specific conductance (micromhos at 25° C)	Chemical constituents in parts per million / equivalents per million								Chemical constituents in parts per million		
					Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Boron B	Total dissolved solids	Total hardness Ca CO_3
1	Gage Canal – 1S/4W–26N	10–19–56	—	559	59 / 2.95	14 / 1.17	32 / 1.39	—	220 / 3.60	45 / 0.94	28 / 0.80	13 / 0.21	0.3	390[2]	206
2	2S/5W–35R	10–19–56	—	617	58 / 2.90	14 / 1.17	39 / 1.70	—	192 / 3.15	55 / 1.15	44 / 1.25	8 / 0.13	0.3	430[2]	204
3	Meeks and Daley Canal – 1S/4W–29A	10–19–56	—	545	46 / 2.30	8 / 0.67	56 / 2.43	—	204 / 3.35	55 / 1.15	32 / 0.90	—	0.5	380[2]	149
4	Riverside Canal – 2S/5W–26B	4–17–57	7.0	747	77 / 3.85	11 / 0.92	46 / 2.00	—	226 / 3.70	55 / 1.15	78 / 2.20	7 / 0.11	0.3	525[2]	239
5	West Riverside Canal – 2S/5W–8L	6–11–57	8.3	632	58 / 2.90	13 / 1.10	51 / 2.20	6 / 0.15	195 / 3.20	80 / 1.67	46 / 1.30	24 / 0.39	0.2	451	200
6	Riverside Conduit – 1S/4W–27H	9–16–54	—	355	32 / 1.60	6 / 0.50	42 / 1.82	—	159 / 2.60	30 / 0.62	25 / 0.70	—	—	250[2]	105

[1] See Plate 20
[2] Calculated from specific conductance

veyed in the conduit and the canal systems did not significantly change with time.

In general, the quality of water available to the study area in the past has been satisfactory. How will this quality change in the future? Will there be a substantial change in ground water quality as a result of certain alternative plans of water resources management in the area? What economic impact will the area feel due to water quality changes? These are questions that both local water agencies and the State are vitally interested in.

TABLE 38

RECENT QUALITY OF CANAL AND CONDUIT WATERS
(1968)

No.*	Source	Location	EC x 10^6 at 25° C	TDS (calculated)
A	Gage canal	At Linden Street (2S/4W-19R)	540	380
B	Riverside canal	At Marlborough Street (2S/5W-13Q)	705	490
C	West Riverside canal	Near Wilson and Avalon Streets (2S/5W-3L)	680	475
	Riverside Conduit	At Lemona Booster Station (2S/4W-19J)	410	285

*Locations are shown on Plate 20.

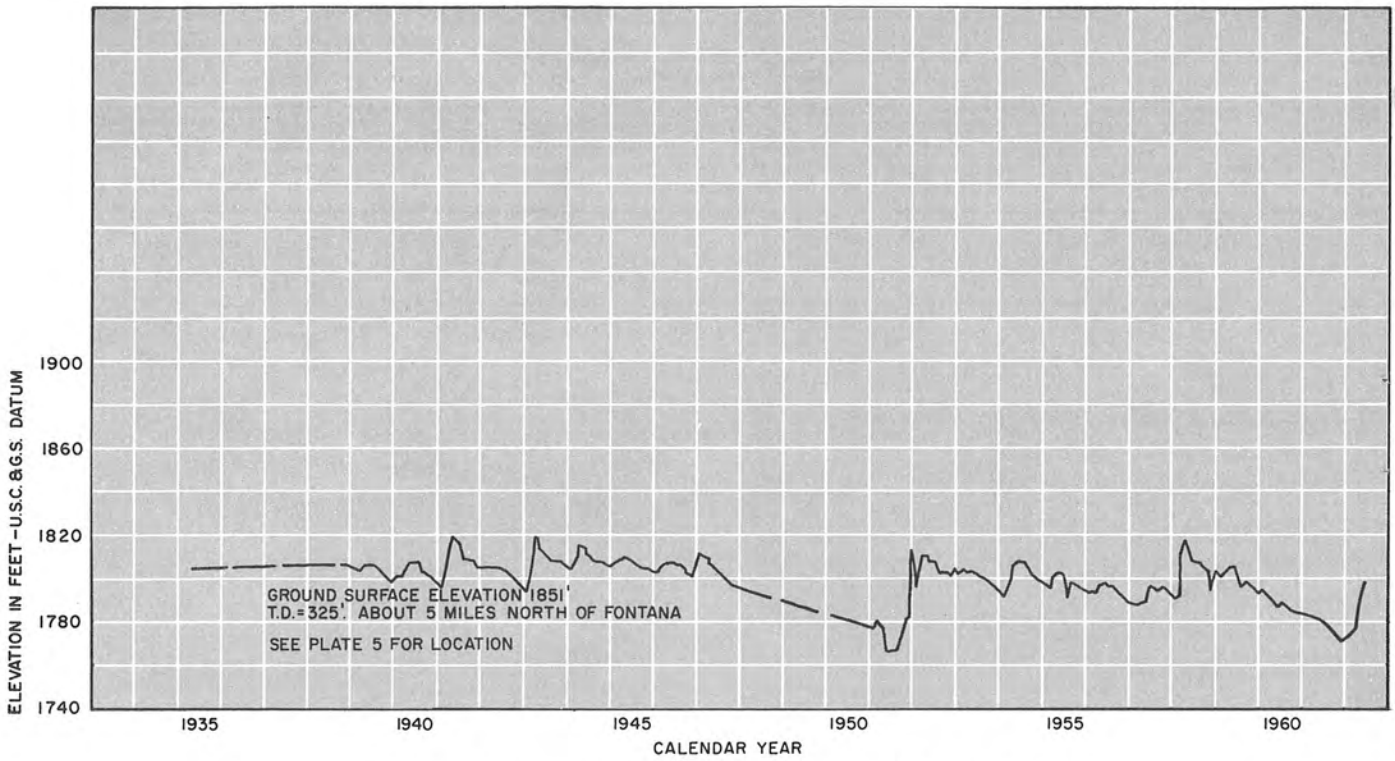


Figure 5. HYDROGRAPH OF STATE WELL No. IN/5W-17K1
(No. 1)

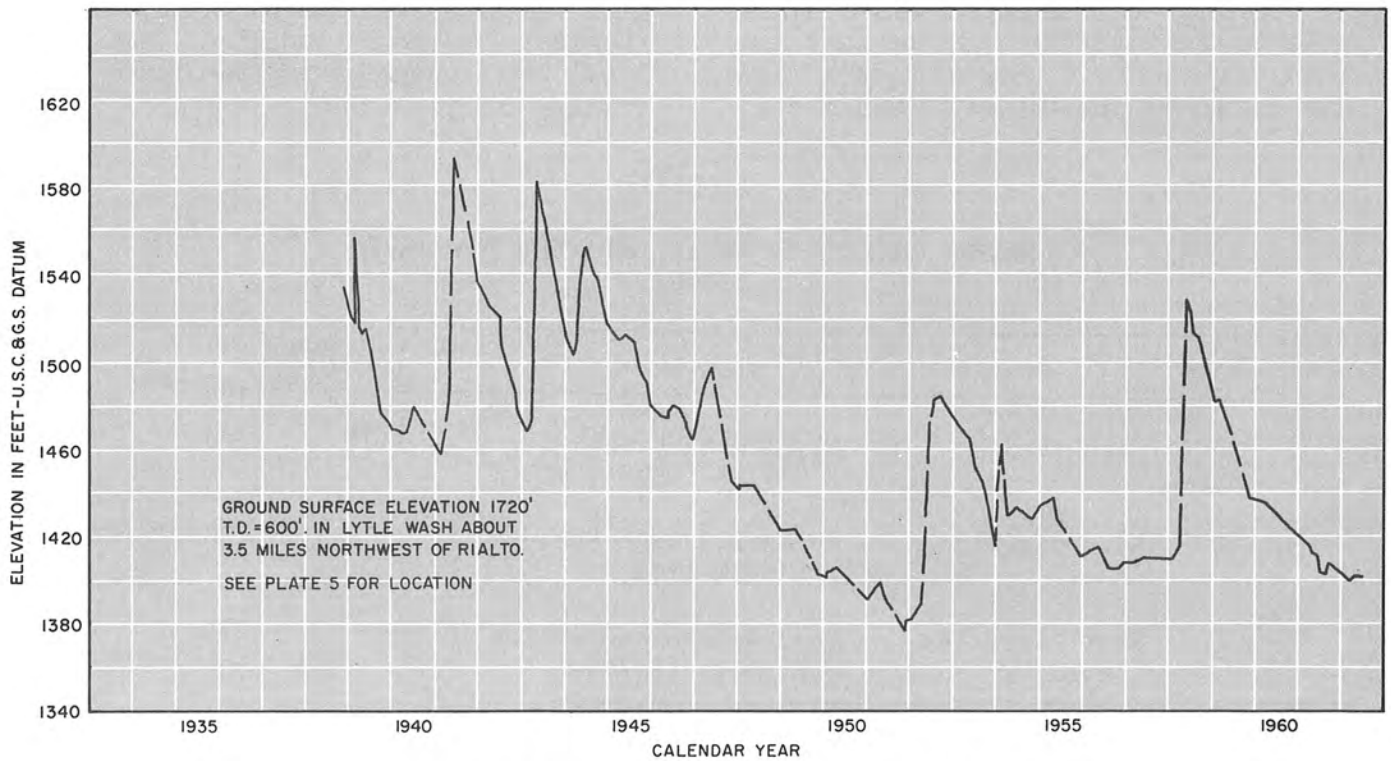


Figure 6. HYDROGRAPH OF STATE WELL No. IN/5W-16K1
(No. 2)

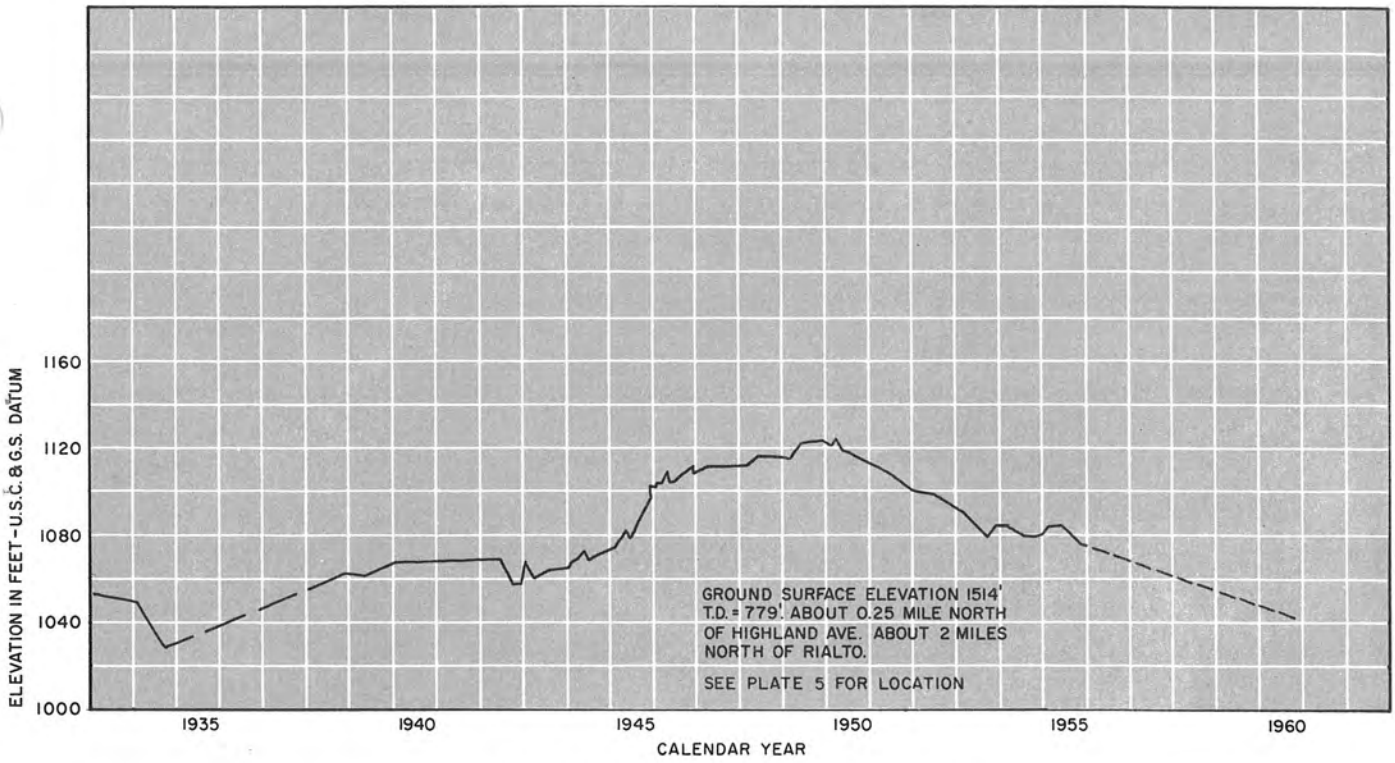


Figure 7. HYDROGRAPH OF STATE WELL No. 1N/5W-28J1
(No. 3)

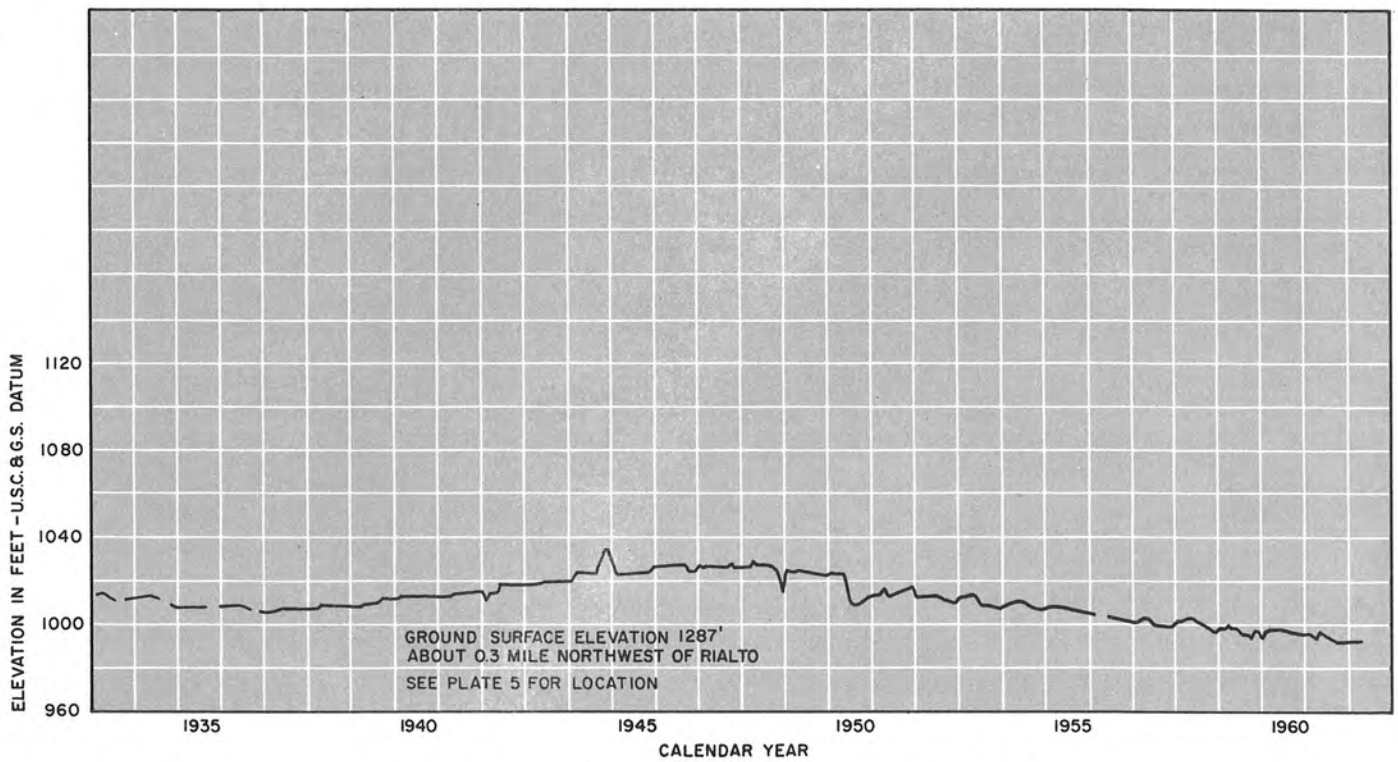


Figure 8. HYDROGRAPH OF STATE WELL No. 1S/5W-2K1
(No. 4)

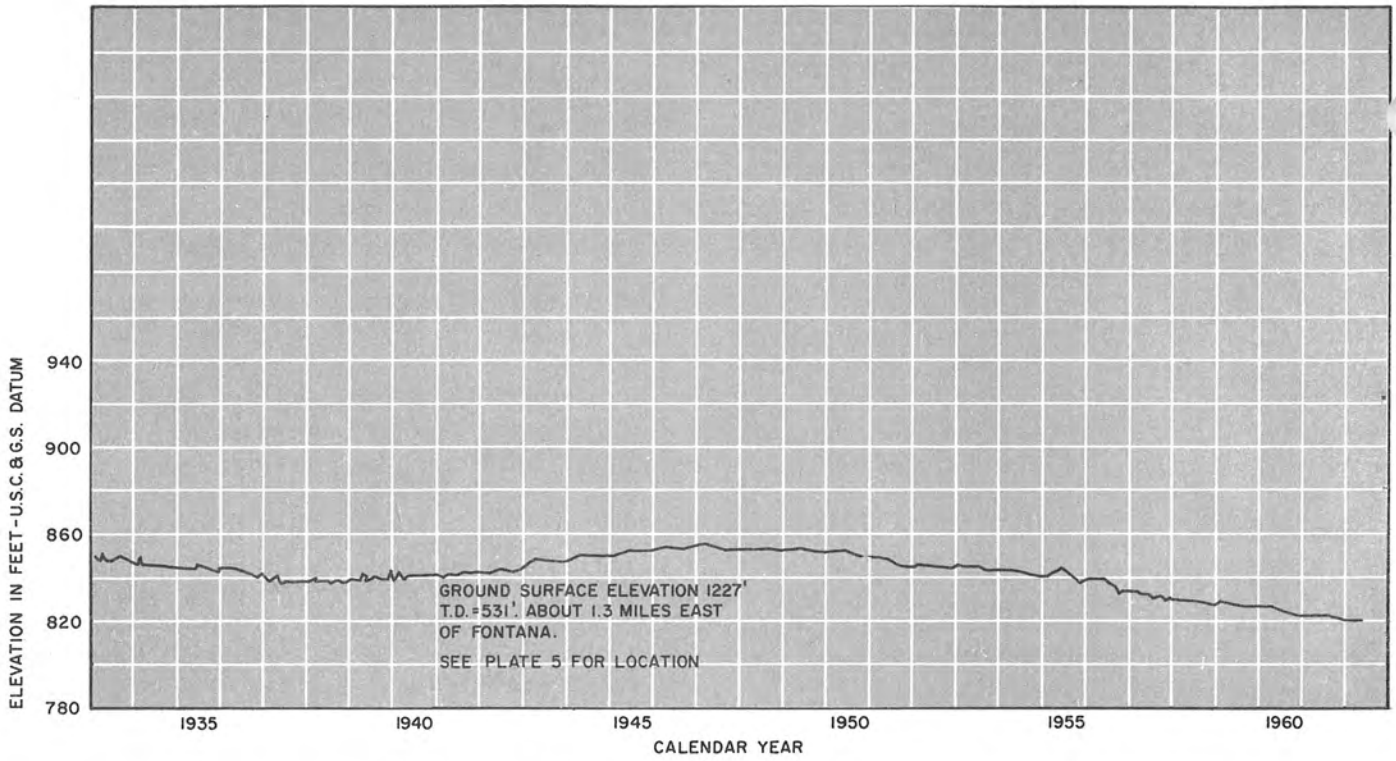


Figure 9. HYDROGRAPH OF STATE WELL No. 1S/5W-16C1
(No. 5)

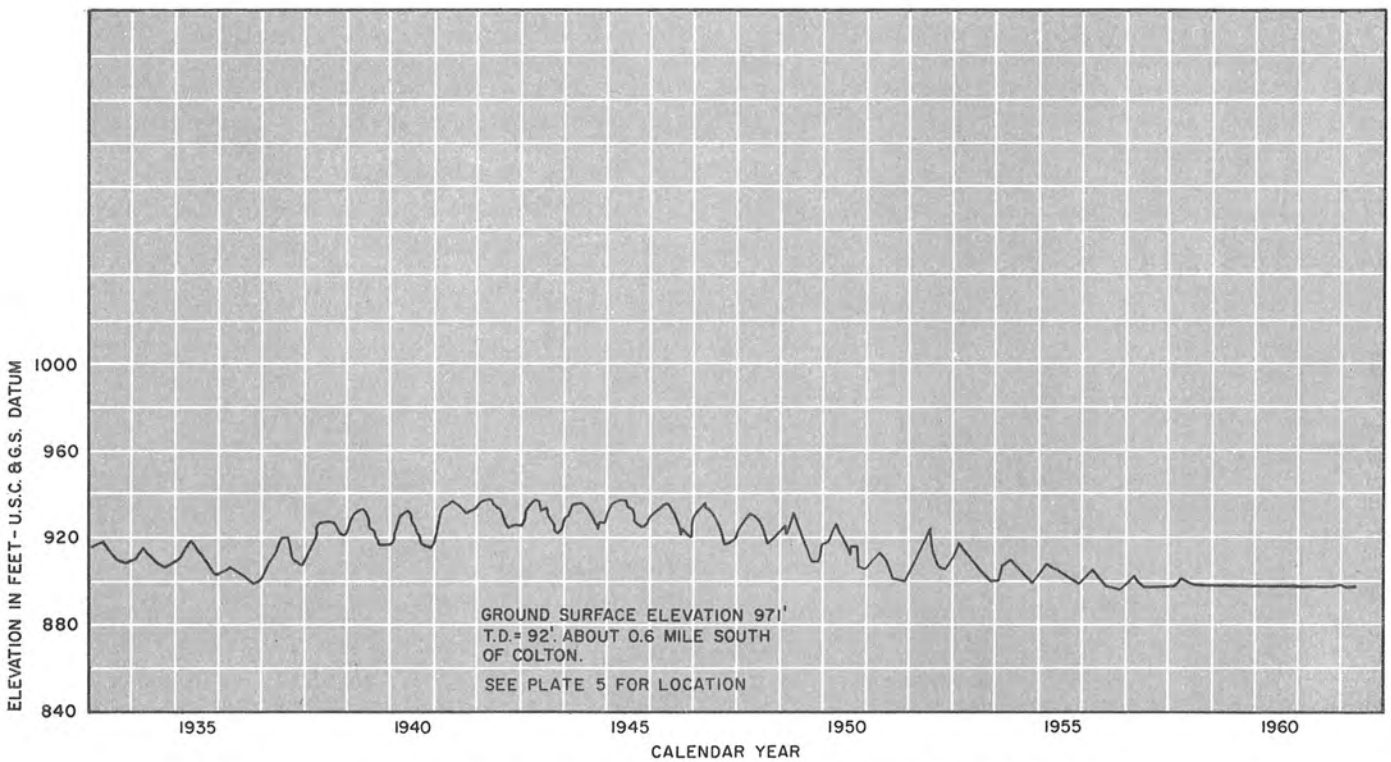


Figure 10. HYDROGRAPH OF STATE WELL No. 1S/4W-28H1
(No. 6)

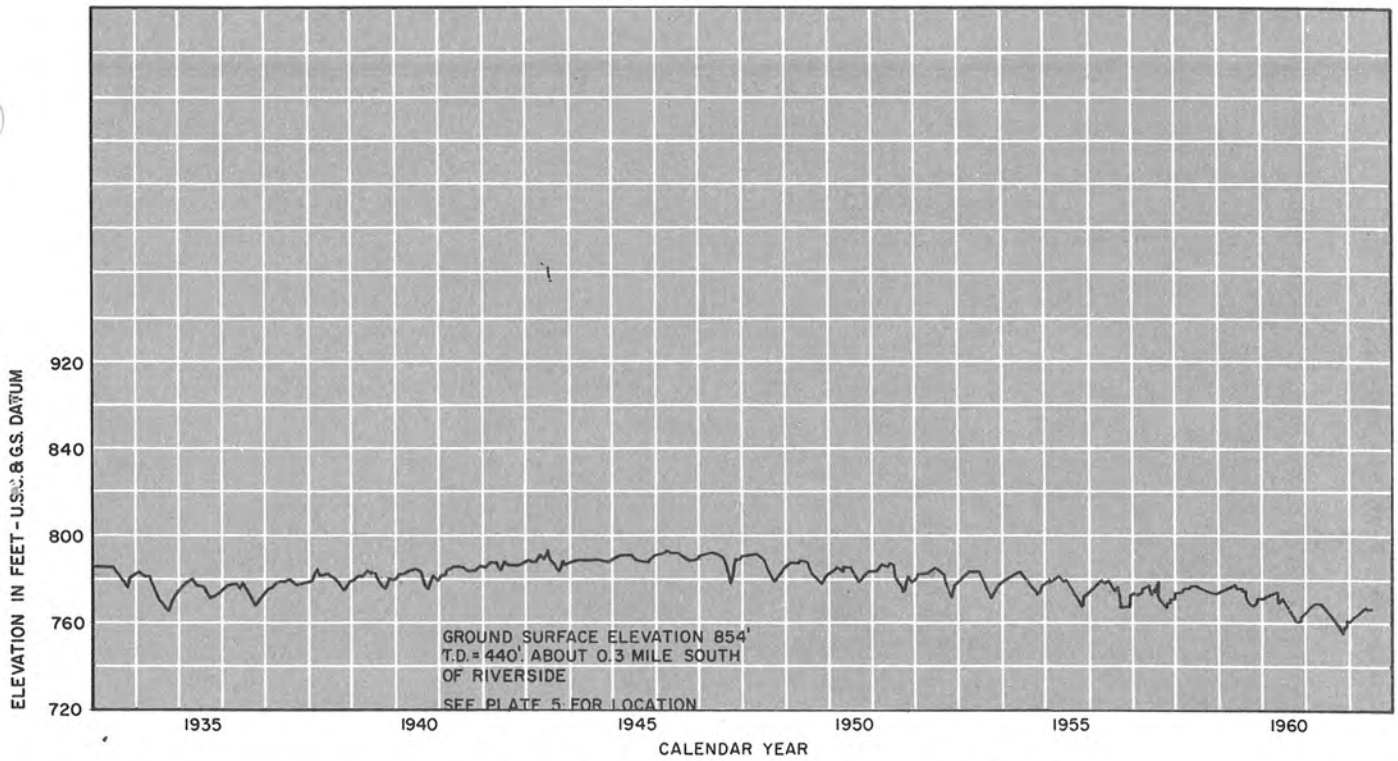


Figure 12. HYDROGRAPH OF STATE WELL No. 2S/5W-23QI
(No. 8)

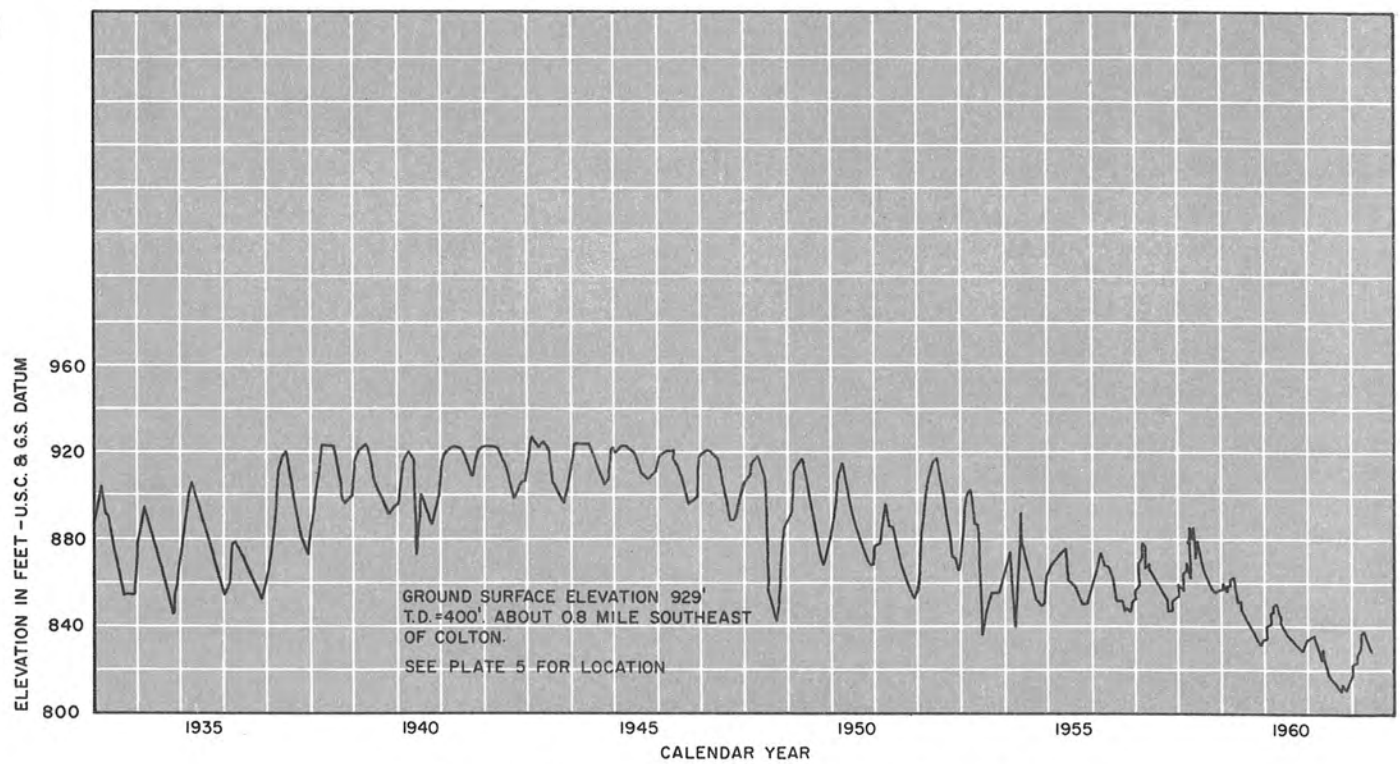


Figure 11. HYDROGRAPH OF STATE WELL No. 1S/4W-29HI
(No. 7)

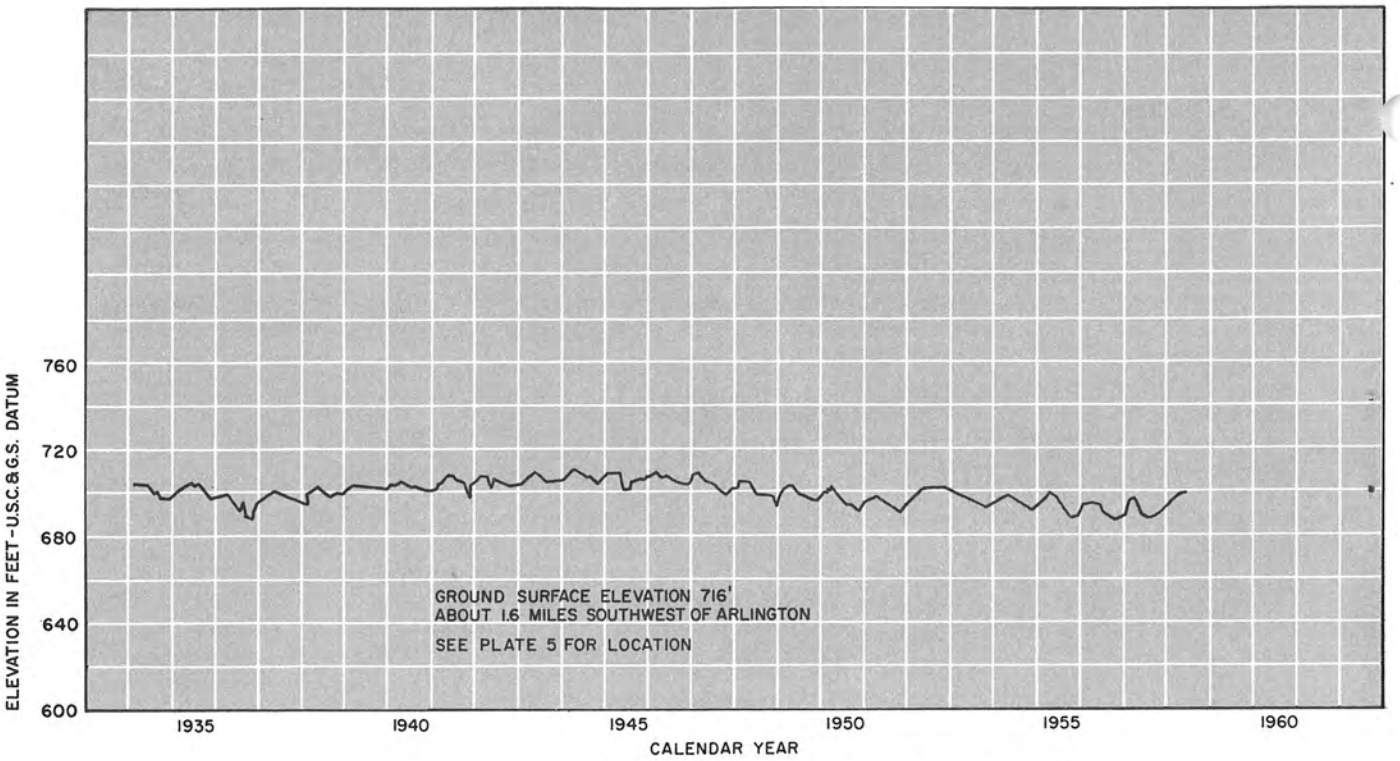


Figure 13. HYDROGRAPH OF STATE WELL No. 3S/6W-13M2
(No. 9)

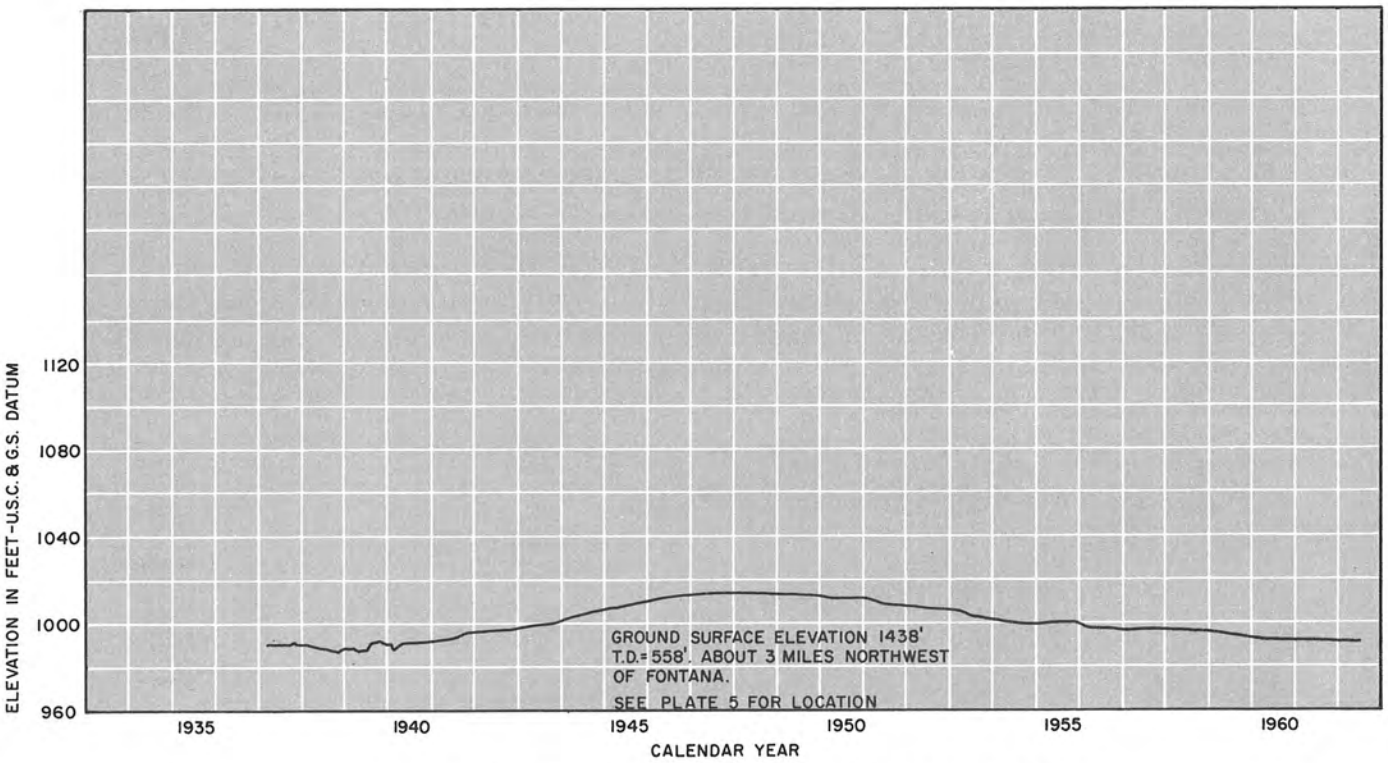


Figure 14. HYDROGRAPH OF STATE WELL No. 1N/6W-35A1
(No. 10)

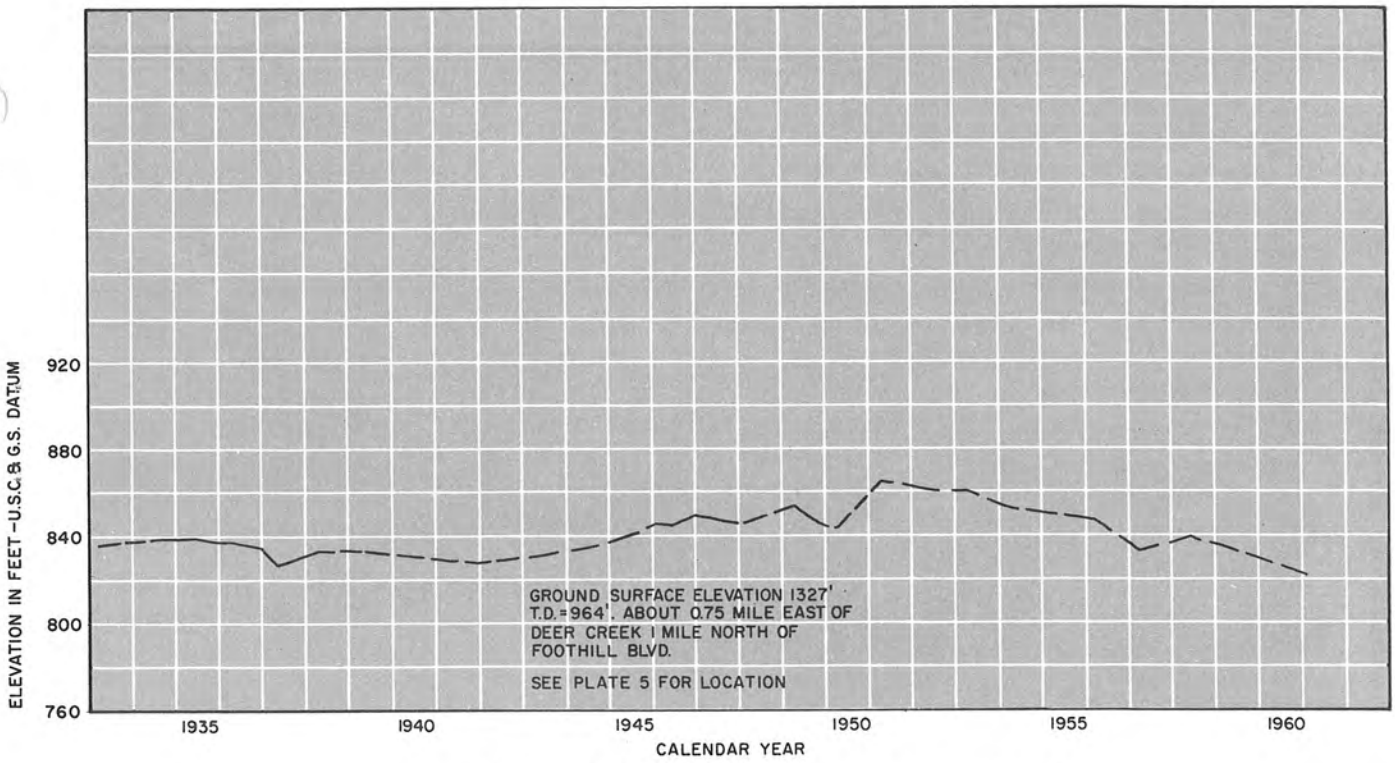


Figure 15. HYDROGRAPH OF STATE WELL No. 1S/7W-1A1
(No.11)

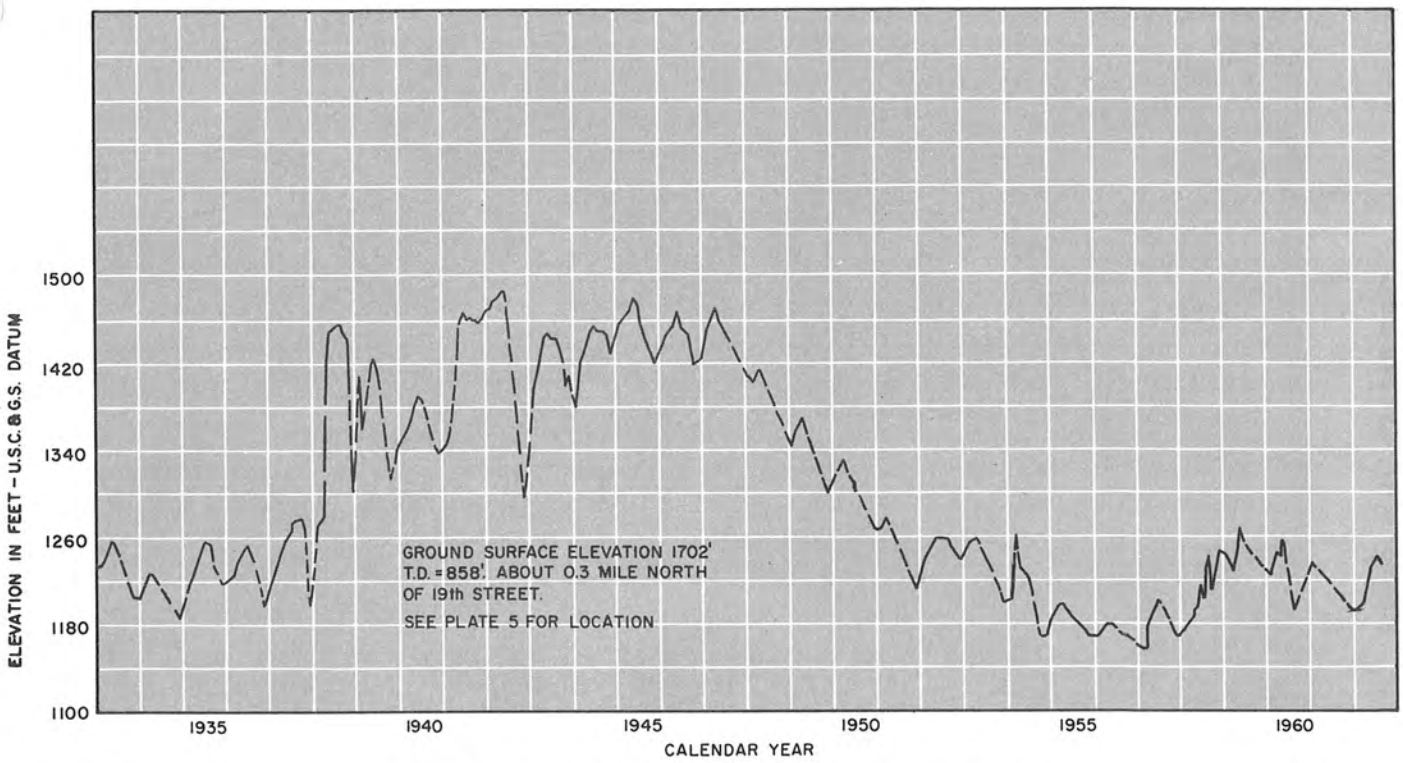


Figure 16. HYDROGRAPH OF STATE WELL No. 1N/7W-29 R3
(No. 12)

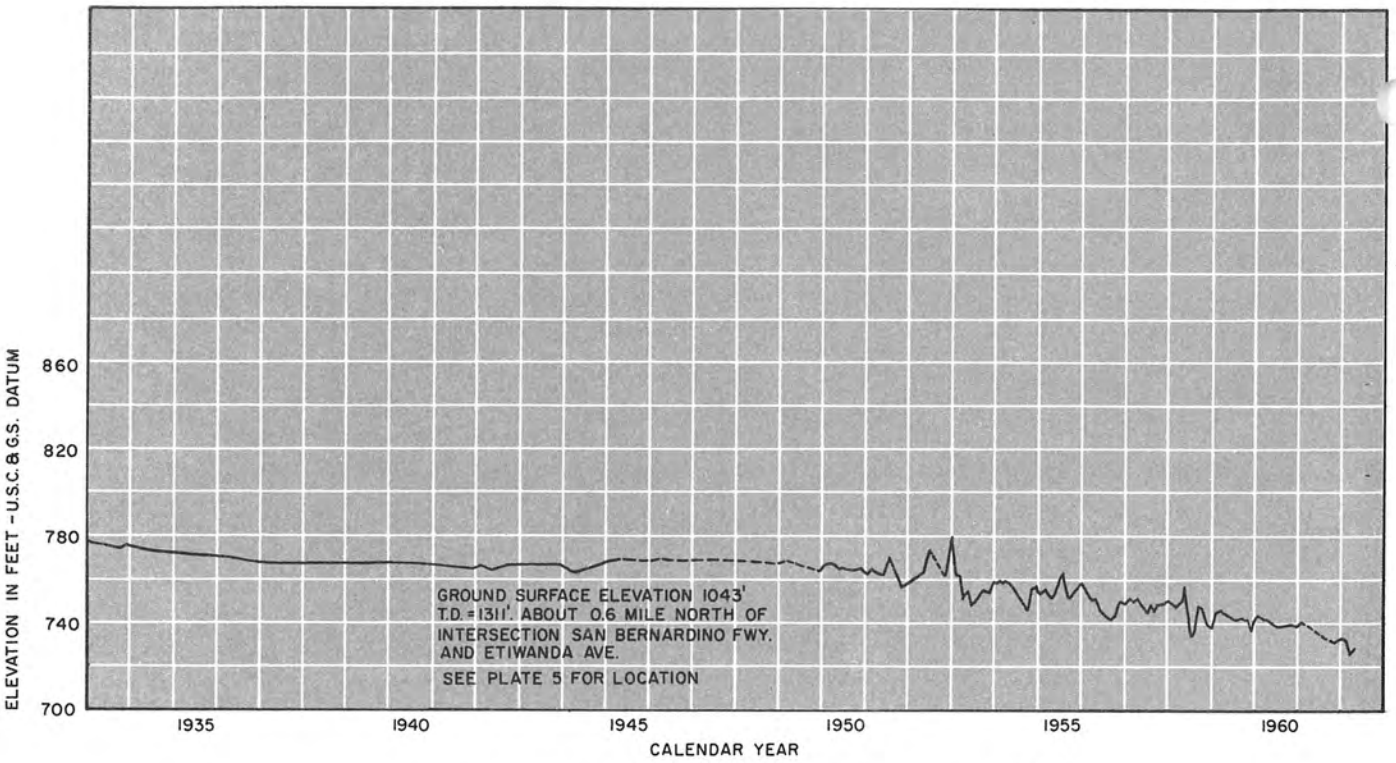


Figure 17. HYDROGRAPH OF STATE WELL No. 1S/6W-20B1
(No. 13)

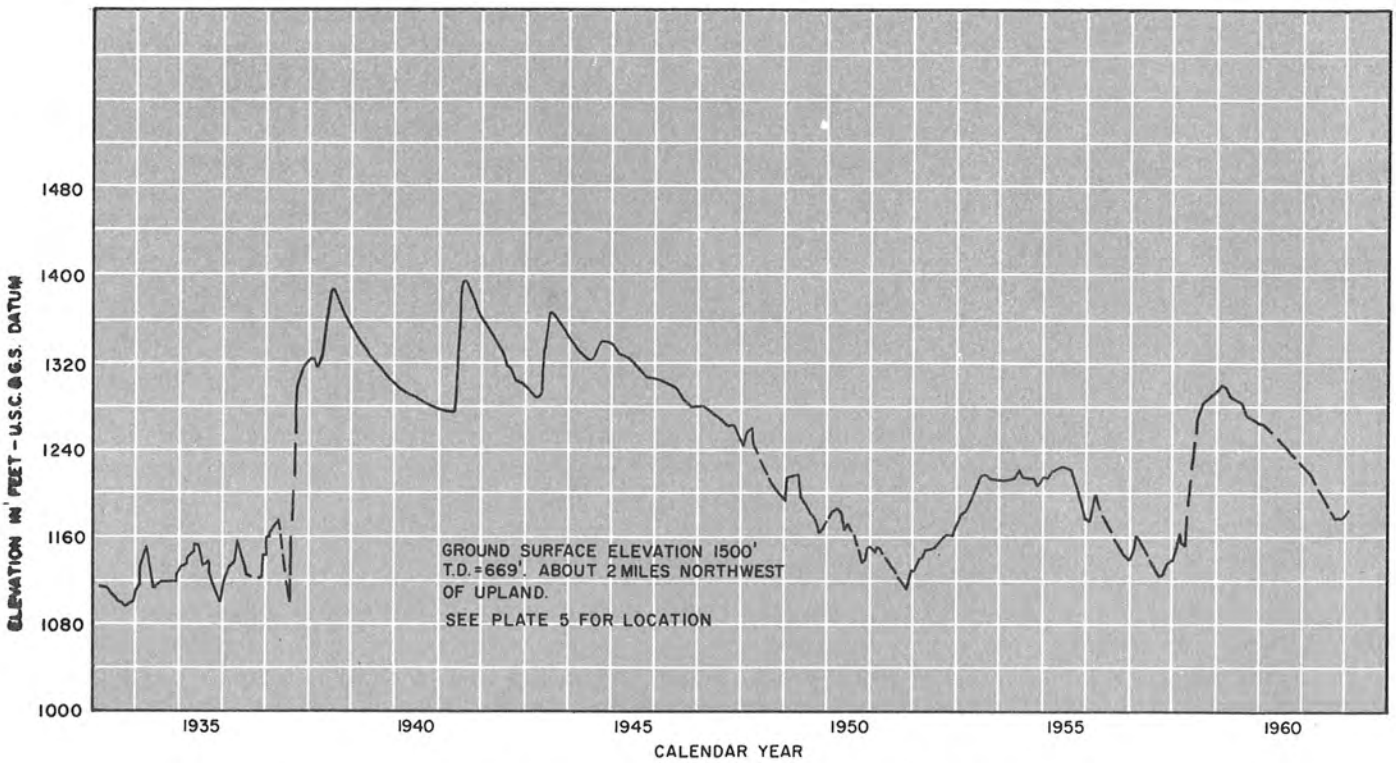


Figure 18. HYDROGRAPH OF STATE WELL No. 1S/8W-1D2
(No. 14)

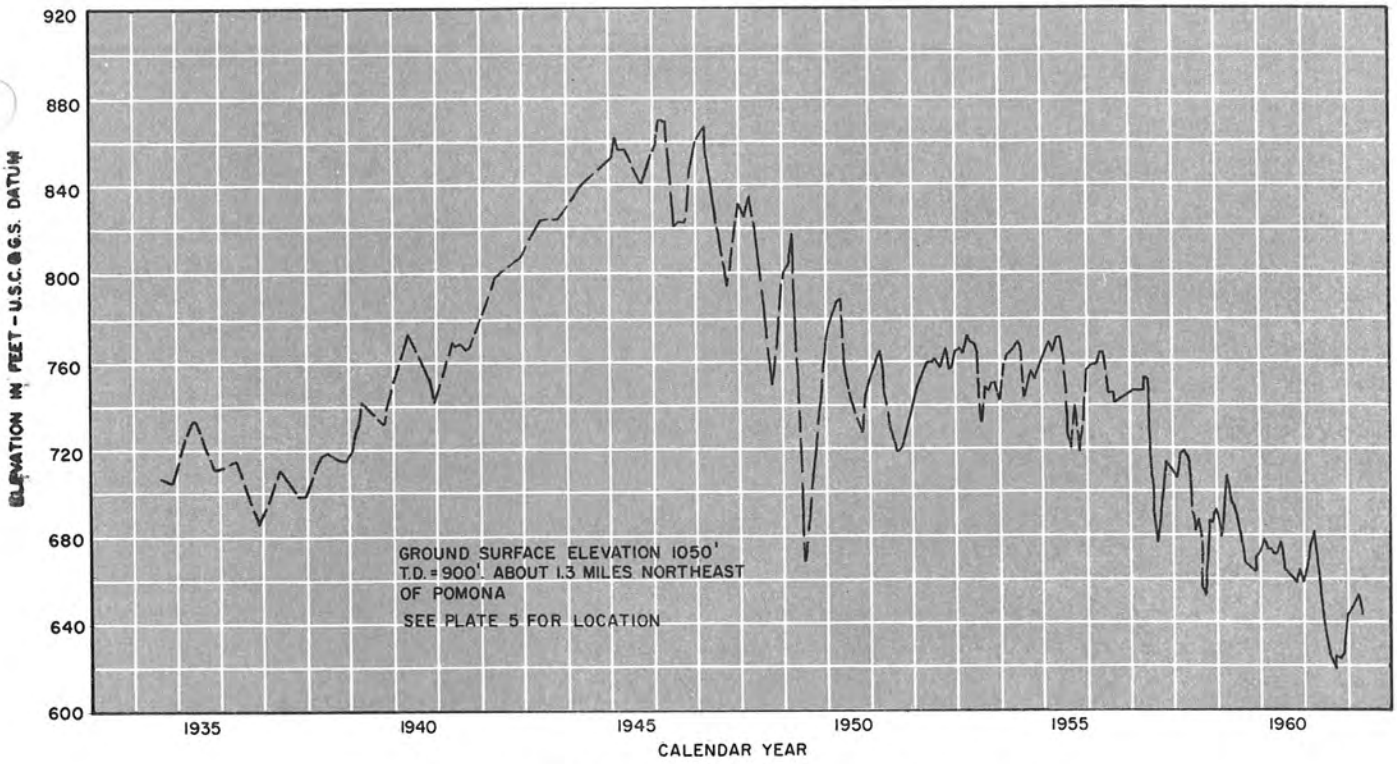


Figure 19. HYDROGRAPH OF STATE WELL No. 1S/8W-17K1
(No. 15)

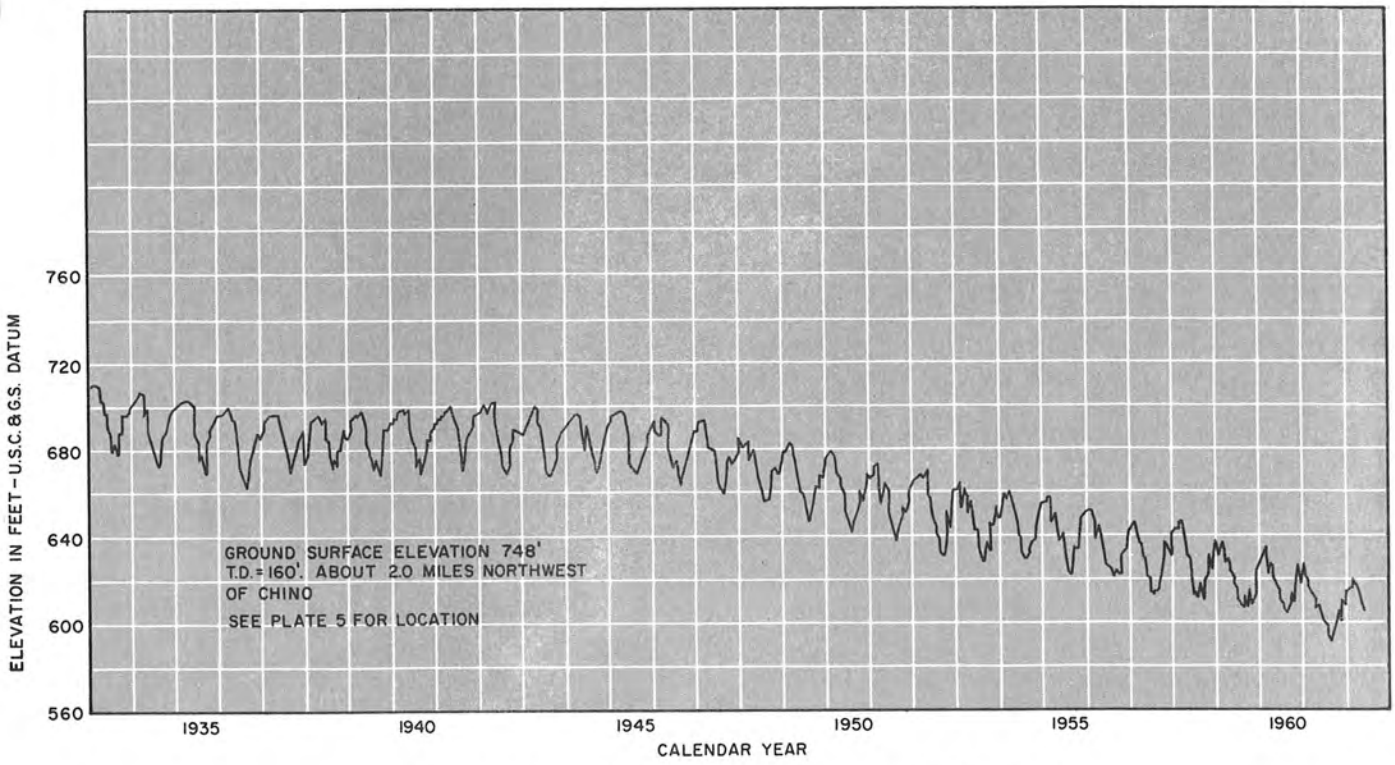


Figure 20. HYDROGRAPH OF STATE WELL No. 2S/8W-4P1
(No. 16)

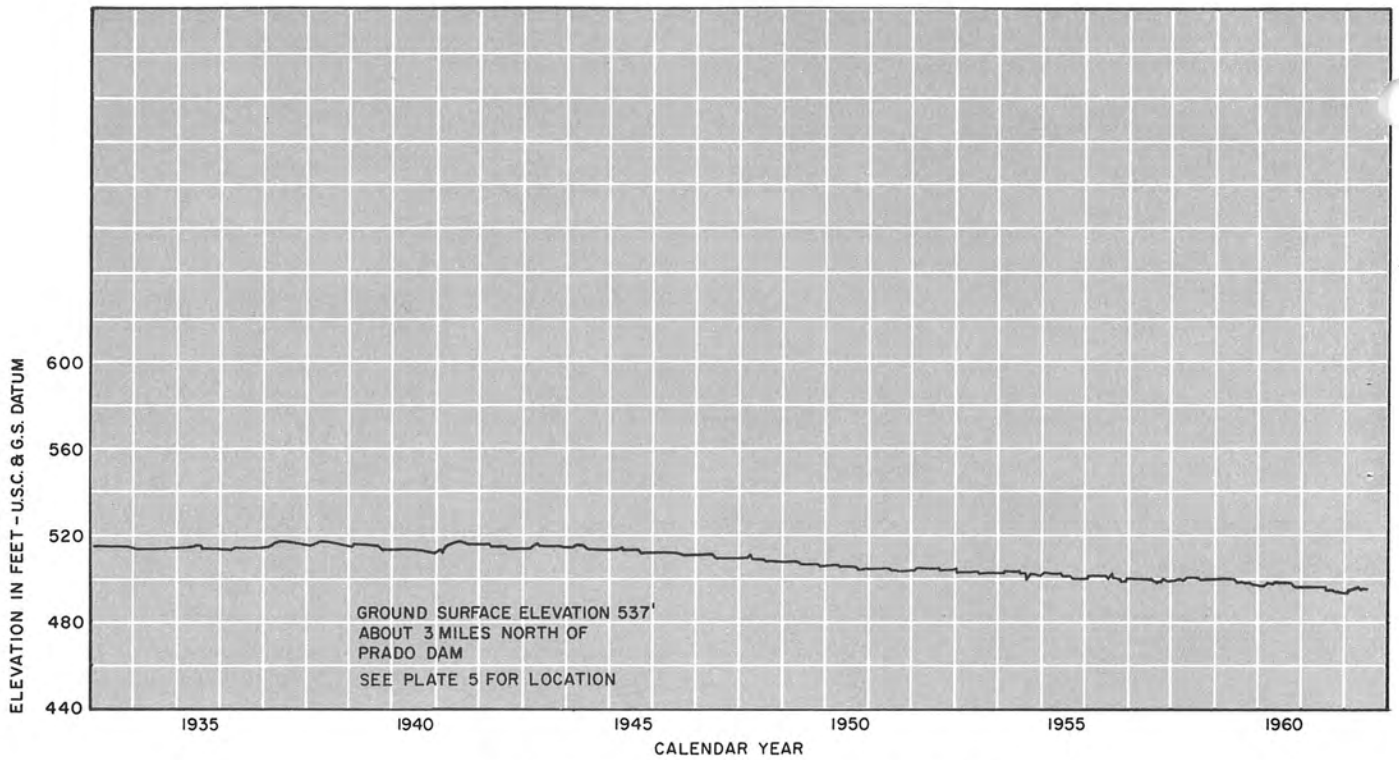


Figure 21. HYDROGRAPH OF STATE WELL No. 3S/7W-8A1
(No.17)

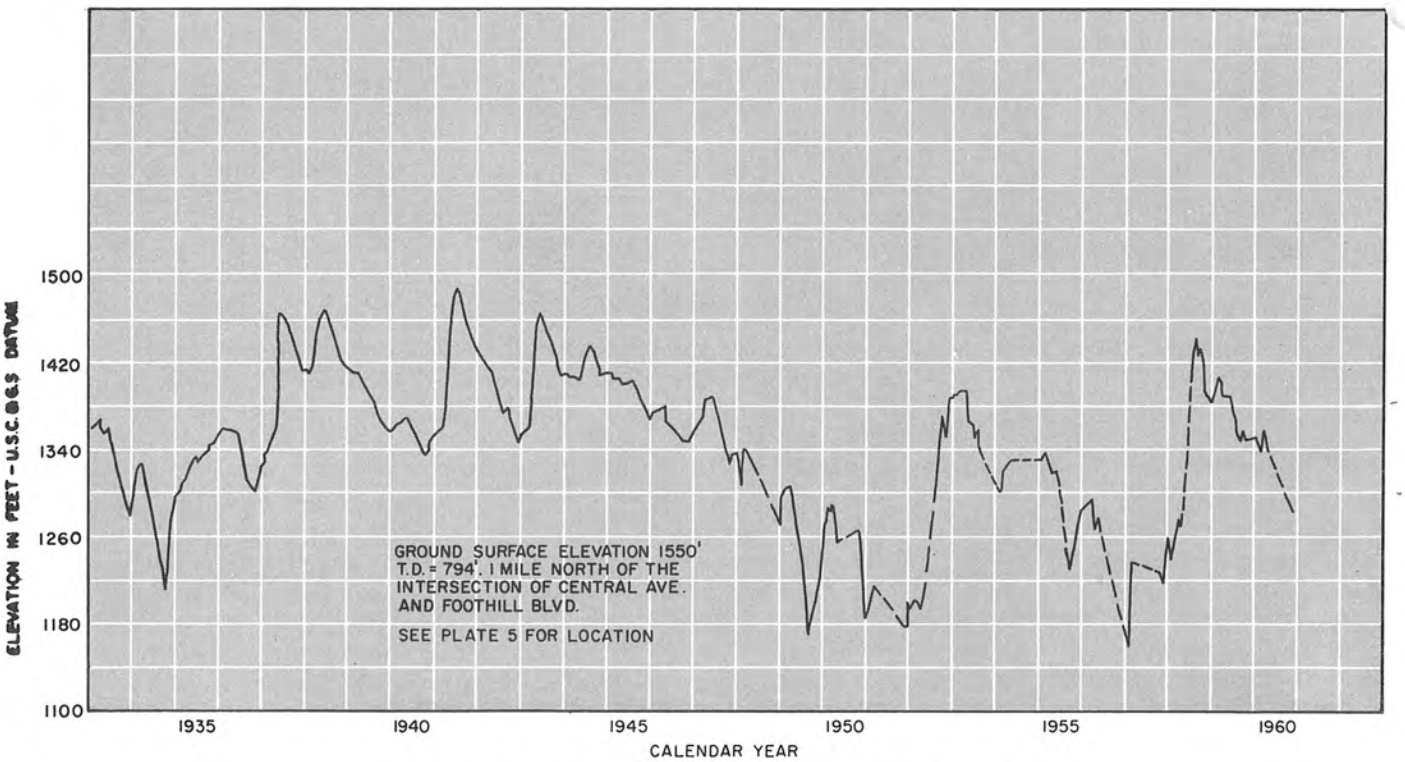


Figure 22. HYDROGRAPH OF STATE WELL No. 1S/8W-2B1
(No. 18)

IV. FUTURE WATER SUPPLY

To satisfy its ever increasing requirements, the Chino-Riverside area will in the future, as in the past, obtain its water supply from local and imported water in varying quantities. The proportions will depend upon the plan of operation selected by local agencies.

Quantity of Water

In 1965, supplies came from imported surface and ground water, surface water diversions, and locally pumped ground water in the proportions shown in Figure 28.

In addition to the supplies that have been used in the past, consumers in the Chino-Riverside area in the future, will use water from the State Water Project. Reclaimed waste water is a potential direct supply for various uses. Also, there is a possibility that converted sea water may become inexpensive enough to be economically justified for various purposes but the probability is not high.

Surface Water Diversions

Local surface water that has been used in the study area has been diverted from Warm Creek, San Antonio Creek, Deer Canyon, and Day Canyon. In planning future supplies, the historical average amount that was diverted and used may be presumed to be available in the future.

However, it should be pointed out that, according to the record, most of the surface water that was diverted for use in the area from 1933 to 1960 was for irrigation and for recharge of the ground water basin. Because of the intermittent nature of stream flows in the Chino-Riverside area, little was used directly for domestic and industrial purposes.

Imported Water Supplies

Importations have been from ground water of the nearby Bunker Hill-San Timoteo area and from the Colorado River through facilities of The Metropolitan Water District of Southern California (MWD).

The amount imported from the Bunker Hill-San Timoteo area is not expected to increase. However, MWD and the San Bernardino Valley Municipal Water District (SBVMWD), both of which have contracts with the State for water through the California Aqueduct, will be able to supply increasing amounts to the Chino-Riverside area.

Availability of MWD Water. In 1971, MWD will begin to supplement its supply with water from Northern California. In the Chino-Riverside area are three local agencies that are members of MWD; these are Chino Basin Municipal Water District (CBMWD), Pomona Valley Municipal Water District (PVMWD)--a portion

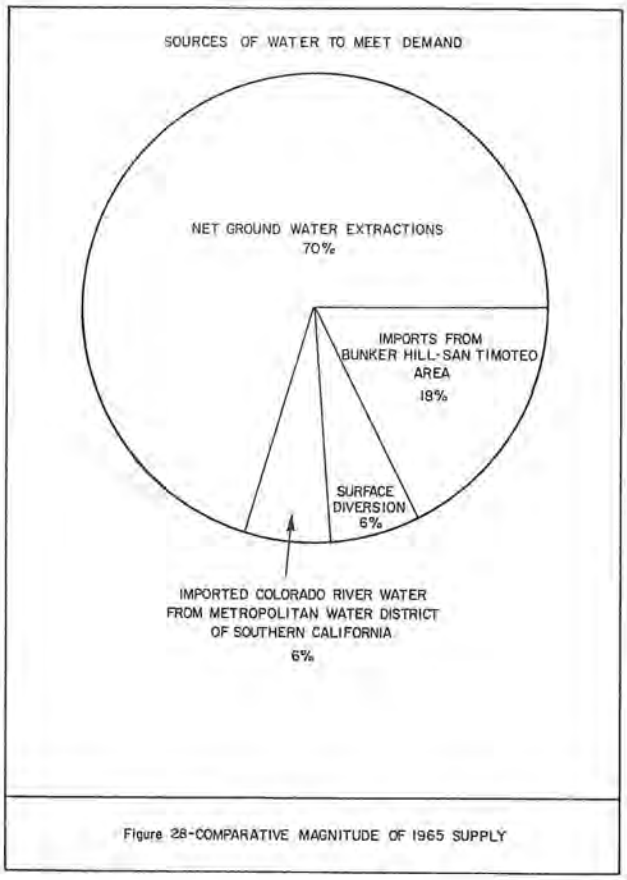


Figure 28-COMPARATIVE MAGNITUDE OF 1965 SUPPLY

of whose service area lies in the study area, and Western Municipal Water District of Riverside County (WMWD).

MWD's present and proposed primary distribution system in the study area (Figure 29) will be able to supply any quantity of water that the area requires, provided that (1) no water shortage exists elsewhere in the MWD service area and (2) local agencies build pipelines to connect their distribution systems to the MWD system.

Availability of SBVMWD Water. 46,000 acre-feet of water from the State Water Project will be available to SBVMWD in 1972, according to its contract with the State. The maximum entitlement which is specified in the contract is 102,600 acre-feet for the calendar year 1991. A portion of this water can be made available to meet demands of the district's service area within the boundaries of the Chino-Riverside area.

Local Ground Water

At present, approximately 12 million acre-feet of ground water is in storage. It is continually being replenished by deep percolation of delivered water, deep percolation of water from precipitation and stream flow, and subsurface inflow of water along the boundaries of the study area. At the same time, it is being reduced by subsurface outflow and by extraction.

The estimates of future items of inflow and outflow are discussed in detail in Attachment 2.

As is shown in Figure 28, a large part of the demand for water has been met by supplies from this underlying ground water basin. The amount from this source may--depending on the management plan implemented--be increased significantly.

Quality of Water

The quality of water available to the Chino-Riverside area at present is acceptable for most purposes. During the foreseeable future--say, the next 50 years--the quality of water supplies can be expected to remain satisfactory to meet most requirements. However, in some isolated locations, the quality may drop below standards.

Surface Water Diversions

Records available from three of the local streams supplying water to the study area indicate the following present average total dissolved solids (TDS) concentrations: Warm Creek, 330 parts per million (ppm); San Antonio Creek, 280 ppm; and Day Canyon, 162 ppm.

Because no change in the watershed of these creeks is expected in the future, the quality of water from these creeks is expected to remain at about the same level.

Imported Water Supplies

The quality of imported ground water from the nearby Bunker Hill-San Timoteo area cannot be projected with assurance at this time; the quality will depend upon the water resources management undertaken in that area. However, it can be predicted with certainty that, for a considerable length of time, the quality will not be degraded to a level where it cannot be used for domestic, industrial, and agricultural purposes.

The quality of imported water delivered by MWD is also uncertain. If Colorado River water is to be delivered exclusively, the TDS value has been estimated to change from 780 ppm in 1965 to about 1,050 ppm by 2000, and to remain at that level, according to a representative of the Colorado River Board of California.

On the other hand, if Northern California water is to be delivered to the study area through the facilities of MWD,

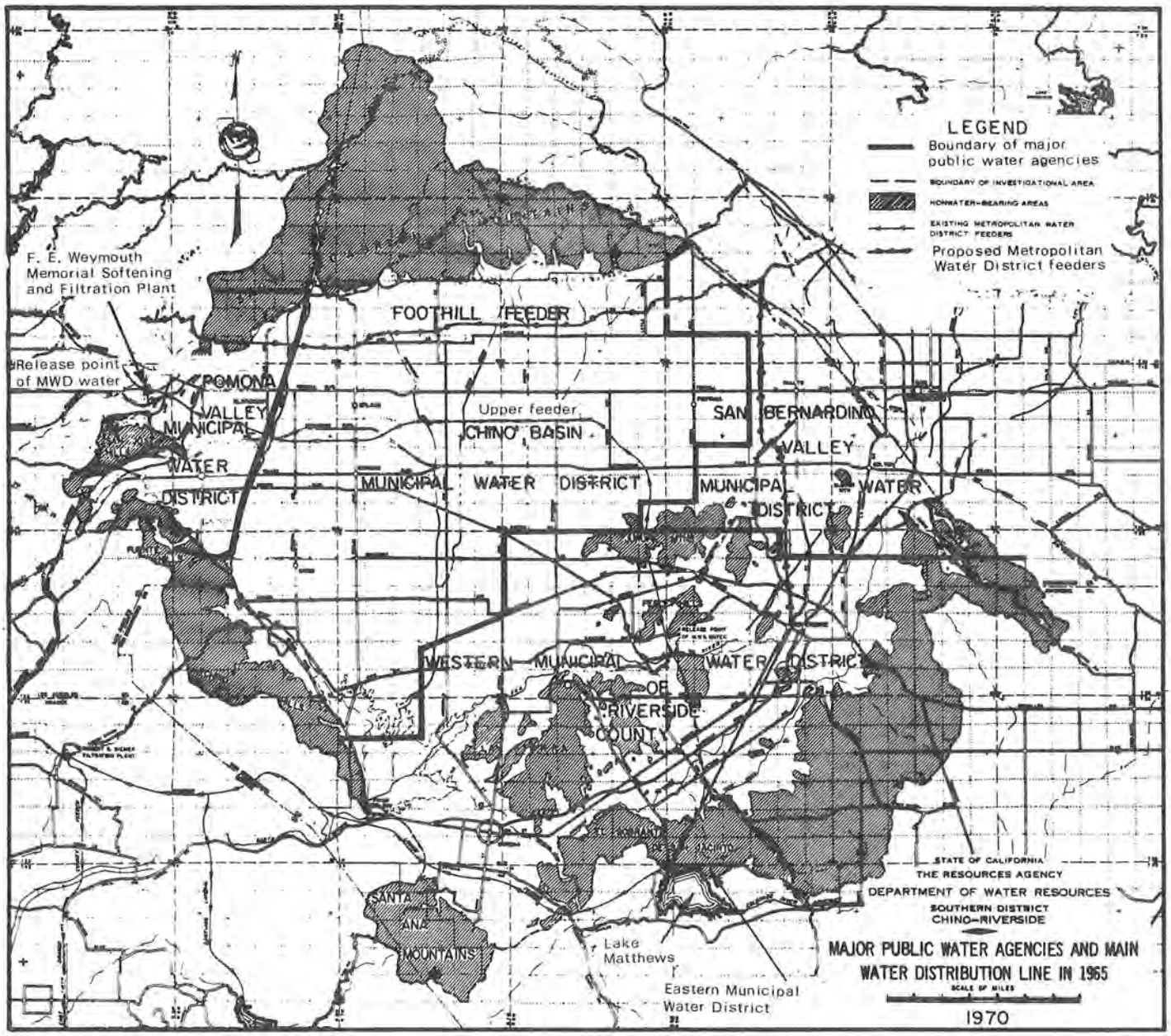


Figure 29

TABLE 39*

RANGE OF MEAN DISSOLVED SOLIDS CONCENTRATIONS
AT SILVERWOOD LAKE
FOR THE YEARS 1975, 1980, and 1985

Month	1975	1980	1985
January	270	128	123
February	272	119	114
March	260	115	111
April	262	117	115
May	279	120	119
June	294	123	121
July	307	124	121
August	321	127	123
September	340	136	134
October	320	136	136
November	306	137	137
December	312	134	132

* California Department of Water Resources, "Estimated Future Water Quality Conditions in the California Aqueduct", Office Report, 1969

the quality will be good. Table 39 provides an indication of the estimated quality of Northern California water which may be distributed in the study area, based on California Department of Water Resources, "Estimated Future Water Quality Conditions in the California Aqueduct", Office Report, 1969. It should be noted that these are only general estimates and should not be taken as absolute values.

Water quality objectives have been stated in contracts between MWD and the Department for water service from the State Water Project as set forth in the Burns-Porter Act (California Department of Water Resources, "The California State Water Project--Water Supply Contracts", Bulletin No. 141, Volume 1, Article 19, Page 600, 1965). The same objectives are stated in contracts with the SBVMWD. The quality objectives of the project water delivered was set at the values shown in Table 40.

Local Ground Water

A study of the records of quality of extracted ground water in the study

area indicates that the quality is declining, principally in the areas affected by waste disposal and agricultural return water and where the basin is shallow. These changes are taking place at a very slow rate, however.

Unless water of much higher quality than is currently available is introduced, the trend is expected to continue. It should be pointed out that, even if such replenishment is made at once, the improvement in quality of ground water would be slow in appearing because of the slow rate of movement of subsurface water.

TABLE 40*

WATER QUALITY OBJECTIVES FOR THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

	Unit	Monthly Average	Average for: Any 10-Year Period	Maximum
Total dissolved solids	ppm	440	220	--
Total hardness	ppm	180	110	--
Chlorides		110	55	--
Sulfates		110	20	--
Sodium percentage		50	40	--
Fluoride		--	--	1.5
Lead		--	--	0.1
Selenium		--	--	0.05
Hexavalent chromium		--	--	0.05
Arsenic		--	--	0.05
Iron and Manganese		--	--	0.3
Magnesium		--	--	125.0
Copper		--	--	3.0
Zinc		--	--	15.0
Phenol		--	--	0.001

* California Department of Water Resources, "The California State Water Project - Water Supply Contracts", Bulletin No. 141, Volume 1, Article 19, Page 600, 1965.

Attachment 1

BIBLIOGRAPHY

Attachment 1

BIBLIOGRAPHY

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Attachment 2

ESTIMATES OF FUTURE INFLOW AND OUTFLOW TO THE ZONE OF SATURATION

Attachment 2

ESTIMATES OF FUTURE INFLOW AND OUTFLOW TO THE ZONE OF SATURATION

The estimated values of the future annual deep percolation of precipitation, delivered water, artificial recharge of local water and streamflow were based on a mean annual rainfall of about 15.7 inches in the area. These values were imposed equally on all alternative plans. The fixed items of inflow were combined with the other assumed common items of inflow (subsurface) and with the outflow (fixed export of ground water) from the area.

This attachment describes the method used to estimate the future amounts of the inflow and outflow. The difference between the fixed inflow and outflow for each year, 1965 through 2015, was determined and this figure represented the fixed net inflow.

Subsurface Flows

In the past, subsurface inflow has occurred along the Bunker Hill-San Timoteo area boundary and from the San Gabriel Mountains, while subsurface outflow has occurred along the boundary of the San Gabriel Valley. The amount of subsurface flow varies with the water level elevations inside and outside the study area and will fluctuate according to the method of operating the ground water basins.

In the absence of definite plans for operating the underground reservoir in the Bunker Hill-San Timoteo area, an arbitrary assumption had to be made regarding the amounts of subsurface flows across the Chino-Bunker Hill-San Timoteo area.

In addition to these basin boundary conditions, a subsurface inflow of 13,000 acre-feet per year was assumed to take place from the San Gabriel Mountains in the north as a result of stored water moving out of the fractures in the basement complex into the alluvial fill. This value was estimated to be the average annual subsurface inflow for 1933-34 through 1959-60.

Historically the subsurface outflow from the Chino-Riverside area along the San Gabriel Valley Boundary has averaged about 7,000 acre-feet per year. However, in the past 10 years this flow has diminished and for the future was assumed to be equal to 7,000 acre-feet per year.

Deep Percolation of Surface Water

Deep percolation of surface water occurs in the water-bearing portion of the area. In this investigation, the total deep percolation of surface water was separated into four components: percolation of (1) delivered water; (2) precipitation; (3) storm water in stream channels (streamflows); (4) local water in off-stream spreading grounds (artificial recharge of local water).

All economic comparisons of alternative plans were made assuming a mean annual precipitation of approximately 15.7

inches in the area. Consequently, all deep percolation values were for this condition.

Percolation of future delivered water can be separated into the following components: (1) agricultural water; (2) waste water; and (3) lawn water. Total deep percolation from this source was estimated to drop from about 105,000 acre-feet in 1965 to approximately 70,000 acre-feet in 2015, a decrease of approximately 30 per cent.

It was estimated that percolation from agricultural water would drop from about 90,000 acre-feet in 1965 to 30,000 acre-feet in 2015. This decrease reflects the general decrease in the size of agricultural lands that has occurred and is expected to occur.

The amount of agriaultural water to be used in the future was determined based on its present and estimated future land use. The agricultural water was then distributed to polygonal areas (nodes) of the mathematical model in proportion to the size of agricultural lands in each.

Percolation of waste water results from the use of cesspools and septic tanks and from treated sewage effluent discharged into the Santa Ana River and percolation basins within the area. It was estimated, based on information obtained from the local agencies, that total percolation from this source would increase from 60,000 acre-feet in 1965 to 370,000 in 2015.

Lawn water is water applied to lawns and gardens. Total percolation from this source was estimated to increase from 11,000 acre-feet in 1965 to 40,000 acre-feet in 2015. The amount of water applied to the lawns was arrived at by multiplying the projected lawn surface area in single-family dwelling residential areas by the average unit value of consumptive use of lawns presented in the main body of this report and dividing the product by the irrigation efficiency. The resulting value was then multiplied by historic average unit values of percolation in acre-feet per acre to obtain the percolation of lawn water.

Percolation of Precipitation

For the percolation of precipitation, criteria were developed which related percolation to "equivalent precipitation", which is equal to precipitation falling directly on pervious surfaces plus runoff from adjacent impervious areas, such as roofs and driveways in single residential unit areas. (Most of the runoff from impervious areas in commercial, industrial, multiple residential dwellings, streets, etc., goes into storm drains). The area of pervious surfaces in future single residential unit areas was estimated on the basis of the past relationship between population density and pervious areas.

The depth of precipitation in each nodal area was estimated to be equal to the future average depth of precipitation for the entire water-bearing portion of the area multiplied by the ratio of the nodal average rainfall to the average rainfall for the entire area determined from 27-year (1933-34 through 1959-60) average isohyetals.

Percolation of precipitation in each node was estimated by using the criteria which was developed based on the past relationships between annual rainfall, runoff and deep percolation of precipitation. The following briefly describes pertinent information regarding this estimate:

> Because cyclic fluctuation of rainfall in the Valley has little economic significance on the comparison of plans of operation, a mean rainfall (15.7 inches) was assumed to occur throughout the period 1970-2015. For the year 1965, a figure representing the actual average rainfall was

used. For each node, this average precipitation was converted into an equivalent precipitation.

With the equivalent precipitation in feet known for each node, the unit percolation of precipitation in acre-feet per acre of pervious area was obtained from the proper criterion curve (see Figure 30).

The percolation of precipitation in acre-feet was made equal to future pervious area in acres multiplied by the unit percolation of precipitation in feet.

Streambed Percolation

In the future, the Santa Ana River will be the only major stream in the Chino-Riverside Area in which percolation will occur. San Antonio and Chino Creeks are presently lined and Cucamonga Creek will be in the near future. Percolation in other, minor streams, was included with percolation of precipitation.

The Santa Ana River enters the Chino-Riverside Area across the San Jacinto Fault. For approximately 10 miles -- from the fault to Riverside Narrows -- the flow in the river is ephemeral. At Riverside Narrows, the river becomes perennial, being fed by water appearing from the ground water reservoir to the streambed because of a high water table. Historically, percolation in the river has occurred only within the 10-mile reach between the San Jacinto Fault and Riverside Narrows.

The ephemeral natural inflow across the San Jacinto Fault consists of storm runoff and water that emerges in the streambed from the ground water reservoir because of a high water table.

Just south of the fault, a considerable amount of this water is diverted during the irrigation season by the City of Riverside. Water passing this diversion point percolates before reaching Riverside Narrows. During the winter months, when the water from the Bunker Hill Basin is not diverted, the flow is occassionally continuous to Riverside Narrows. During storms, the flow is generally continuous from the San Jacinto Fault to Riverside Narrows.

The criterion for percolation in the Santa Ana River takes the form of a graph in which percolation is plotted as a function of the net inflow to the river (Figure 31). Net surface inflow equals the total inflow of storm water minus the water diverted by the City of Riverside just south of the San Jacinto Fault. The storm flow includes estimated accretions to the river from local runoff within the Chino-Riverside Area. These accretions were estimated by multiplying the unit net precipitation by the estimated impervious area contributing runoff to the river. The unit net precipitation was obtained by subtracting unit evaporation loss on the impervious area (refer to the consumptive use study in Chino-Riverside Area) from the unit precipitation falling on the land. The impervious area contributing runoff to the river was assumed to consist of all impervious areas except the impervious portions of the residential single, residential rural, irrigated agricultural, and nonwater service area. The percolation in the Santa Ana River was then determined by subtracting the storm flow at the Riverside Narrows from the net inflow to the river.

The criterion for the percolation in the Santa Ana River, shown on Figure 31, consists of two curves. This is attributed to the fact that after a series of wet years, the Riverside portion of the basin fills up and there is less percolation in the river. The years of relatively high storm flow in the river, therefore, formed the lower curve. It has been found that the upper curve is generally related to those years in which the ground water elevations at

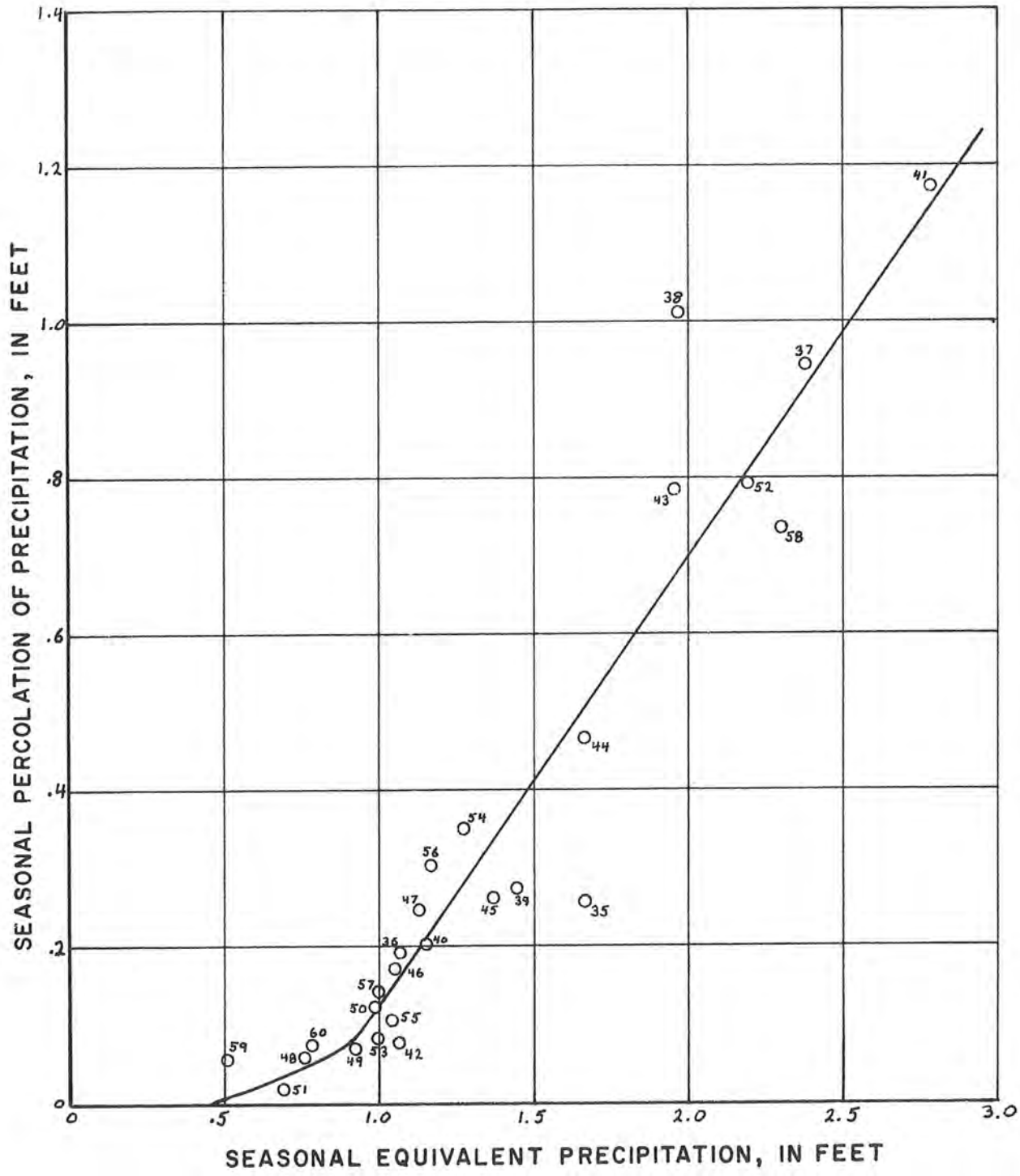

Figure 30 CRITERIA FOR PERCOLATION OF PRECIPITATION IN THE CHINO-RIVERSIDE AREA

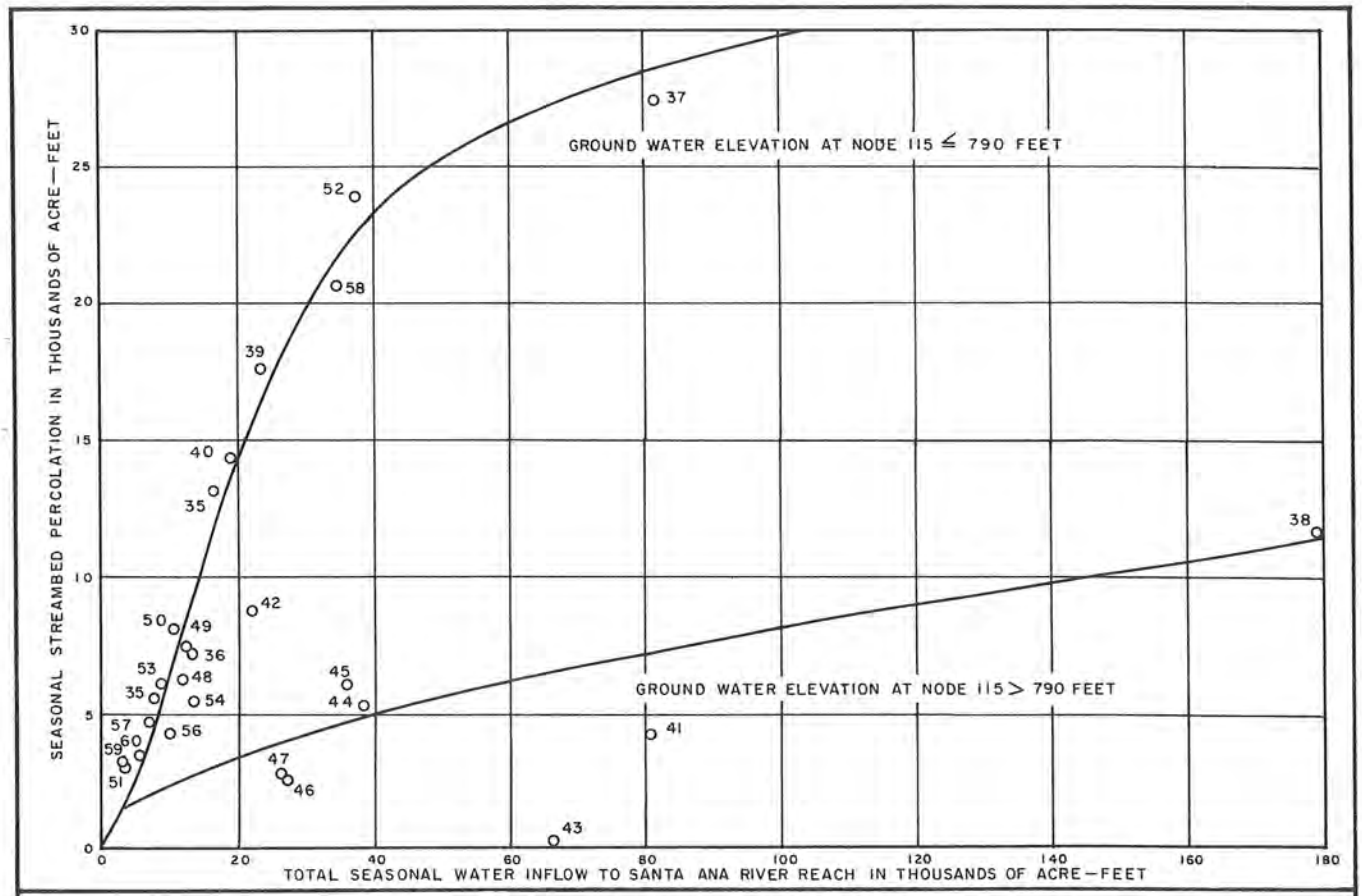

Figure 31-CRITERIA FOR STREAMBED PERCOLATION
IN SANTA ANA RIVER REACH BETWEEN THE SAN JACINTO FAULT
AND RIVERSIDE NARROWS WITHIN THE CHINO-RIVERSIDE AREA

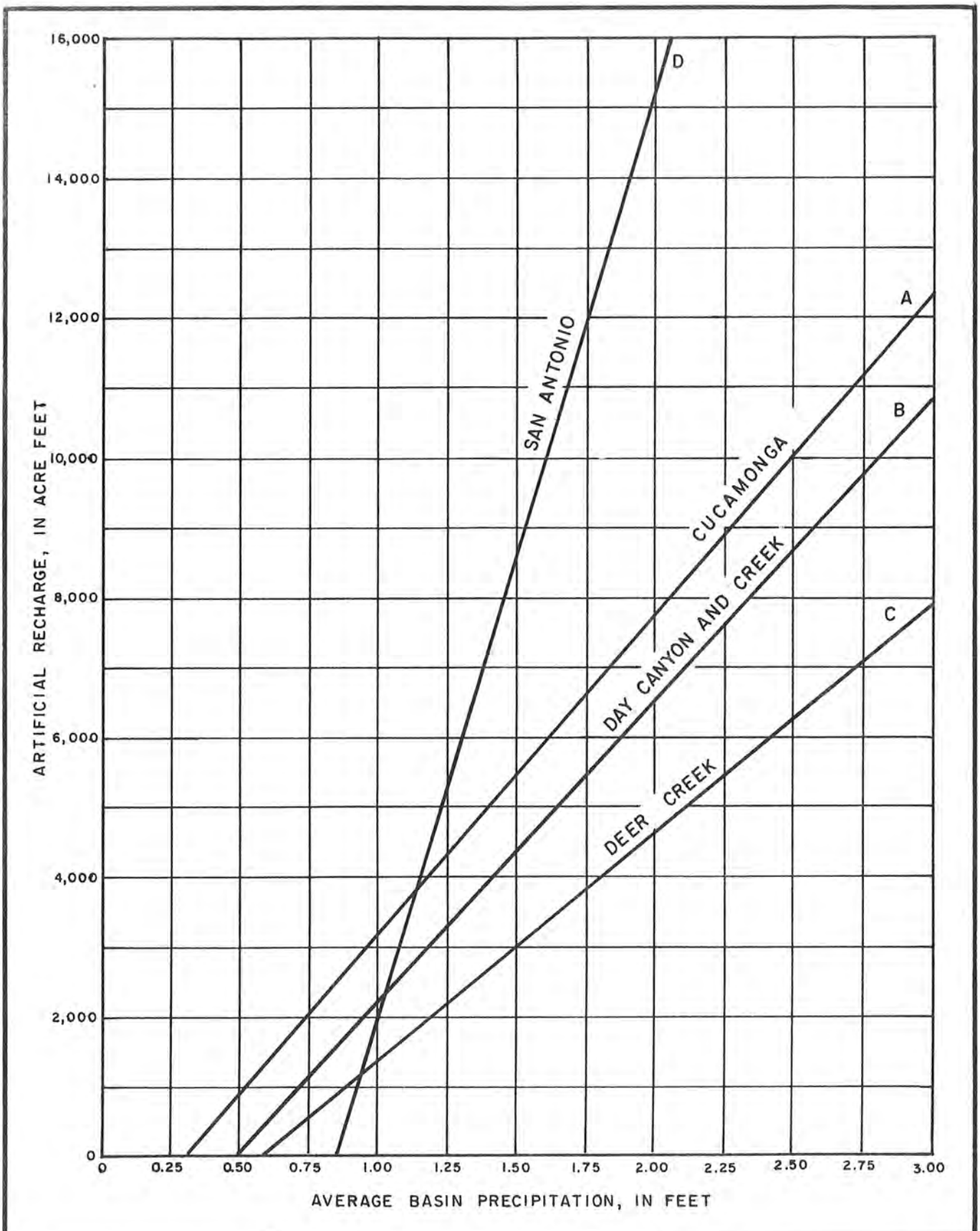

Figure 32 - CRITERIA FOR ARTIFICIAL RECHARGE
IN MAJOR SPREADING GROUNDS IN THE CHINO-RIVERSIDE AREA

the center of Node 115 (mathematical model) are equal to or less than 790 feet above sea level, while the lower curve is generally related to those years in which the ground water elevations at the same point were more than 790 feet above sea level.

The total percolation in the river can be obtained from Figure 31 if rainfall on the water-bearing portion of the area is known. Distribution of percolation to the affected nodes was made in proportion to the area of the river area contained in the particular node.

The Santa Ana River reach between Riverside Narrows and Prado Flood Control Dam has historically been a perennial stream, and the amount of percolation in this reach is expected to be insignificant. The amount of percolation in the stretch between the San Jacinto Fault and Riverside Narrows varies depending on the water level elevations below the stretch. This amount can be estimated by the use of a criterion curve described above.

Artificial Recharge

Artificial recharge of natural local water takes place in spreading grounds throughout the study area. The average historical amount of artificial recharge of local water in the spreading grounds was estimated to be 18,000 acre-feet and is expected to be approximately 16,000 acre-feet for the 50 years 1965-2015.

The total amount of water spread and percolated depends upon the amount of precipitation, resulting surface inflow, and percolation capacities of the recharge areas. A graph relating the amounts of water spread (in cubic feet per second) to precipitation, is shown as Figure 32

TABLE 41

ESTIMATED INFLOW TO AND OUTFLOW FROM ZONE OF SATURATION COMMON TO ALL PLANS OF OPERATION FOR CHINO-RIVERSIDE UNDER WATER SUPPLY CONDITIONS OF HISTORICAL PRECIPITATION, 1965 TO 2015

In thousands of acre-feet

	Inflow						Outflow		
	Deep Percolation								
Year	Local Spread	Stream Flow	Delivered Water	Precipitation [A]	Waste Water Percolation [B]	Sub-Surface Flow	Sub-Surface Flow	Misc. Extraction [C]	Net Inflow
1965	14.3	16.0	105.7	56.4	60.7	19.8	-.7	-23.1	249.1
1970	16.7	19.5	98.7	64.2	81.7	19.8	-.7	-22.1	277.8
1975	16.7	19.7	94.5	62.3	113.2	19.8	-.7	-22.1	303.4
1980	16.7	19.9	90.5	60.2	150.5	19.8	-.7	-22.1	334.8
1985	16.7	20.1	87.5	58.8	185.1	19.8	-.7	-22.1	365.2
1990	16.7	20.3	84.5	57.3	219.5	19.8	-.7	-22.1	395.3
1995	16.7	20.5	82.0	56.0	253.3	19.8	-.7	-22.1	425.5
2000	16.7	20.6	79.9	54.8	285.8	19.8	-.7	-22.1	454.8
2005	16.7	20.8	77.2	54.0	316.5	19.8	-.7	-22.1	482.2
2010	16.7	20.9	74.8	53.2	347.0	19.8	-.7	-22.1	509.6
2015	16.7	20.4	72.5	52.5	372.5	19.8	-.7	-22.1	531.6
TOTAL	181.3	218.7	947.8	629.7	2385.8	217.8	-7.7	-244.1	4329.3
AVERAGE	16.5	19.9	86.2	57.2	216.9	19.8	-.7	-22.1	393.6

A Actual precipitation used for 1965, mean rainfall conditions thereafter.
B Waste water percolation assuming maximum retention of waste and maximum import and percolation of San Bernardino treatment plant effluent.
C Includes all interoperational area transfers of extraction and ground water exported to other basins.

For any anticipated precipitation, the amounts of artificial recharge in acre-feet can be estimated for each spreading ground. Percolation capacities and other pertinent data for each of the existing spreading grounds in the area are tabulated in Table 4. In the alternative plans considered in this study additional spreading grounds were not considered.

Ground Water Extraction

The extraction of ground water contributed to the diminution of water in ground water basins. Because there is a large amount of ground water in storage in the Chino Basin, a large amount of annual extraction can be presumed in this area depending on a plan of basin operation. However, because of the shallow aquifer in the Riverside area, the annual amounts of ground water extraction in the latter area is presumed to be limited to the historical average.

In addition to the ground water consumptively used in the study area, a very small quantity is exported. In 1960, exports amounted to 5,000 acre-feet. For purposes of this study, the amount of exported water was assumed to be about the same in the future.

Table 41 lists the fixed values of inflow for the period 1965 to 2015 and also the amounts of exported water.

MOJAVE DESERT

TRANSVERSE RANGES

SAN GABRIEL MOUNTAINS

MT. SAN ANTONIO

CUCAMONGA PK.

CUCAMONGA FAULT ZONE

SAN BERNARDINO MOUNTAINS

SAN ANDREAS FAULT ZONE

SAN BERNARDINO VALLEY

SAN GABRIEL VALLEY

SAN GABRIEL RIVER

RIO HONDO

LOS ANGELES RIVER

INGLEWOOD

LOS ANGELES

HUNTINGTON PARK

PASADENA

WHITTIER

WHITTIER FAULT ZONE

SAN JOSE HILLS

SAN JOSE WASH

POMONA

CHINO

ONTARIO

CHINO PLAIN

SANTA ANA RIVER

SANTA ANA

PUENTE HILLS THRUST FAULT

CHINO FAULT

LOS ANGELES BASIN

BUENA PARK

SANTA ANA MOUNTAINS

CORONA

LA SIERRA

ARLINGTON

PEDLEY HILLS

JURUPA HILLS

COLTON

LA LOMA HILLS

FONTANA

SAN BERNARDINO

RIVERSIDE

RECHE CYN.

BOX SPRINGS MT.

SAN JACINTO FAULT ZONE

REDLANDS

SANTA ANA RIVER

BANNING

BEAUMONT

SAN JACINTO

HEMET

PERRIS

TEMESCAL VALLEY

ELSINORE FAULT ZONE

TEMECULA

FALLBROOK

COACHELLA VALLEY

SAN JACINTO MOUNTAINS

PENINSULAR RANGES

LEGEND

- ALLUVIUM AND ASSOCIATED DEPOSITS OF RECENT OR PLEISTOCENE AGE
- SEDIMENTARY ROCKS, LARGELY TERTIARY WITH SOME ROCK OF PLIO-PLEISTOCENE AND CRETACEOUS AGE
- CRYSTALLINE AND METAMORPHIC ROCKS, CRETACEOUS OR OLDER; SOME TERTIARY ROCKS
- PATTERN INDICATES ORIENTATION OF REGIONAL STRUCTURAL TREND
- KNOWN FAULTS
- INFERRED FAULTS
- CONCEALED FAULTS
- BOUNDARY OF STUDY AREA

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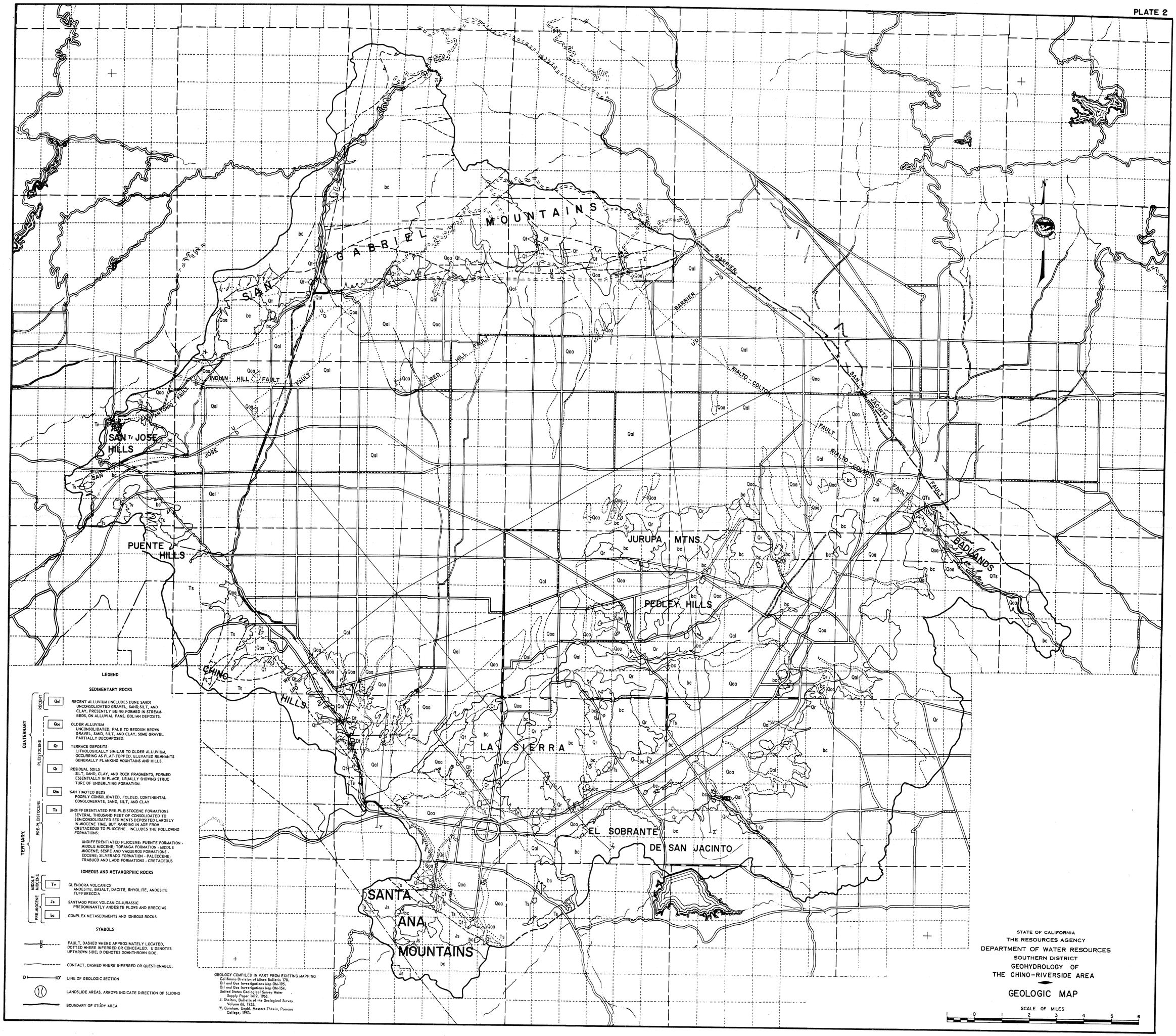
SOUTHERN DISTRICT

GEOHYDROLOGY OF THE CHINO-RIVERSIDE AREA

GENERALIZED GEOLOGIC MAP SHOWING LOCATION OF THE STUDY AREA AND RELATIONSHIP OF GEOMORPHIC PROVINCES

SCALE OF MILES 5 0 5 10

OREGON
SAN FRANCISCO
SACRAMENTO
LAKE TAHOE
MONO LAKE
NEVADA
PACIFIC OCEAN
LOS ANGELES
AREA SHOWN
MEXICO
SALTON SEA
ARIZONA



LEGEND

SEDIMENTARY ROCKS

QUATERNARY

RECENT

- Qal — RECENT ALLUVIUM (INCLUDES DUNE SAND) UNCONSOLIDATED GRAVEL, SAND, SILT, AND CLAY; PRESENTLY BEING FORMED IN STREAM BEDS, ON ALLUVIAL FANS; EOLIAN DEPOSITS.

PLEISTOCENE

- Qoa — OLDER ALLUVIUM UNCONSOLIDATED, PALE TO REDDISH BROWN GRAVEL, SAND, SILT, AND CLAY; SOME GRAVEL PARTIALLY DECOMPOSED.
- Qt — TERRACE DEPOSITS LITHOLOGICALLY SIMILAR TO OLDER ALLUVIUM, OCCURRING AS FLAT-TOPPED, ELEVATED REMNANTS GENERALLY FLANKING MOUNTAINS AND HILLS.
- Qr — RESIDUAL SOILS SILT, SAND, CLAY, AND ROCK FRAGMENTS, FORMED ESSENTIALLY IN PLACE, USUALLY SHOWING STRUCTURE OF UNDERLYING FORMATION.

TERTIARY

PRE-PLEISTOCENE

- Qts — SAN TIMOTEO BEDS POORLY CONSOLIDATED, FOLDED, CONTINENTAL CONGLOMERATE, SAND, SILT, AND CLAY
- Ts — UNDIFFERENTIATED PRE-PLEISTOCENE FORMATIONS SEVERAL THOUSAND FEET OF CONSOLIDATED TO SEMICONSOLIDATED SEDIMENTS DEPOSITED LARGELY IN MIOCENE TIME, BUT RANGING IN AGE FROM CRETACEOUS TO PLIOCENE. INCLUDES THE FOLLOWING FORMATIONS:

  UNDIFFERENTIATED PLIOCENE- PUENTE FORMATION - MIDDLE MIOCENE; TOPANGA FORMATION - MIDDLE MIOCENE; SESPE AND VAQUEROS FORMATIONS - EOCENE; SILVERADO FORMATION - PALEOCENE; TRABUCO AND LADD FORMATIONS - CRETACEOUS

IGNEOUS AND METAMORPHIC ROCKS

MIDDLE MIOCENE

- Tv — GLENDORA VOLCANICS ANDESITE, BASALT, DACITE, RHYOLITE, ANDESITE TUFFBRECCIA

PRE-MIOCENE

- Js — SANTIAGO PEAK VOLCANICS-JURASSIC PREDOMINANTLY ANDESITE FLOWS AND BRECCIAS
- bc — COMPLEX METASEDIMENTS AND IGNEOUS ROCKS

SYMBOLS

- U D — FAULT, DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE INFERRED OR CONCEALED. U DENOTES UPTHROWN SIDE; D DENOTES DOWNTHROWN SIDE.
- CONTACT, DASHED WHERE INFERRED OR QUESTIONABLE.
- D — D' — LINE OF GEOLOGIC SECTION
- LANDSLIDE AREAS, ARROWS INDICATE DIRECTION OF SLIDING
- BOUNDARY OF STUDY AREA

GEOLOGY COMPILED IN PART FROM EXISTING MAPPING

California Division of Mines Bulletin 178.
Oil and Gas Investigations Map OM-195.
Oil and Gas Investigations Map OM-154.
United States Geological Survey Water Supply Paper 1419, 1963.
J. Shelton, Bulletin of the Geological Survey Volume 66, 1955.
W. Burnham, Unpbl. Masters Thesis, Pomona College, 1953.

STATE OF CALIFORNIA
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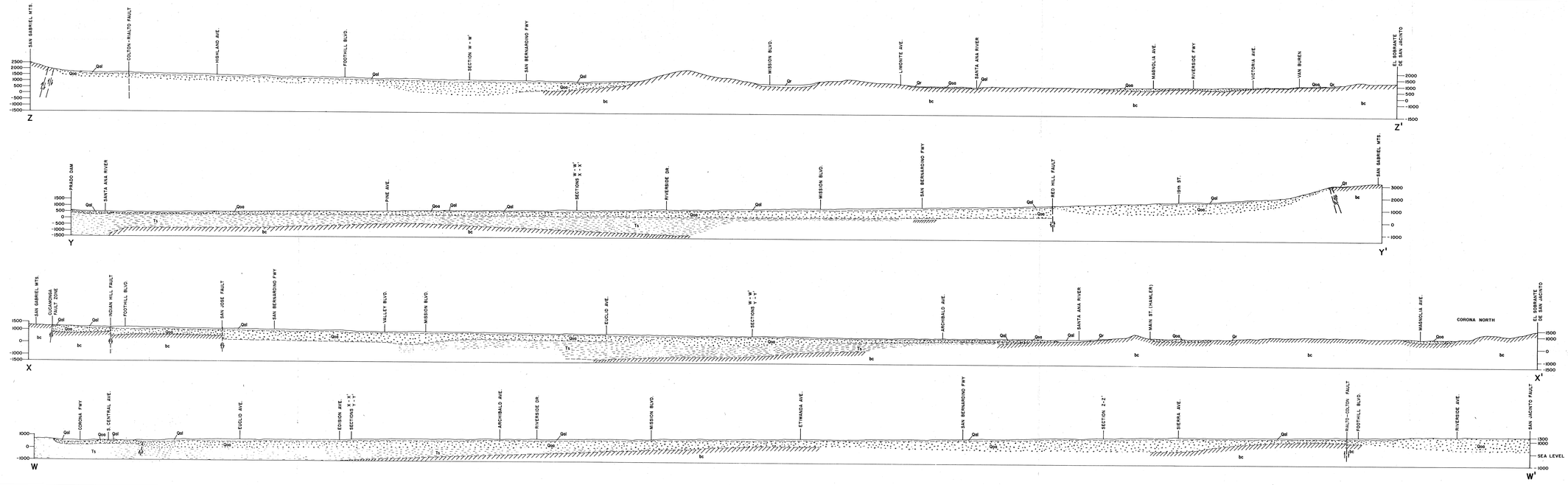
GEOHYDROLOGY OF THE CHINO-RIVERSIDE AREA

GEOLOGIC MAP

SCALE OF MILES
0 1 2 3 4 5 6



LEGEND

- Qal — RECENT ALLUVIUM
- Qoa — OLDER ALLUVIUM
- Qr&Qt — TERRACE DEPOSITS AND RESIDUAL SOILS
- Ts — TERTIARY SEDIMENTS
- bc — BASEMENT COMPLEX

STATE OF CALIFORNIA
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SOUTHERN DISTRICT

GEOHYDROLOGY OF
THE CHINO - RIVERSIDE AREA

GEOLOGIC SECTIONS

SCALE OF MILES
0 1/2 1 2

PLATE 4

SAN GABRIEL MOUNTAINS

SAN JOSE HILLS

PUENTE HILLS

CHINO HILLS

JURUPA MTNS.

PEDLEY HILLS

LA SIERRA

EL SOBRANTE DE SAN JACINTO

SANTA ANA MOUNTAINS

BADLANDS

SLOVER MTN.

LAKE ARROWHEAD

LAKE GREGORY

LAKE MATHEWS

CLAREMONT

UPLAND

POMONA

ONTARIO

CHINO

CORONA

FONTANA

RIALTO

SAN BERNARDINO

COLTON

RIVERSIDE

ARLINGTON

LOS ANGELES CO.
ORANGE CO.

SAN BERNARDINO CO.
RIVERSIDE CO.

LEGEND

BOUNDARY OF STUDY AREA.

NONWATER-BEARING ROCKS.

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN.

—750— LINES OF EQUAL ELEVATION ON THE EFFECTIVE BASE OF THE GROUND WATER RESERVOIR. DATUM MEAN SEA LEVEL. INTERVAL 100 FEET.

STATE OF CALIFORNIA
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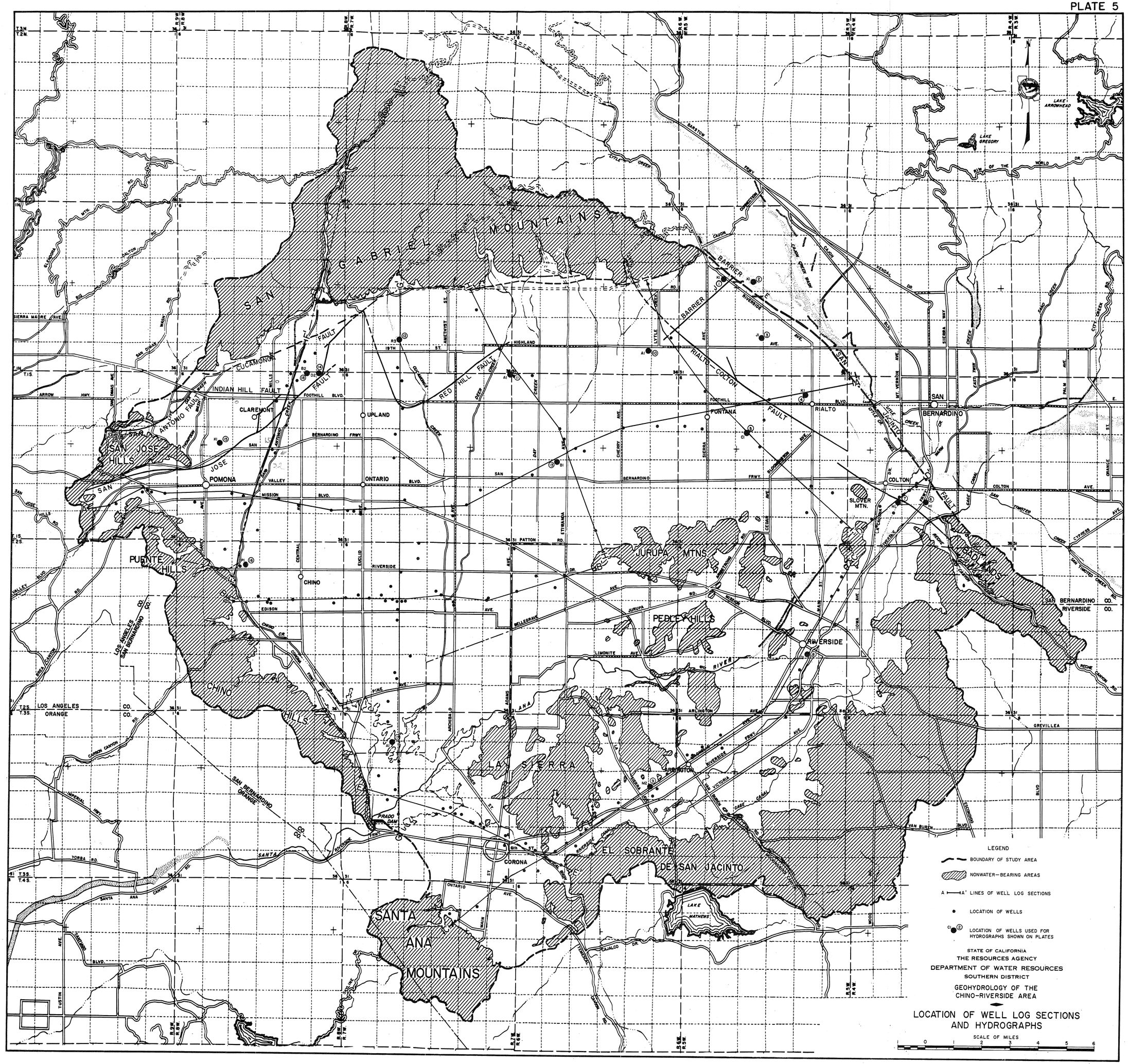
GEOHYDROLOGY OF
THE CHINO-RIVERSIDE AREA

LINES OF EQUAL ELEVATION ON
THE EFFECTIVE BASE OF
THE GROUND WATER RESERVOIR

SCALE OF MILES
0 1 2 3 4 5 6

PLATE 5



STATE OF CALIFORNIA
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SOUTHERN DISTRICT

GEOHYDROLOGY OF THE CHINO-RIVERSIDE AREA

LOCATION OF WELL LOG SECTIONS AND HYDROGRAPHS

ELEVATION IN FEET — U. S. G. S. DATUM

-300 -100 100 300 500 700 900 1100 1300

A W

SAN JOSE HILLS
IS/9W-27
SAN JOSE WASH CHANNEL
VALLEY BLVD.
SOUTHERN PACIFIC R.R.
IS/9W-27
IS/9W-26
IS/9W-26
IS/9W-26
IS/9W-25
IS/9W-25
IS/8W-30
IS/8W-29
IS/8W-28
SECTION F-F'
COUNTY LINE
SAN ANTONIO WASH CHANNEL
MISSION BLVD.
IS/8W-27
CENTRAL AVE.
IS/8W-25
IS/7W-30
SAN ANTONIO AVE.
IS/7W-30
IS/7W-30
EUCLID AVE.
IS/7W-30
CUCAMONGA CREEK
IS/7W-34
ARCHIBALD AVE.
NO LOG
ARGYLE CAMPBELL NO. 1
DEER CREEK
IS/7W-26
SAN BERNARDINO FWY.
NO LOG IS/6W-19
DAY CREEK
IS/6W-20
ETIWANDA AVE.
SECTION H-H'
IS/6W-16
NO LOG CHERRY AVE.
IS/6W-11
NO LOG IS/6W-12
NO LOG IS/5W-7
NO LOG IS/5W-7
SIERRA AVE.
SECTION I-I'
FOOTHILL BLVD.
IS/5W-10
RIALTO COLTON FAULT
IS/5W-3
IS/5W-2
MAIN ST.
IN/5W-36
E A'

SEA LEVEL

EFFECTIVE BASE OF GROUND WATER LEVEL OCTOBER 1960

TERTIARY SEDIMENTS

BASEMENT COMPLEX

RESERVOIR

HORIZONTAL SCALE OF FEET
2000 0 2000 4000

SECTION A-A' — SAN JOSE HILLS EASTERLY TO BASIN BOUNDARY

LEGEND

SAND
GRAVEL
CLAY
CLAY & GRAVEL
SEDIMENTARY BEDROCK
BASEMENT COMPLEX
FAULTS

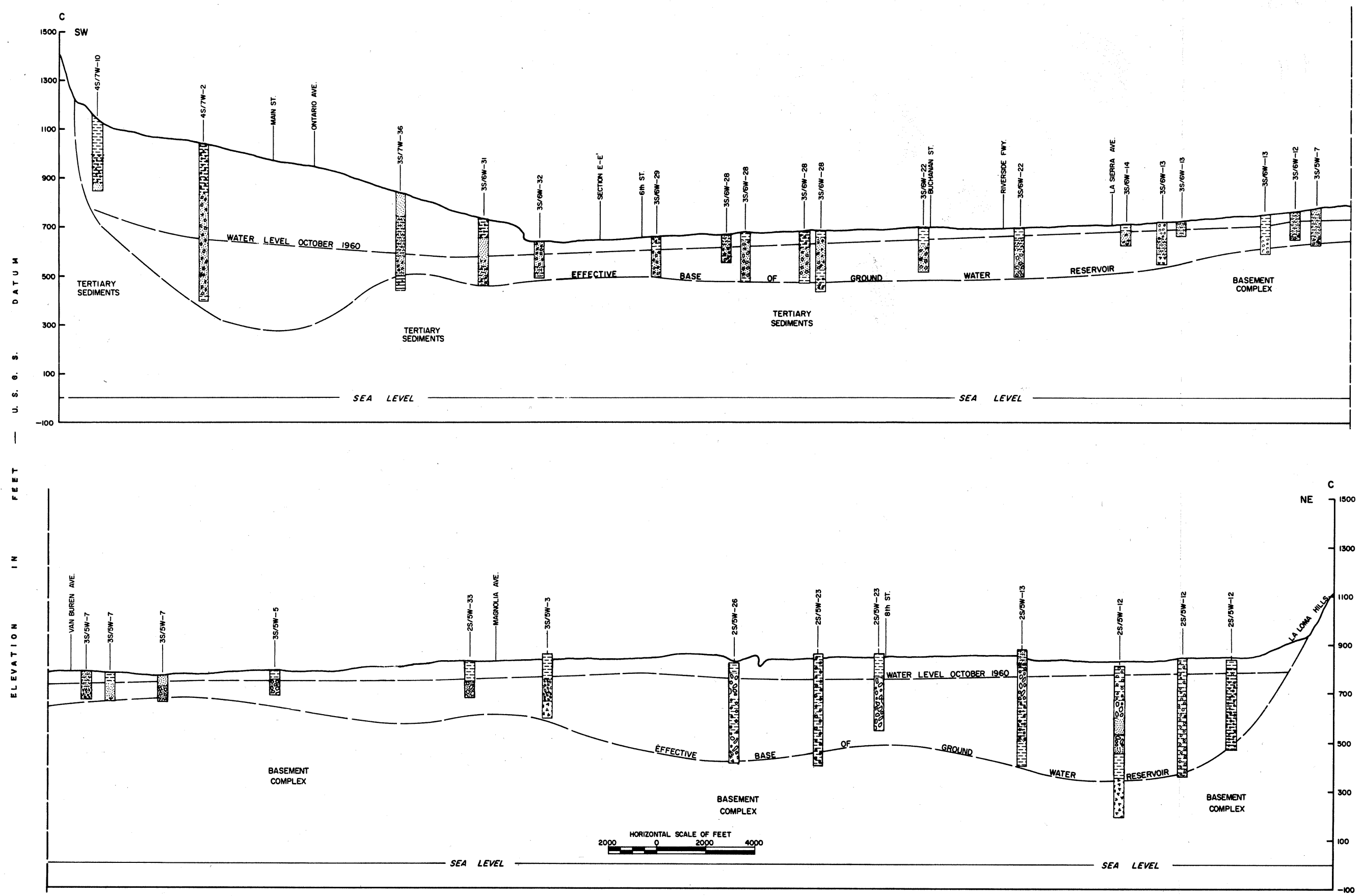
NOTE: LOCATIONS OF SECTIONS SHOWN ON PLATE 5

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF THE
CHINO-RIVERSIDE AREA

WELL LOG SECTIONS
A-A'

PLATE 6

ELEVATION IN FEET — U. S. G. S. DATUM
SECTION D-D'—LOMA LINDA HILLS NORTHEASTERLY TO BASIN BOUNDARY
SECTION B-B'—PUENTE HILLS EASTERLY TO JURUPA MOUNTAINS
SECTION E-E'—PRADO DAM EASTERLY TO EL SOBRANTE DE SAN JACINTO
SEA LEVEL
HORIZONTAL SCALE OF FEET
2000 0 2000 4000
BASEMENT COMPLEX
EFFECTIVE BASE OF GROUND WATER RESERVOIR
GROUND WATER RESERVOIR
WATER LEVEL OCTOBER 1960
RIALTO-COLTON FAULT
SAN BERNARDINO FWY
CHINO CREEK
SECTION G-G'
SANTA ANA RIVER
TERTIARY SEDIMENTS
TD 1200 IN SHALE
J.B. NELSON CO. LILLIBRIDGE GOV'T
TEMESCAL FAN MATERIAL
MAIN ST.
RIVERSIDE FWY.
TEMESCAL WASH
6th ST.
HIGHWAY 71
CHINO CREEK
EUCLID AVE.
SECTION F-F'
CUCAMONGA CREEK CHANNEL
DEER CREEK CHANNEL
ARCHIBALD AVE.
ADAMS AVE.
WINEVILLE RD.
VAN BUREN BLVD.
RIVERSIDE DRIVE
JURUPA MTS.
NO LOG
CENTRAL AVE.
LEGEND
SAND
GRAVEL
CLAY
CLAY & GRAVEL
SEDIMENTARY BEDROCK
BASEMENT COMPLEX
FAULTS
NOTE : LOCATIONS OF SECTIONS SHOWN ON PLATE 5
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF THE CHINO-RIVERSIDE AREA
WELL LOG SECTIONS B-B', D-D' AND E-E'
PLATE 7



SECTION C-C' — SANTA ANA MOUNTAINS NORTHEASTERLY TO LOMA LINDA HILLS

LEGEND

- SAND
- GRAVEL
- CLAY
- CLAY & GRAVEL
- SEDIMENTARY BEDROCK
- BASEMENT COMPLEX
- FAULTS

NOTE - LOCATIONS OF SECTIONS SHOWN ON PLATE 5

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOHYDROLOGY OF THE
CHINO—RIVERSIDE AREA

WELL LOG SECTIONS
C—C'

SECTION F-F' — PUENTE HILLS NORTHERLY TO CUCAMONGA FAULT ALONG COUNTY LINE

SECTION G-G' — RIVERSIDE FREEWAY NORTH TO CUCAMONGA FAULT

PLATE 9

LEGEND

SAND

GRAVEL

CLAY

CLAY & GRAVEL

SEDIMENTARY BEDROCK

BASEMENT COMPLEX

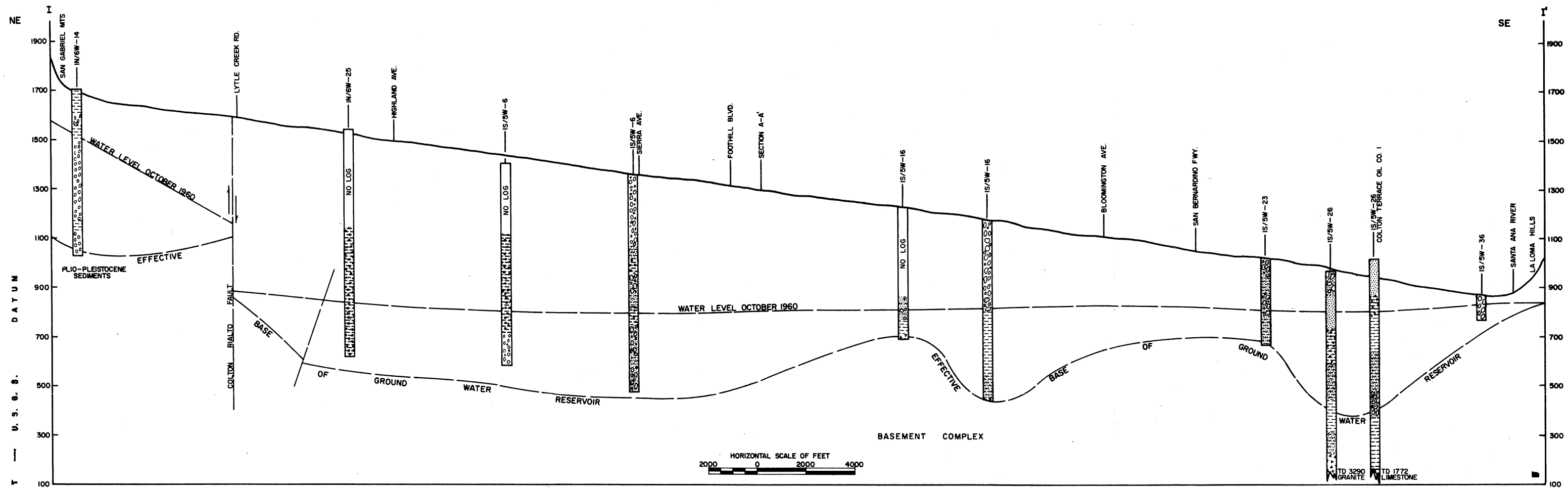
FAULTS

NOTE - LOCATIONS OF SECTIONS SHOWN ON PLATE 5

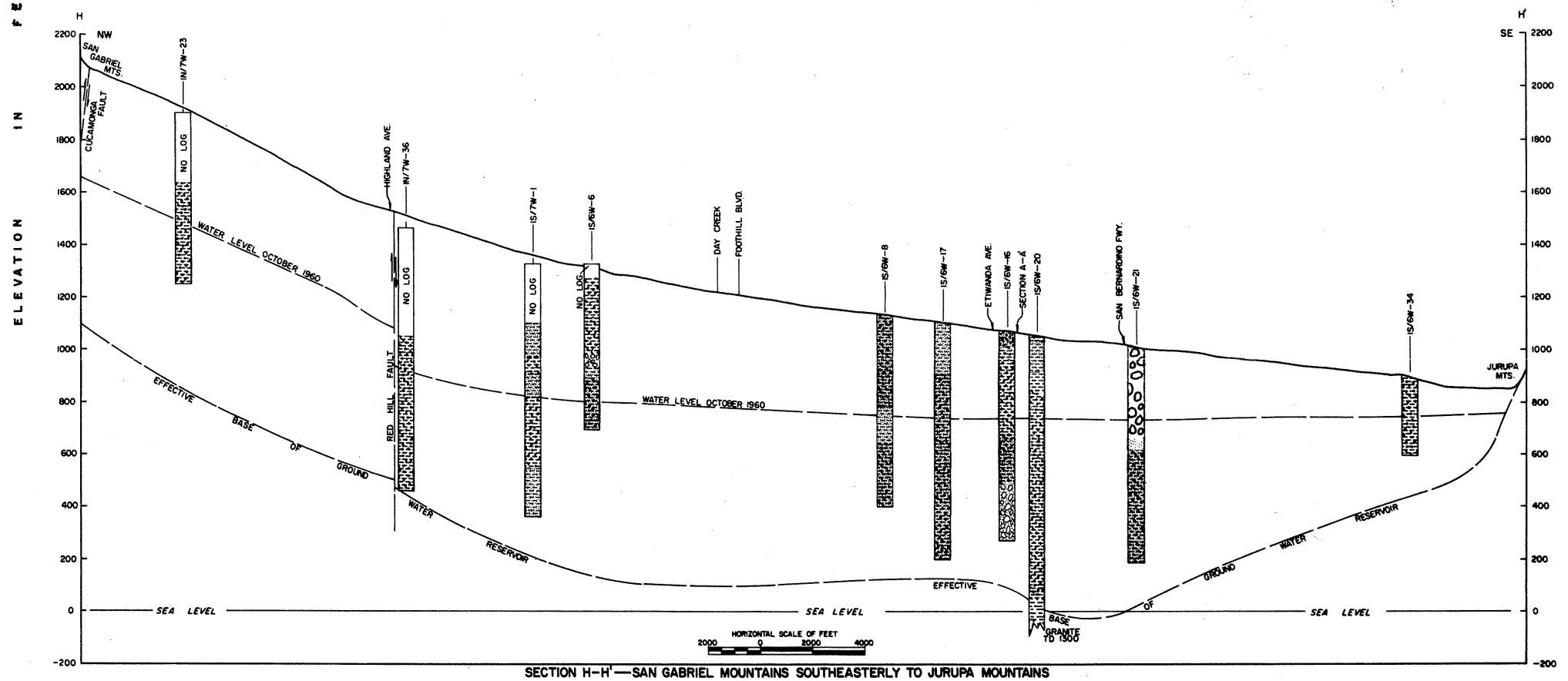
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOHYDROLOGY OF THE
CHINO-RIVERSIDE AREA

WELL LOG SECTIONS
F-F' AND G-G'



SECTION I–I' — SAN GABRIEL MOUNTAINS SOUTHEASTERLY TO LA LOMA HILLS



SECTION H–H' — SAN GABRIEL MOUNTAINS SOUTHEASTERLY TO JURUPA MOUNTAINS

NOTE: LOCATIONS OF SECTIONS SHOWN ON PLATE 5

LEGEND

- SAND
- CLAY
- CLAY & GRAVEL
- GRAVEL
- SEDIMENTARY BEDROCK
- BASEMENT COMPLEX
- FAULTS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOHYDROLOGY OF THE CHINO–RIVERSIDE AREA

WELL LOG SECTIONS H–H' AND I–I'

PLATE II

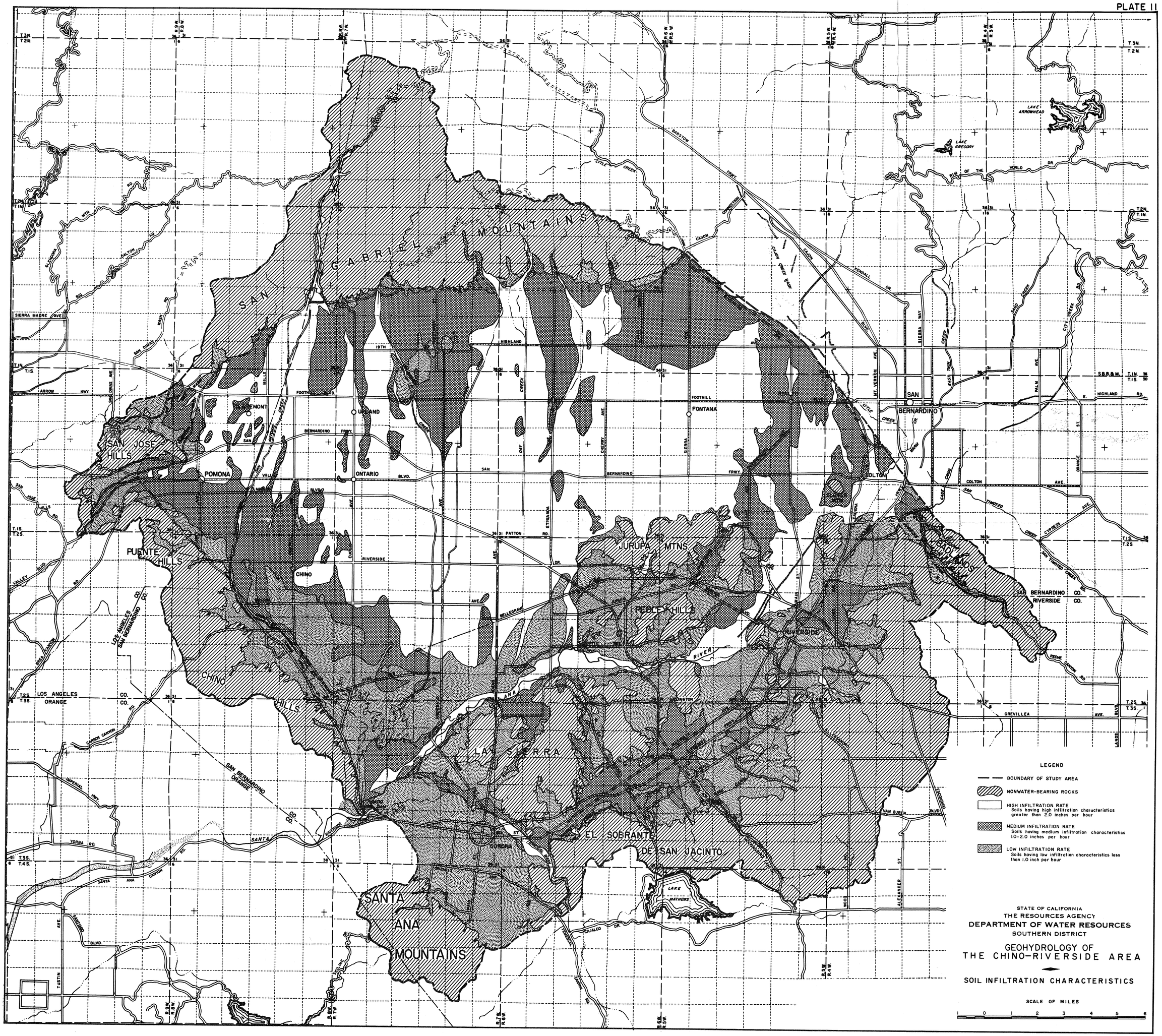
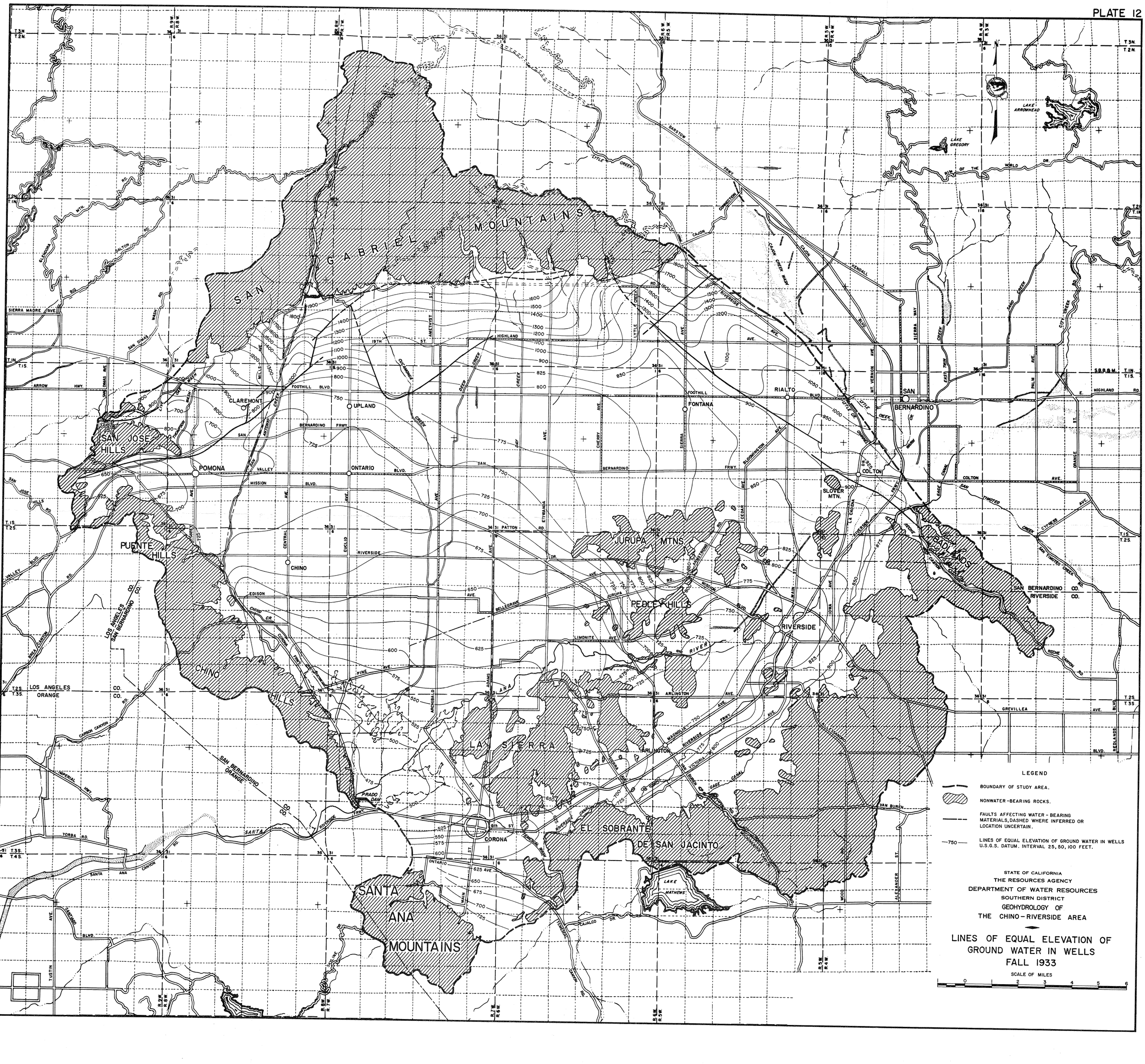

SAN GABRIEL MOUNTAINS
SAN JOSE HILLS
PUENTE HILLS
CHINO HILLS
JURUPA MTNS.
PEDLEY HILLS
LA SIERRA
EL SOBRANTE DE SAN JACINTO
SANTA ANA MOUNTAINS
SAN TIMOTEO CANYON
POMONA
CLAREMONT
UPLAND
ONTARIO
CHINO
FONTANA
SAN BERNARDINO
COLTON
RIVERSIDE
LAKE ARROWHEAD
LAKE GREGORY
LAKE MATHEWS
SAN BERNARDINO CO.
RIVERSIDE CO.
LOS ANGELES CO.
ORANGE CO.
LEGEND
BOUNDARY OF STUDY AREA
NONWATER-BEARING ROCKS
HIGH INFILTRATION RATE
Soils having high infiltration characteristics greater than 2.0 inches per hour
MEDIUM INFILTRATION RATE
Soils having medium infiltration characteristics 1.0-2.0 inches per hour
LOW INFILTRATION RATE
Soils having low infiltration characteristics less than 1.0 inch per hour
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF
THE CHINO-RIVERSIDE AREA
SOIL INFILTRATION CHARACTERISTICS
SCALE OF MILES
0 1 2 3 4 5 6

PLATE 12



LEGEND

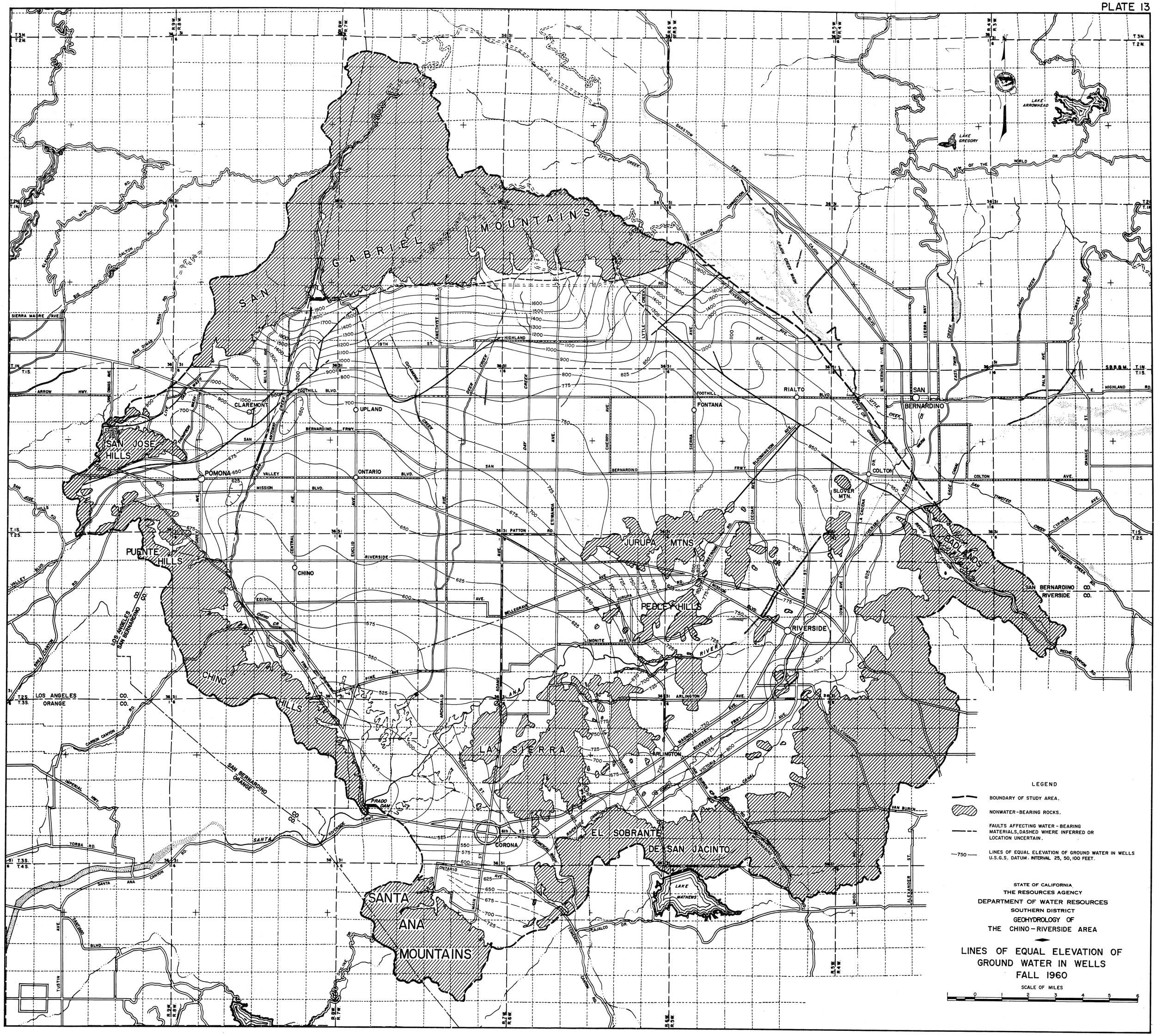
- BOUNDARY OF STUDY AREA.
- NONWATER-BEARING ROCKS.
- FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN.
- —750— LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS U.S.G.S. DATUM. INTERVAL 25, 50, 100 FEET.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF
THE CHINO-RIVERSIDE AREA

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1933

SCALE OF MILES

0 2 3 4 5 6



LEGEND

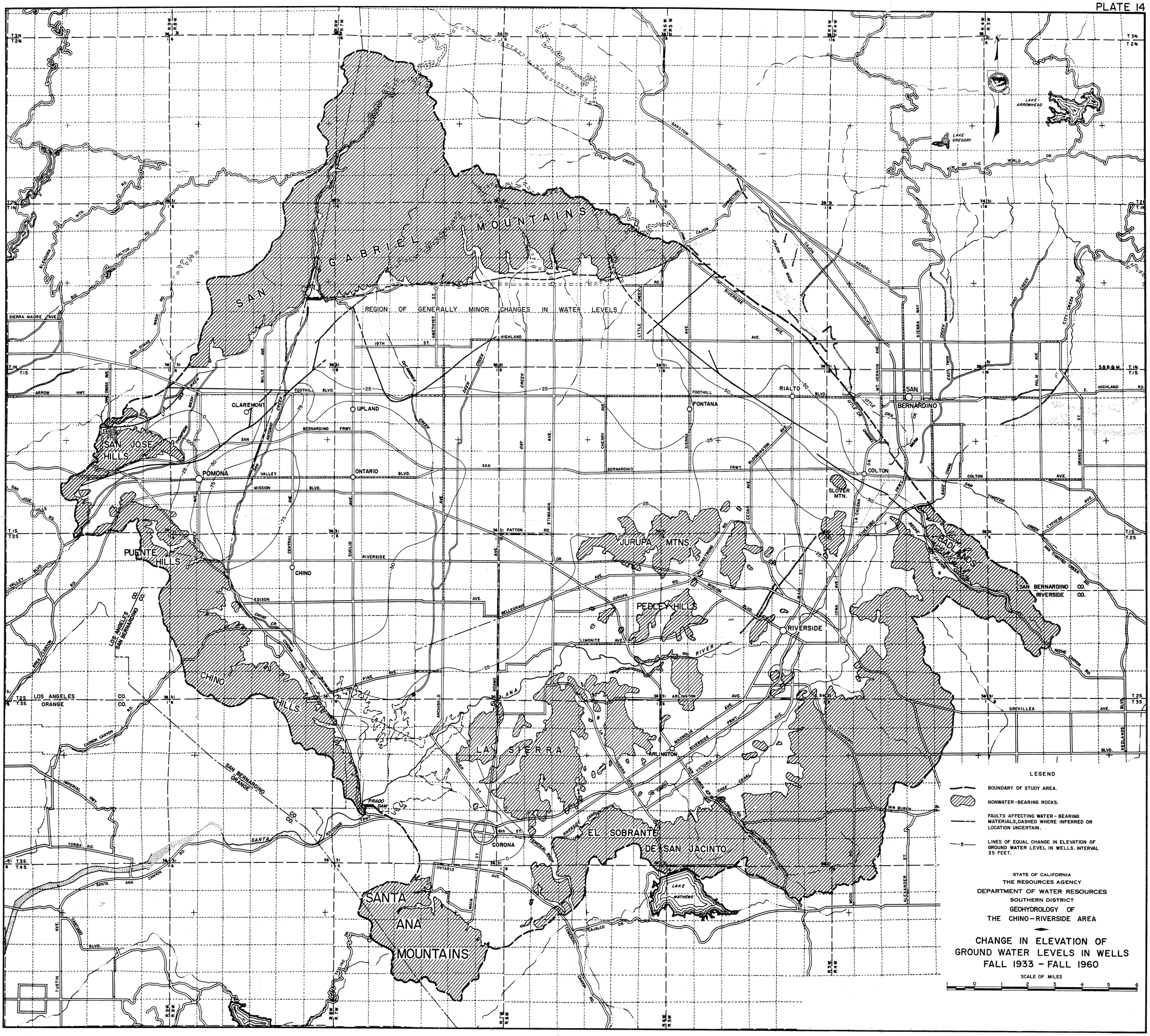
- BOUNDARY OF STUDY AREA.
- NONWATER-BEARING ROCKS.
- FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN.
- —750— LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS U.S.G.S. DATUM. INTERVAL 25, 50, 100 FEET.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF
THE CHINO-RIVERSIDE AREA

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1960

SCALE OF MILES

0 1 2 3 4 5 6


SAN GABRIEL MOUNTAINS
REGION OF GENERALLY MINOR CHANGES IN WATER LEVELS
SAN JOSE HILLS
PUENTE HILLS
CHINO HILLS
SANTA ANA MOUNTAINS
JURUPA MTNS
PEDLEY HILLS
LA SIERRA
EL SOBRANTE DE SAN JACINTO
BADLANDS
SLOVER MTN.
CLAREMONT
UPLAND
POMONA
ONTARIO
CHINO
FONTANA
RIALTO
SAN BERNARDINO
COLTON
RIVERSIDE
ARLINGTON
CORONA
LAKE ARROWHEAD
LAKE GREGORY
LAKE MATHEWS
SAN BERNARDINO CO.
RIVERSIDE CO.
LOS ANGELES CO.
ORANGE CO.
LEGEND
BOUNDARY OF STUDY AREA.
NONWATER-BEARING ROCKS.
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN.
-5- LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER LEVEL IN WELLS. INTERVAL 25 FEET.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF
THE CHINO-RIVERSIDE AREA
CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS
FALL 1933 - FALL 1960
SCALE OF MILES
0 2 3 4 5 6

SPREADING GROUNDS

1. ALTA LOMA
2. ARCHIBALD AVENUE
3. ARLINGTON
4. BANANA AVENUE
5. CACTUS
6. CHURCH
7. COLLEGE HEIGHTS
8. CUCAMONGA
9. DAY CANYON
10. DAY CREEK
11. DEER CREEK
12. EAST AVENUE
13. EIGHTH STREET
14. ELY STREET
15. ETIWANDA
16. ETIWANDA CONSERVATION BASIN
17. FIFTEENTH STREET
18. LINDEN
19. LIVE OAK
20. MERRILL
21. MILL
22. MONTCLAIR
23. NINETEENTH STREET
24. PEPPER
25. POMONA
26. RANDALL
27. RED HILL
28. RIVERSIDE
29. SAN ANTONIO
30. SAN SEVAINE
31. TEMESCAL
32. THOMPSON
33. WINEVILLE

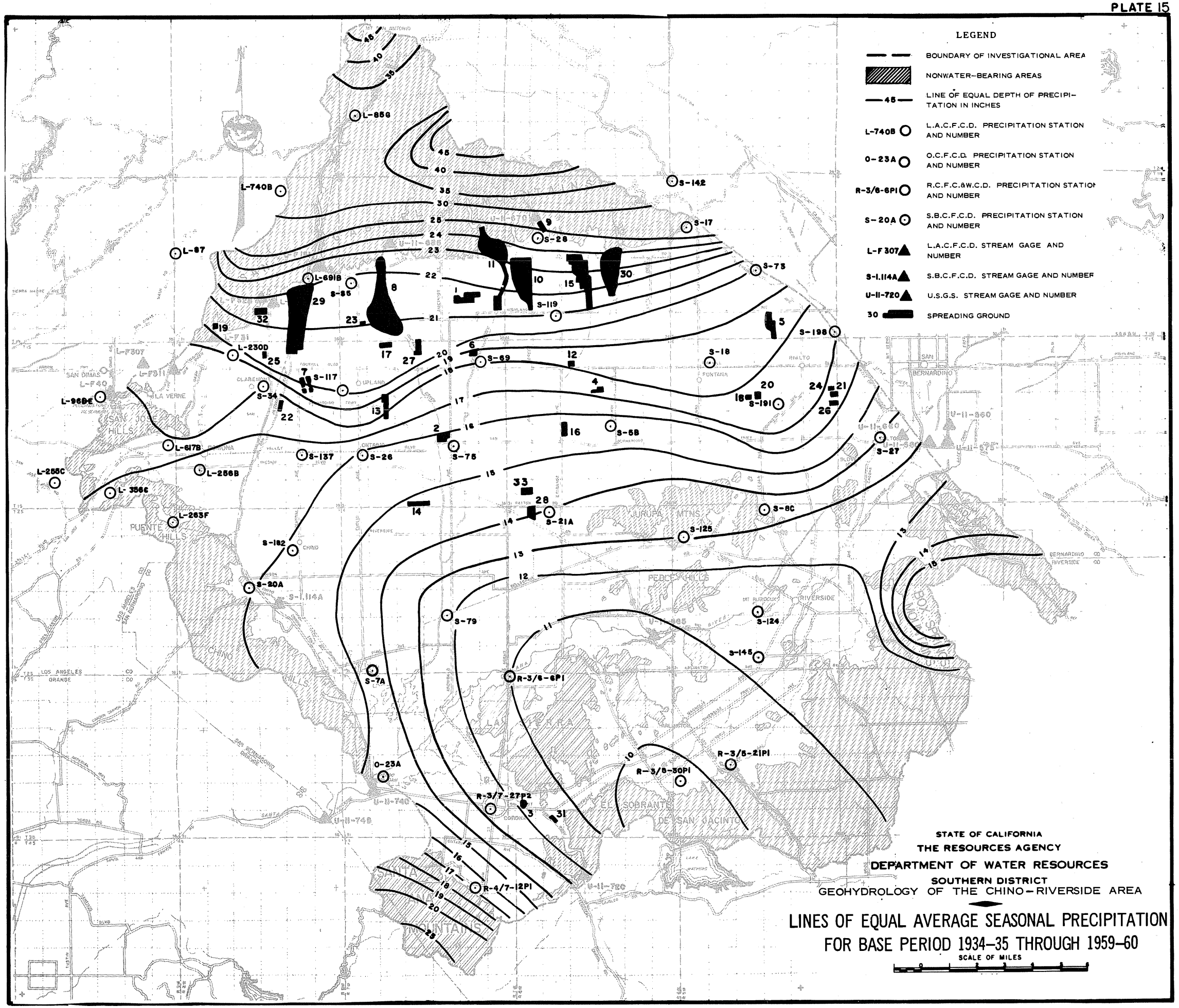
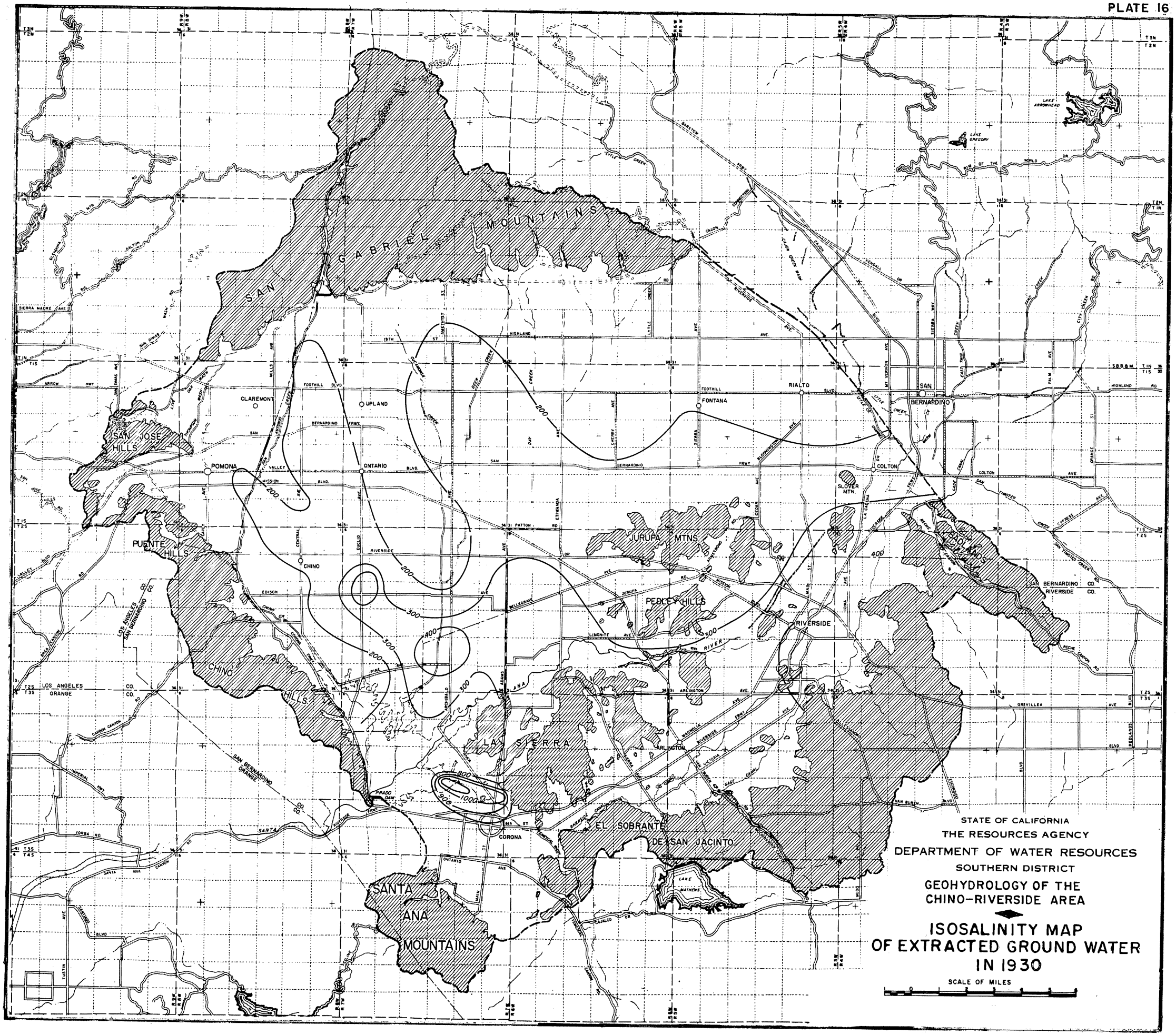


PLATE 16

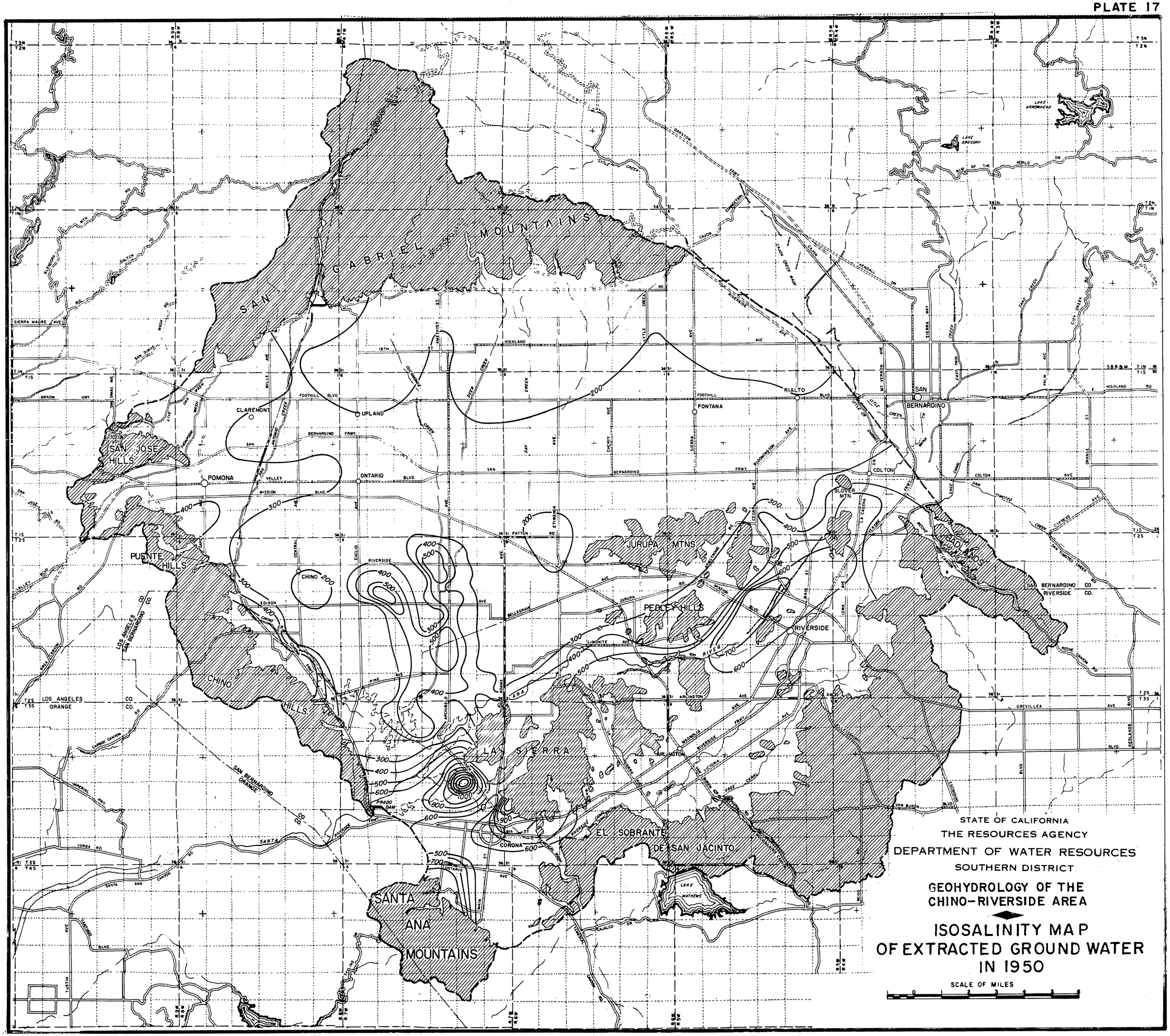


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOHYDROLOGY OF THE
CHINO–RIVERSIDE AREA

ISOSALINITY MAP OF EXTRACTED GROUND WATER IN 1930

SCALE OF MILES

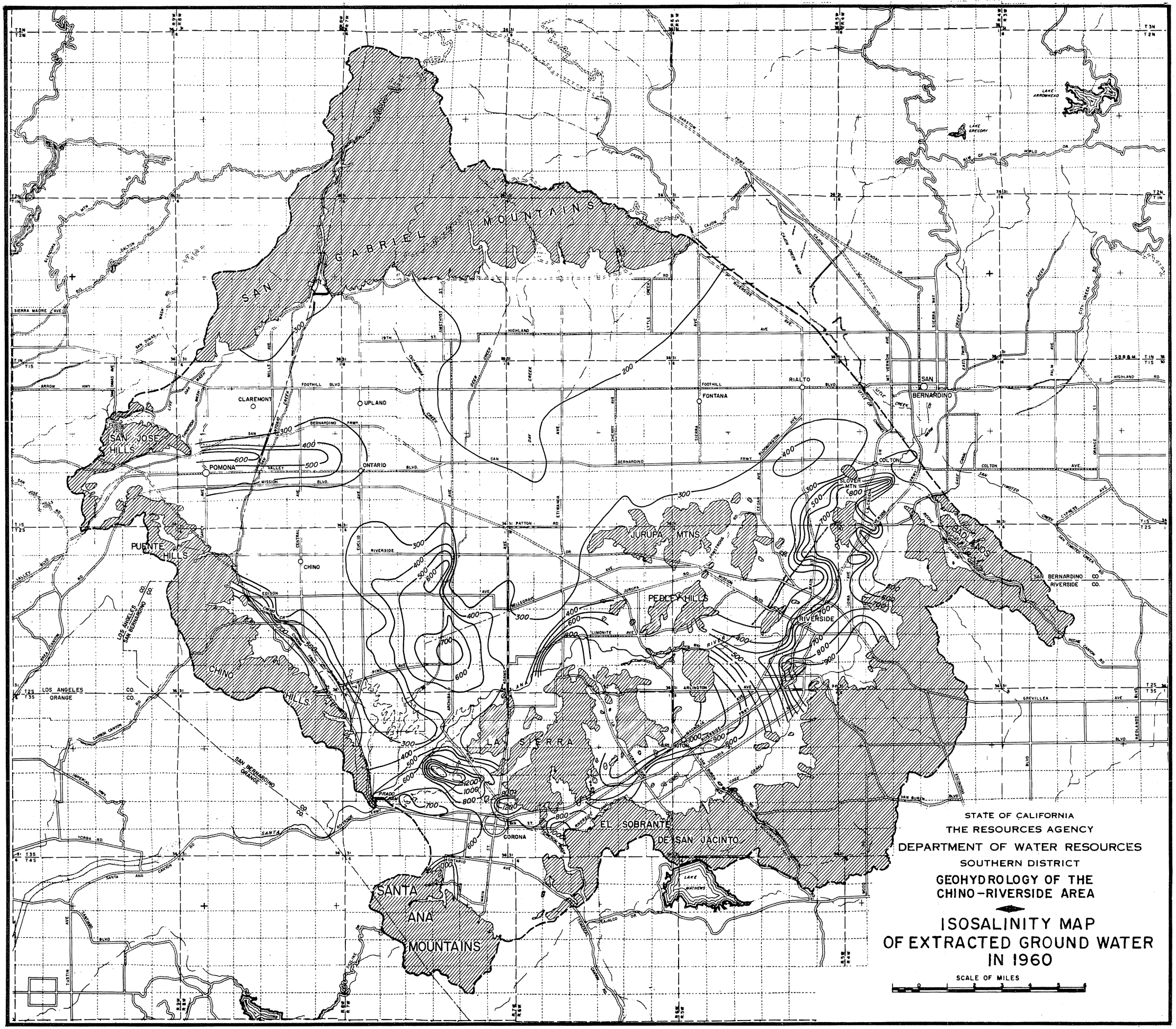


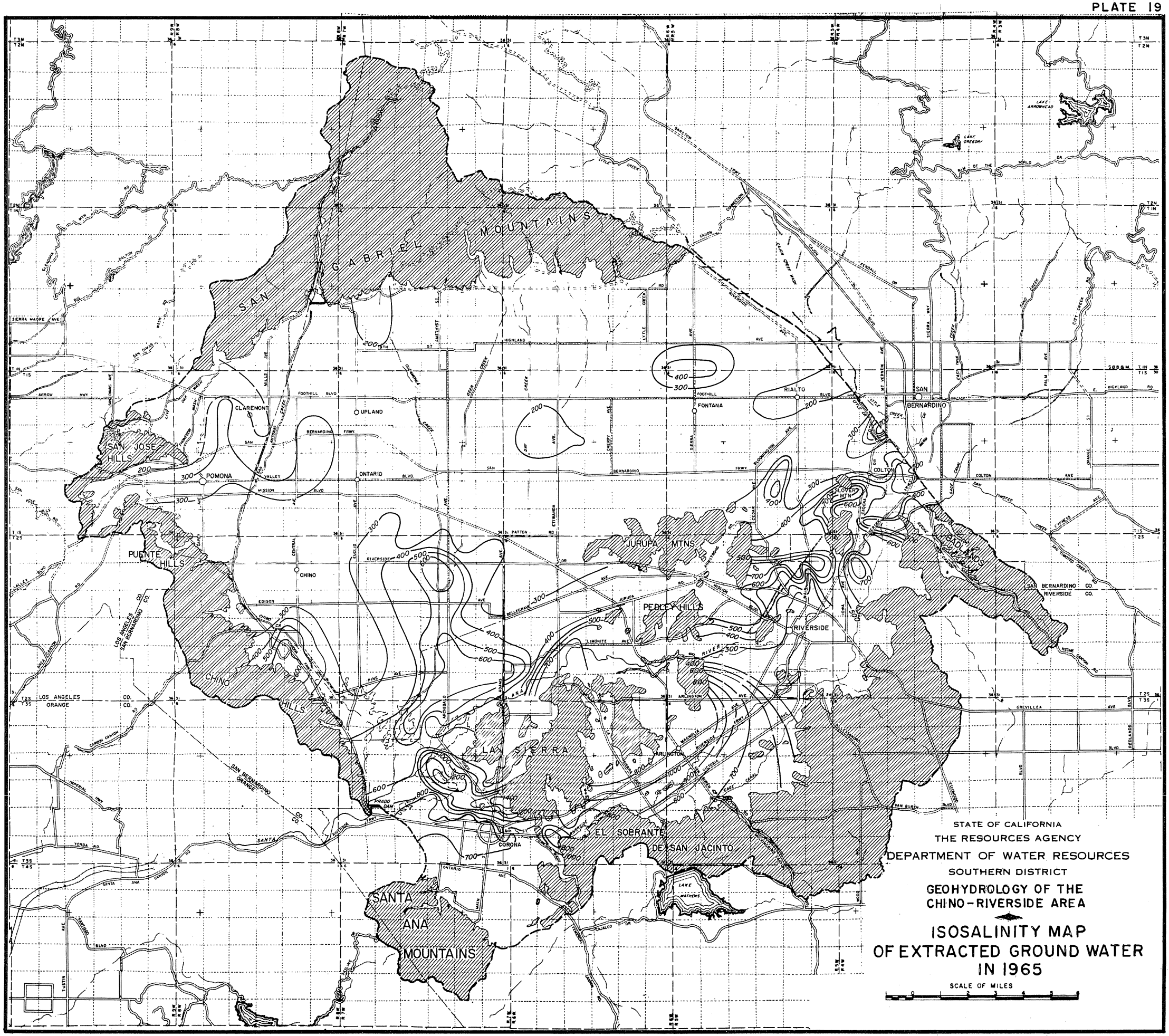
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

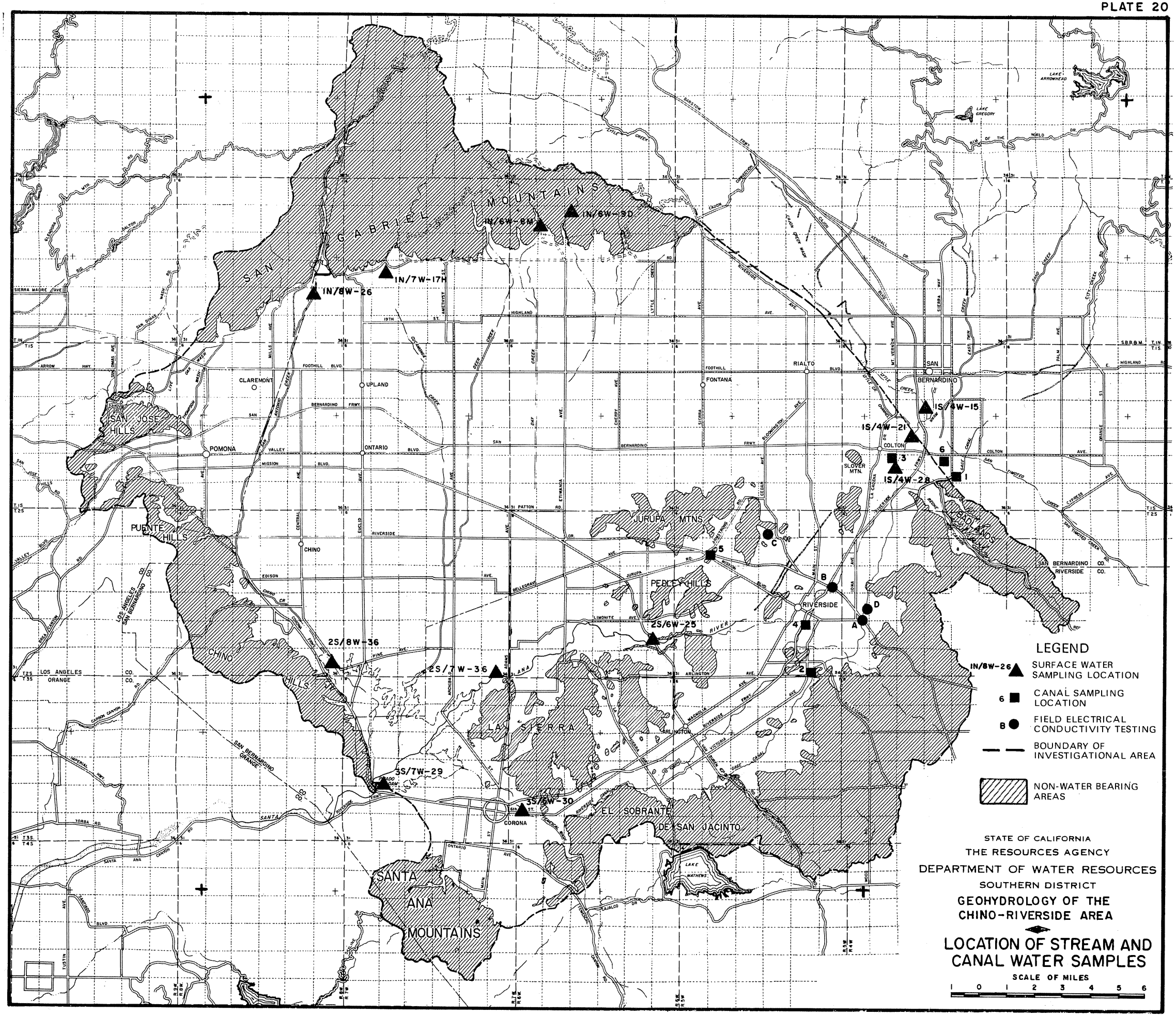
GEOHYDROLOGY OF THE CHINO–RIVERSIDE AREA

ISOSALINITY MAP OF EXTRACTED GROUND WATER IN 1950

SCALE OF MILES


SAN GABRIEL MOUNTAINS
SAN JOSE HILLS
PUENTE HILLS
CHINO HILLS
SANTA ANA MOUNTAINS
JURUPA MTNS.
PEDLEY HILLS
LA SIERRA
EL SOBRANTE DE SAN JACINTO
BADLANDS
CLAREMONT
UPLAND
POMONA
ONTARIO
CHINO
FONTANA
RIALTO
SAN BERNARDINO
COLTON
RIVERSIDE
CORONA
LAKE MATHEWS
LAKE ARROWHEAD
LAKE GREGORY
SLOVER MTN
SAN BERNARDINO CO
RIVERSIDE CO.
LOS ANGELES CO
ORANGE CO
300
400
500
600
700
800
900
1000
1200
1400
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF THE
CHINO-RIVERSIDE AREA
ISOSALINITY MAP
OF EXTRACTED GROUND WATER
IN 1960
SCALE OF MILES


SAN GABRIEL MOUNTAINS
SAN JOSE HILLS
PUENTE HILLS
CHINO HILLS
SANTA ANA MOUNTAINS
JURUPA MTNS
PEDLEY HILLS
LA SIERRA
EL SOBRANTE DE SAN JACINTO
SLOVER MTN
CLAREMONT
UPLAND
POMONA
ONTARIO
CHINO
FONTANA
RIALTO
SAN BERNARDINO
COLTON
RIVERSIDE
CORONA
LAKE ARROWHEAD
LAKE GREGORY
LAKE MATHEWS
SAN BERNARDINO CO.
RIVERSIDE CO.
LOS ANGELES CO.
ORANGE CO.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF THE
CHINO-RIVERSIDE AREA
ISOSALINITY MAP
OF EXTRACTED GROUND WATER
IN 1965
SCALE OF MILES


SAN GABRIEL MOUNTAINS
1N/6W-8M
1N/6W-9D
1N/7W-17H
1N/8W-26
1S/4W-15
1S/4W-21
1S/4W-28
2S/6W-25
2S/8W-36
2S/7W-36
3S/7W-29
3S/6W-30
SAN JOSE HILLS
PUENTE HILLS
CHINO HILLS
JURUPA MTNS
PEDLEY HILLS
LA SIERRA
EL SOBRANTE DE SAN JACINTO
SANTA ANA MOUNTAINS
BADLANDS
CLAREMONT
UPLAND
POMONA
ONTARIO
CHINO
CORONA
FONTANA
RIALTO
SAN BERNARDINO
COLTON
RIVERSIDE
SLOVER MTN.
LAKE ARROWHEAD
LAKE GREGORY
LAKE MATHEWS
SAN BERNARDINO CO.
RIVERSIDE CO.
LOS ANGELES CO.
ORANGE CO.
LEGEND
1N/8W-26 SURFACE WATER SAMPLING LOCATION
6 CANAL SAMPLING LOCATION
B FIELD ELECTRICAL CONDUCTIVITY TESTING
BOUNDARY OF INVESTIGATIONAL AREA
NON-WATER BEARING AREAS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOHYDROLOGY OF THE CHINO-RIVERSIDE AREA
LOCATION OF STREAM AND CANAL WATER SAMPLES
SCALE OF MILES
1 0 1 2 3 4 5 6