EXHIBIT 11

PART 1

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA
IN AND FOR THE COUNTY OF LOS ANGELES

THE CITY OF LOS ANGELES,
a Municipal Corporation,
Plaintiff,

vs.

CITY OF SAN FERNANDO,
a Municipal Corporation, et al.,
Defendants.

No. 650079

REPORT OF REFEREE

Volume I

TEXT AND PLATES

By

STATE WATER RIGHTS BOARD
REFEREE

July, 1962

APPROVAL AND ADOPTION BY STATE WATER RIGHTS BOARD

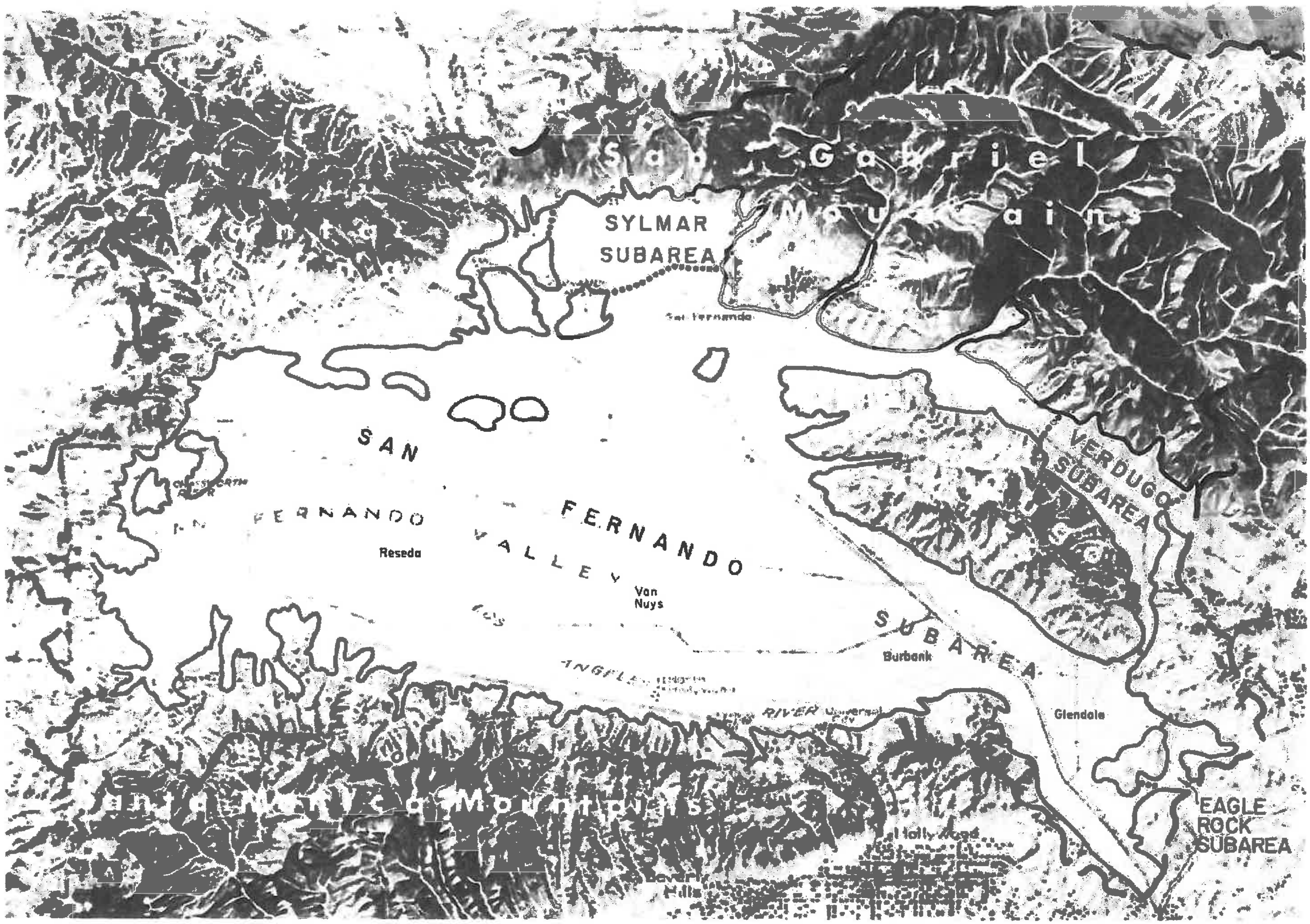
The State Water Rights Board, Referee in the action entitled "The City of Los Angeles, a Municipal Corporation, Plaintiff, vs. City of San Fernando, a Municipal Corporation, et al., Defendants," before the Superior Court of the State of California in and for the County of Los Angeles, No. 650079, approves and adopts this "Report of Referee" dated July 1962, pursuant to the requirements of the "Order of Reference to State Water Rights Board to Investigate and Report Upon the Physical Facts (Section 2001, Water Code)," dated June 11, 1958, and the "Interim Order," dated November 19, 1958, entered by the Court in said action. In accordance with paragraph III of said Order of Reference dated June 11, 1958, the Board will file with the Court and retain in its office the basic data upon which it bases its findings.

Approved and adopted by the State Water Rights Board at a meeting duly called and held at Sacramento, California, on the 27th day of July, 1962.

Kent Silverthorne, Chairman

Ralph J. McGill, Member

W. A. Alexander, Member



SYLMAR SUBAREA
San Fernando
SAN FERNANDO
Reseda
VALLEY
Van Nuys
SUBAREA
Burbank
RIVER
VERDUGO SUBAREA
Glendale
EAGLE ROCK SUBAREA

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Volume II   Appendixes A through T

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BASIC DATA

ORGANIZATION

STATE WATER RIGHTS BOARD

Kent Silverthorne	Chairman
Ralph J. McGill	Member
W. A. Alexander*	Member

Leland K. Hill . . . Executive Officer

This Investigation Was Conducted And Report Prepared Under The General Direction Of

Leslie C. Jopson . . . . Chief Engineer

And The Technical Direction Of

John M. Page . . . . Supervising Engineer, Water Resources

By

Donald J. Finlayson . . . . Senior Engineer, Water Resources**
In Charge of Los Angeles Office

Assisted By

Wilbert T. Chung . . . . Associate Engineer, Water Resources

Hydrologic Studies

Elwood C. Johnson . . . . Water Resources Engineering Associate
David J. Love . . . . Assistant Civil Engineer
Ronald H. Barrett . . . . Assistant Civil Engineer
Joseph F. Montagna . . . . Assistant Civil Engineer

Geologic And Water Quality Studies

Glenn A. Brown . . . . Senior Engineering Geologist***
Joseph M. Gonzalez . . . . Geologic Aid

Special Studies By

Gilbert J. Matson . . . . Senior Engineer, Water Resources
Alvin L. Franks . . . . Associate Engineering Geologist
Ben Rinehart . . . . Assistant Civil Engineer
John Shannon . . . . Land and Water Use Specialist***

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Legal Review By

Gavin M. Craig . . . . Chief Counsel
Luther H. Gulick . . . . Senior Attorney

Plates And Drawings By

Virginia Richardson . . . . Delineator
Leonard E. Grady . . . . Delineator

* Replaced W. P. Rowe whose term expired on January 15, 1961, and who was continued in office to April 9, 1961.

** Resigned July 1, 1962.

*** Under service agreement with the Department of Water Resources.

ACKNOWLEDGMENTS

Preliminary study of the availability of hydrologic data in the area involved in the reference indicated that much of the information needed by the Referee was available from various public agencies and other sources. As a result, the State Water Rights Board contacted various entities and individuals not parties to the lawsuit to secure from them this information prior to and during original investigations of its own.

The Board is greatly indebted to the sources contacted for the material supplied, and wishes to acknowledge its appreciation of the cooperation and helpful attitude of the entities and individuals and their staffs in providing copies of the available information to the Board. Particular appreciation is expressed to the following agencies:

- Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture
- Ground Water and Surface Water Branches, Geological Survey, U. S. Department of Interior
- California Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture
- State Department of Water Resources
- Division of Oil and Gas, State Department of Natural Resources
- Water Resources Center, University of California at Los Angeles
- Department of Irrigation, University of California at Davis
- Metropolitan Water District of Southern California
- Los Angeles County Flood Control District

The whole-hearted assistance of these agencies and their staffs appreciably lightened the task of the Referee and lessened the time and expense which would otherwise have been required to develop the information needed. Many other entities and parties not herein named were helpful in many ways and their services to the Board are appreciated.

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DEFINITIONS

Alluvial Fan or Cone[2/] - A body of alluvial material deposited by a stream debouching from the region undergoing erosion above the apex of the cone.

Aquiclude[2/] - A formation which, although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring.

Aquifer[2/] - A geologic formation or structure that transmits water in sufficient quantity to supply pumping wells or springs.

Artesian[1/] - An adjective applied to ground water, or things connected with ground water, such as a well, underground basin, etc., where water is under pressure and will rise to a higher elevation if afforded an opportunity to do so.

Capillary Fringe - The partly saturated zone immediately above the water table in which water is held above the water table by capillary forces.

Consumptive Use - The amount of water used by the vegetative growth of a given area in transpiration or building of plant tissue and evaporated from adjacent soil. It also includes the evaporation of precipitation intercepted by vegetative growth or impervious area, the water evaporated in industrial processes, household uses, or that which is permanently incorporated in the product.

Culture (Land Use) - The land use or land cover existing under natural conditions or as modified by man.

Deep Percolation[1/] - The moisture which penetrates below the depths from which it may be used by plants; it represents that part of the water absorbed which exceeds the field capacity of the soil within the depth of root development. In this report deep percolation is water which moves downward from the surface of the ground and reaches the water table.

Evaporation[1/] - The process by which water passes from a liquid state, at temperatures below the boiling point, to vapor.

Export - Water that is conveyed out of the drainage area in artificial conduits for use in other areas or as sewage.

Fall Soil Moisture Deficiency - The depth of water in inches required at the beginning of the rainy season to bring the soil up to field capacity.

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Field Capacity - The maximum amount of capillary water that can be held in a freely drained root zone, measured as the ratio of weight of water retained by the soil to the weight of the dry soil.

Ground Water[2/] - The water in the zone of saturation.

Ground-Water Cascade - Descent of ground water on a steep hydraulic gradient to a lower and flatter water table slope. A cascade occurs when ground water flows over a sharp drop in the configuration of the nonwater-bearing rock forming the base of a free ground water body.

Ground Water, Confined[2/] - A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying ground water except at the intake.

Ground Water, Free, (Unconfined)[4/] - Unconfined water is found in the zone of saturation whenever the upper surface of the zone forms a water table under atmospheric pressure, free to rise and fall with changes in volume of stored water.

Import - Water supplied from a source outside the area.

Irrigation Efficiency - The percentage of irrigation water applied that is consumed.

Isohyet[1/] - A line on the earth's surface as represented on a map connecting all points of equal precipitation.

Percolation[1/] - The movement or flow of water through the interstices or the pores of a soil or other porous medium.

Permeability[1/] - The property of a material which permits appreciable movement of water through it when saturated and actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.

Permeability, Coefficient of[1/] - The rate of flow of a fluid through a cross section of a porous mass under a unit hydraulic gradient, at a temperature of 60°F. The standard coefficient of permeability used in the hydrologic work of the United States Geological Survey is defined as the rate of flow of water at 60°F, in gallons a day, through a cross section of one square foot, under a hydraulic gradient of 100 percent.

Permeability, Field Coefficient of[5/] - The rate of flow of water, in gallons a day, under prevailing conditions, through each foot of thickness of a given aquifer in a width of one mile, for each foot per mile of hydraulic gradient.

Phreatophyte[1/] [3/] - A plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe.

Porosity - The sum of specific yield and specific retention which is equivalent to the total void space in the material, expressed as a percentage of the total volume of the material.

Precipitation[1/] - The total measurable supply of water received directly from clouds, as rain, snow, hail, and sleet; usually expressed as depth in a day, month, or year, and designated as daily, monthly or annual precipitation.

Residual Rain - The residual amount of precipitation on a given impervious area after evaporation has occurred, expressed either in units of depth or in acre-feet.

Rising Water - Ground water effluent which appears as surface flow in stream channels.

Safe Yield - The maximum quantity of water which can be withdrawn annually from a ground water supply under a given set of conditions without causing an undesirable result.

Sewage Export - Sewage that is removed from the drainage area by pipelines or other artificial conduits.

Sewer Infiltration - Movement of ground water into conduits.

Specific Capacity - The discharge in gallons per minute per foot of drawdown in a pumped well.

Specific Retention - As applied to water-bearing material it is the ratio of the volume of water which will be retained by the material against the force of gravity, expressed as a percentage of the total volume of the material.

Specific Yield - As applied to water-bearing materials it is the volume of water drained by the force of gravity from a saturated material over a reasonably long period of time, expressed as a percentage of the total volume of the saturated material.

Spread Water - Native or imported water discharged into spreading basins for the purpose of percolating to the zone of saturation.

Storm Runoff - The residual of precipitation that is drained from the surface of the land and appears in surface streams. (Storm runoff does not include rising water, industrial waste, or sewage which may comprise a portion of the flow in surface streams).

Thiessen Polygon - The area, surrounding a precipitation station, which is circumscribed by the perpendicular bisectors of straight lines drawn to adjacent stations.

Transmissibility - The characteristic property of the entire saturated portion of an aquifer to transmit water.

Transmissibility, Coefficient of[5/] - The field coefficient of permeability multiplied by the thickness, in feet, of the saturated part of the aquifer.

Underflow - Relatively horizontal movement of water through saturated granular material under hydraulic gradients commonly developed underground.

Water Table - The upper surface of the body of free water which completely fills all openings in a granular material sufficiently pervious to permit percolation.

Wilting Point - The amount of water present in the soil when the leaves of plants first undergo permanent reduction in their water content as the result of deficiency in the supply of soil moisture.

Year - Unless otherwise noted, the water year from October 1 to September 30. The year 1928-29 is October 1, 1928 through September 30, 1929. The period 1929-57 is October 1, 1928 through September 30, 1957.

Zone of Aeration - The zone above the water table in which interstices are partly filled with air.

Zone of Saturation - The zone below the water table in which interstices are completely filled with ground water.

1/ Glossary - Water and Sewage Control Engineering, APHA, ASCE, AWWA, FSWA.
2/ Tolman, C. F. - "Ground Water", 1937.
3/ Glossary of Geology and Related Sciences, AGI, 2nd Edition, November, 1960.
4/ Ground Water Basin Management, ASCE Manual of Engineering Practice No. 40.
5/ Meinzer, O.E. - "Hydrology", 1942.

SUMMARY OF FINDINGS

The Order of Reference in the case of City of Los Angeles vs. City of San Fernando, et al., No. 650079, Superior Court, Los Angeles County, directs the State Water Rights Board to investigate, find, and report upon physical facts as enumerated in the Order. The results of the referee's investigation are contained in this report and are summarized as follows, with reference at the beginning of each section to the specific requirements of the Order.

Description of Area

> "I.1. THE GEOGRAPHIC AND HYDROLOGIC (SURFACE AND GROUND WATER) BOUNDARIES OF THE WATERSHED OF THE LOS ANGELES RIVER AND ITS TRIBUTARIES ABOVE THE JUNCTION OF THE SURFACE CHANNELS OF THE LOS ANGELES RIVER AND THE ARROYO SECO AT A POINT NOW DESIGNATED AS LOS ANGELES COUNTY FLOOD CONTROL DISTRICT GAUGING STATION NO. F57. (NOTE: IF SAID BOUNDARY DIFFERS FROM THAT DEPICTED ON AND DESCRIBED IN APPENDICES 'A' AND 'B' ATTACHED TO PLAINTIFF'S AMENDED COMPLAINT, THEN THE AREAS INCLUDED WITHIN BOTH BOUNDARIES SHALL BE STUDIED AND SHALL BE INCLUDED IN THE TERM 'SAID AREA' AS HEREINAFTER USED.)"

The term "Upper Los Angeles River Area", as used in this report, refers to the surface area comprising all of the watershed of the Los Angeles River and its tributaries above the junction of the surface channels of the Los Angeles River and the Arroyo Seco at a point now designated as Los Angeles County Flood Control District gaging station No. F-57. The geographic boundary of this area has been interpreted to mean and is in fact identical with the boundary of the Upper Los Angeles River area and conforms generally with that described in Appendixes A and B attached to Plaintiff's Amended Complaint. This boundary is described on pages 17 and 18 and is the watershed boundary delineated on Plate 2. The hydrologic boundary has been

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interpreted as that boundary which delimits the areal extent of major ground water sources within the Upper Los Angeles River area and is the boundary of valley fill depicted on Plate 5 and described on pages 43 and 44 of Chapter III. A bedrock ridge located to the west of Pickens Canyon traverses the valley fill in a southwesterly direction (see Plate 6 and page 42) and is an impediment to ground water flow. The Report of Referee, Raymond Basin Reference, used the easterly bank of Pickens Canyon as an approximation of this impediment, the valley fill area to the east being a portion of the Monk Hill Basin. For convenience this boundary has also been adopted by the Referee for the San Fernando Valley Reference (see Plate 5).

The Upper Los Angeles River area is situated northwesterly of the original Pueblo of Los Angeles and contains a total of about 329,000 acres, of which about 123,000 are valley fill area and about 206,000 are hill and mountain area. The major tributary streams, Pacoima Wash and Tujunga Wash, originate in the San Gabriel Mountains, which form the northeasterly portion of the watershed. These streams traverse the valley fill area in a southerly direction and join the Los Angeles River, which follows an easterly course along the base of the Santa Monica Mountains before it turns south through the Los Angeles River Narrows leaving the Upper Los Angeles River area at Gage F-57. Several minor streams in the Simi Hills and Santa Susana Mountains in the westerly portion of the watershed are tributary to the Los Angeles River in the westerly portion of the valley fill area. Other minor streams, including Verdugo Wash, drain the easterly portion of the watershed comprising the Verdugo Mountains, the Elysian, San Rafael and Repetto Hills and the La Crescenta area.

Ground Water Occurrence and Movement

"I.2. THE COMPLETE GEOLOGY, INSOFAR AS IT AFFECTS THE OCCURRENCE AND MOVEMENT OF GROUND WATER, AND THE SURFACE AND GROUND WATER HYDROLOGY OF SAID AREA, INCLUDING BASINS AND SUB-BASINS THEREIN, INCLUDING BUT NOT LIMITED TO:

A. THE TOPOGRAPHY AND SOILS.

B. THE SURFACE LOCATION OF THE BED AND BANKS OF THE CHANNELS OF THE LOS ANGELES RIVER AND ITS TRIBUTARIES.

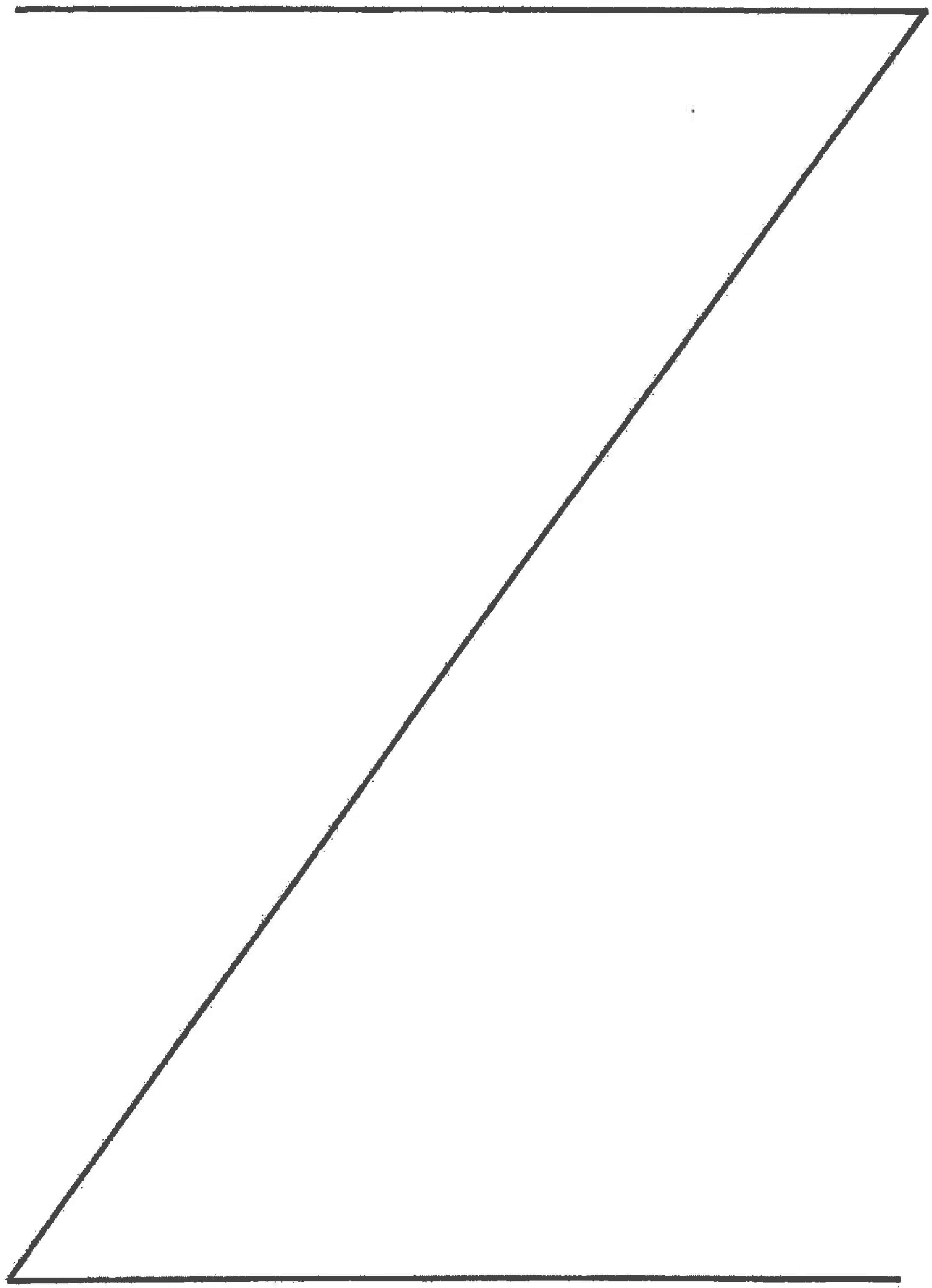
C. THE AREAS, LIMITS AND DIRECTION OF FLOW OF ALL GROUND WATER IN SAID AREA, INCLUDING, BUT NOT LIMITED TO, ANY AND ALL WATERS PERCOLATING THEREIN."

The major water-bearing formation is the valley fill material areally bounded by the generally nonwater-bearing hill and mountain formations which also comprise the underlying bedrock (See Plate 4 and pages 27 through 40). Topographically the valley fill area has a generally uniform grade in a southerly and easterly direction with the slope gradually decreasing from the base of the hills and mountains to the surface drainage outlet at Gage F-57. The valley fill soil mantle is of greatest permeability along and easterly of Pacoima and Tujunga Washes and generally throughout the eastern portion of the valley fill area except in the vicinity of the City of Glendale where it is of lesser permeability. Valley soils west of Pacoima Wash are in turn generally less permeable than those in the vicinity of Glendale. Topography and soil types are depicted on Plates 2 and 3 respectively. Source and characteristics of the valley soils are described on pages 24 and 25.

Ground water occurs mainly within the valley fill with only minor amounts occurring in hill and mountain areas. Ground water movement into the water-bearing valley fill from bedrock fractures and from the small amounts of permeable materials existing in the hill and mountain formations is possible but is believed to be minor and is not susceptible to evaluation. Available geologic data do not indicate that there are any sources of native ground water other than that which is derived from precipitation. No indications of juvenile water or water transported from outside the watershed along faults or fracture systems have been found.

Ground water movement in the valley fill generally follows the surface topography and drainage except where geologic or man-made impediments occur or where the natural flow has been modified by extensive pumping. The area of the major water-bearing material is described by the boundary of valley fill delineated on Plates 2 and 5. Vertical limits of this water-bearing fill material are defined by the surface topography elevation shown on Plate 2 and the bedrock elevations depicted by contours on Plate 6 and are described on pages 40 through 43. Direction of ground water flow within the water-bearing fill material is along the gradient taken normal to the ground water contours.

The ground water conditions which have existed during the 1928-29 through 1957-58 period are illustrated by Plates 27, 28, 29 and 30 which show ground water contours for the years 1931, 1938, 1944 and 1958 respectively.



The valley fill material is a heterogeneous mixture of clays, silts, sands and gravels laid down by the alluviation process. Characteristic composition of the fill is depicted on Plates 5A through 5H. Clays and finer materials predominate west of Pacoima Wash, whereas coarser materials predominate in the easterly portion of the valley. Specific yields or water-yielding capacities of these materials vary from 3 percent for clay to 26 percent for coarse sand or fine gravel. Specific yield of the water-bearing materials is set forth on page 63.

The surface location of the bed and banks of the Los Angeles River and its tributaries is shown on Plate 2. Location of these channels on the valley floor in 1893 is shown on Plate 11 and the improved channels existing in 1958 are shown on Plate 12.

Hydrologic Subareas

"I.2,D. THE AREA, LOCATION, NATURE, CHARACTERISTICS AND LIMITS OF ANY AND ALL BASINS AND SUB-BASINS AND THE INTERCONNECTION OR INTERDEPENDENCE THEREOF, WITHIN SAID AREA."

There are four hydrologic subareas consisting of San Fernando, Sylmar, Verdugo and Eagle Rock which, along with the portion of the Monk Hill Basin within the area (609 acres), comprise the ground water reservoir of the Upper Los Angeles River area. The areal extent of these subareas and the portion of Monk Hill Basin, which occupy the total valley fill area, are shown on Plate 5. The subareas are bounded by impediments to flow of ground water which are caused by faulting, folding, alluvial constrictions or man-made works. The San Fernando, Sylmar, Verdugo and Eagle Rock Subareas comprise 90.8, 4.5, 3.8 and 0.6 percent of the total valley fill respectively.

The San Fernando Subarea is adjacent to and receives surface drainage from each of the other three subareas. The amount of subsurface flow from the smaller subareas to San Fernando Subarea depends upon ground water gradient, transmissibility and the extent of the connection between the subareas. The Eagle Rock, Sylmar and Verdugo Subareas are not directly interrelated or interdependent upon each other. Estimated amount of subsurface flow from the Sylmar Subarea to the San Fernando Subarea is shown in Table 32, page 161, and averages 550 acre-feet annually. Subsurface flow from the Verdugo and Eagle Rock Subareas to the San Fernando Subarea is insignificant and has been considered as nil.

The San Fernando Hydrologic Subarea contains 112,047 acres and occupies all of the valley fill area except that occupied by the other three subareas and the Monk Hill Basin. The valley fill materials in the eastern portion of the subarea are generally sand and gravel and have the ability to store a higher percentage of water than the fine-grained materials in the western portion (see pages 46 through 50).

The Sylmar Hydrologic Subarea contains 5,565 acres and is located northerly of the San Fernando Subarea. Both free and confined ground water areas exist in this subarea. Subsurface flow from the Sylmar Subarea to the San Fernando Subarea takes place at two notches that have been eroded into the truncated south limb of the Little Tujunga syncline which forms the southern boundary of the Sylmar Subarea (see pages 51 through 55).

The Verdugo Hydrologic Subarea is located northeasterly of the San Fernando Subarea and contains 4,400 acres. Available information indicates that movement of ground water from the Verdugo Subarea to the San Fernando Subarea is almost completely controlled by a man-made submerged dam and well diversions by the City of Glendale in the cross-sectional area of the Verdugo Wash Canyon between the Verdugo Mountains and the San Rafael Hills. Subsurface outflow from the portion of the Monk Hill Basin (609 acres) within the Upper Los Angeles River area easterly to the main portion of the Monk Hill Basin is by means of a buried erosion channel of an ancestral Pickens Canyon Wash and has ranged from 250 acre-feet to 400 acre-feet per year and has averaged 300 acre-feet per year during the base period (see pages 42, 56 through 58, and Table 31 on page 160). Subsurface flow from Monk Hill Basin southwesterly to the Verdugo Subarea is prevented, in all but high ground water conditions, by a bedrock ridge on the westerly side of the above ancestral Pickens Canyon Wash.

The Eagle Rock Hydrologic Subarea contains 807 acres and is situated to the southeast of the San Fernando Subarea. Eagle Rock Subarea is an artesian basin lying above the Raymond fault zone. Available information indicates that subsurface flow to the San Fernando Subarea is entirely or almost entirely stopped by this fault zone (see pages 58 through 61).

Amounts and Quality of Water Supply

"I.2.E. THE QUALITY OF ALL WATERS WITHIN SAID AREA AND THE EFFECT THEREON OF THE IMPORTATION OF OWENS VALLEY WATER.

I.2.F. THE SOURCE AND QUANTITY OF ALL WATERS, AND THE PLACES OF APPLICATION AND USE OF FOREIGN WATERS, ENTERING SAID AREA EACH WATER YEAR FOR THE PERIOD COVERED BY AVAILABLE RECORDS AND INFORMATION.

I.7. ALL SOURCES OF WATER SUPPLY OF PLAINTIFF AND DEFENDANTS, AND THE QUANTITY THEREOF FOR THE PERIOD OF AVAILABLE RECORDS AND INFORMATION TO AND INCLUDING THE DATE OF THE REPORT:

(a) DIVERTED AND USED; AND

(b) AVAILABLE FOR DIVERSION AND USE."

The present water supply to the Upper Los Angeles River area is comprised of precipitation on the watershed, import from the Mono Basin Owens River System and import from the Colorado River. The average annual precipitation for the 85-year period, 1871-72 through 1956-57 on the valley floor is about 16.3 inches or 167,740 acre-feet, and on the hill and mountain area is about 22 inches or 377,110 acre-feet, making a total average annual water crop of about 544,850 acre-feet. Of the rain on the mountain and hill areas only an average of 44,000 acre-feet per year reached the valley fill area as runoff during the 29-year base period from 1928-29 through 1956-57. During the 29-year base period, the annual precipitation was above normal for about one-third of the years and subnormal for about two-thirds. This approximates the proportion of years of subnormal and above normal annual precipitation occurring in the 85-year period. Annual precipitation for the 29-year period averaged 541,720 acre-feet or 99.5 per cent of the 85-year normal. During this 29-year period the annual water crop from precipitation ranged from a minimum of about 50 per cent of normal in 1947-48 and 1950-51, to a maximum of 224 per cent of normal in 1940-41. Annual amounts of precipitation are listed in Table 1, page 69, for the period 1928-29 through 1957-58.

Runoff from the hill and mountain area plus precipitation on the valley fill less storm runoff at Gage F-57 is the native water supply available to the valley fill area. An average of about 88 per cent of the annual precipitation on the hill and mountain area is consumed there. Runoff to the valley floor accounts for the remaining 12 per cent. Annual runoff reaching the valley floor from precipitation on the hill and mountain area ranged from 3,450 acre-feet in 1950-51 to 191,400 acre-feet in 1940-41 and averaged 44,000 acre-feet during the base period (Table 3, page 76 and pages 74 and 75).

Annual storm runoff leaving the area at Gage F-57 has varied from 1,330 acre-feet in 1929-30 to 138,990 acre-feet in 1940-41 and averaged 30,790 acre-feet during the base period 1928-29 through 1956-57 (Table 28,
24 page 155).

Owens River water was first served in the Upper Los Angeles River area via the Los Angeles Aqueduct, owned and operated by the City of Los Angeles, in May 1915. A portion of the water from this source is passed through the area to serve other portions of the City of Los Angeles. The net annual amount of Owens River water remaining in the area during the 30-year period from 1928-29 through 1957-58 has varied from 74,000 acre-feet in 1940-41 to about 162,000 acre-feet in 1957-58 including the portion which has been spread for direct recharge of ground water which has averaged 7,800 acre-feet per year during the base period (Table 8, page 97 and Table 24, page 145).

Colorado River water has been imported into the area since 1939-40 with the 70 acre-feet imported that year increasing to 13,250 during 1956-57. Annual amounts imported from this source during the 19-year period averaged about 4,300 acre-feet (Table 8, page 97).

The amounts of water available at their source of import for diversion and import and use by the parties from sources outside the Upper Los Angeles River area have been considered primarily from the viewpoint of physical availability at points of diversion of existing works. A determination of legal availability would involve findings concerning other rights to these sources which are not within the purview of this reference. Information available indicates that there is no additional firm supply for plaintiff and for defendants from the Central and West Coast Basins because these ground water sources are now overdrawn. Runoff which has occurred in channels tributary to diversion works of the Los Angeles Aqueduct from the Owens and Mono Basins and amounts in excess of the quantities diverted are shown in Table 5 on page 83. The net diversions from the Colorado River by The Metropolitan Water District of Southern California are shown in Table 6 on page 86. Preferential rights and priorities of members of The Metropolitan Water District are shown on pages 88 and 91 respectively.

Annual amounts of water imported through the Los Angeles and Colorado River Aqueducts for delivery within the Upper Los Angeles River area are listed in Table 8, page 97, for the years prior to 1958-59.

The water service areas are shown on Plates 19 and 20 respectively for large and small entities. The annual amounts of imported water delivered to each of the larger entities are listed by water service areas in Table M-2 for Mono Basin-Owens River water and in Table M-3 for Colorado River water.

Water delivered in the Upper Los Angeles River area may be imported water, local ground water or local surface diversions, or a mixture depending on the area and water system operation. In the 1928-29 through 1957-58 period, gross ground water extractions in the Upper Los Angeles River area for all purposes including export have increased from 67,330 acre-feet in 1932-33 to 163,270 acre-feet in 1956-57 and have averaged 111,920 acre-feet during the base period (See Table 15, page 124). During the same period, surface water diversions averaged 660 acre-feet and varied from 160 acre-feet in 1956-57 to 1,470 acre-feet in 1943-44 (See Table 16, page 125).

Quality of water imported from the Owens-Mono Basins is good, being of sodium calcium bicarbonate character and averaging about 215 parts per million (ppm) total dissolved solids (TDS). Colorado River import is of sodium sulfate character and has averaged about 774 parts per million (ppm) total dissolved solids (TDS). Surface runoff in the Upper Los Angeles River area varies from a calcium sulfate type in the southwesterly portion to a predominantly calcium bicarbonate type from the north and easterly portion. Concentration of total dissolved solids in surface runoff at the valley outlet vary generally in an inverse proportion to the magnitude of runoff rates and vary from about 100 ppm at peak flows to over 1,000 ppm during times of minimum flow. Ground waters reflect the same general source area influence on their character as indicated by surface flows, being predominantly calcium sulfate in the westerly portion and calcium bicarbonate in the remainder of the area. Ground waters of the basin are generally within U. S. Public Health Drinking Water Standards of 1946 (See pages 98 through 105).

Quality characteristics of Upper Los Angeles River area ground waters and waters imported thereto are shown on Plate 15. Concentrations of total dissolved solids, and sulfate, chloride and nitrate ions found in solution in ground waters in the area are shown in Table 9, on pages 101 and 102 and Plates 17A, B, C and D.

Except for a short period of time in 1932 when boron concentrations were above normal, the quality of waters imported from Owens River and Mono Basin have been equal or superior to the native waters of the Upper Los Angeles River area and have not otherwise adversely affected the quality of the native waters (page 105).

Water Use and Disposal in the Upper Los Angeles River Area

"I.2,G. THE NATURE AND QUANTITY OF ALL WATER LOSS AND DIMINUTION WITHIN AND FROM SAID AREA, EACH WATER YEAR FOR THE PERIOD COVERED BY AVAILABLE RECORDS AND INFORMATION.

I.4. AS TO EACH PARTY TO THE WITHIN ACTION FOR THE PERIOD OF AVAILABLE RECORDS AND INFORMATION:

(a) THE LOCATION AND CAPACITY OF HIS OR ITS DIVERSION WORKS;

(b) THE CHARACTER OF HIS OR ITS USE OR USES OF WATER; AND

(c) THE AMOUNT OF HIS OR ITS TAKING AND USE OF WATER."

Water is used in the area for agricultural and municipal purposes, the latter including commercial, industrial and recreational uses. Diminution of water so used is by evaporation, or transpiration to the air or by leaving the area as sewage or waste outflow in surface channels. Major surface outflow occurs from storm runoff. Minor additional outflows occur comprised of rising ground water and Owens River water released to the river system in excess of percolation and rediversion. Minor subsurface outflow occurs through the alluvium at Gage F-57 and from the Verdugo Subarea immediately east of Pickens Canyon Wash.

Land Use

During the 30-year period 1928-29 through 1957-58, the type of land use has changed from primarily agricultural to urban. In that period irrigated agriculture was reduced from 58,400 acres, or 47 per cent of the 123,400 acres of valley fill in 1928-29, to about 16,200 acres or 13 per cent in 1957-58. Urban land use, comprising residential, commercial and industrial

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acreage, has more than tripled during the period, increasing from about 22,000 acres in 1928-29 to about 75,400 acres during 1957-58 (See Plates 22 through 25, Table 17, page 128 and Figure 1, page 129).

Extraction and Export of Ground Water

In addition to import supplies, ground water is pumped from the valley fill and applied thereon for the named uses. Total annual extractions so used ranged from 34,890 acre-feet in 1928-29 to 73,390 acre-feet in 1952-53 and averaged 54,320 acre-feet during the base period (Table 20, page 138).

The capacity and location of the diversion works of the parties are listed in Tables 11 and 12 on pages 112 through 115 and 117 through 119 respectively. The location of all wells of record is shown on Plate 18. Where more than one party has an interest in a diversion works, the data on the diversion works are listed under the party believed to have the major interest. A cross reference to joint interests of parties is shown in Table 10 on pages 107 through 109.

The character of water use (accounted as municipal, domestic, irrigation, industrial, commercial or recreation) is indicated for each of the parties in Table 11 on pages 112 through 115.

Annual amounts of the taking of water by each of the parties are listed in Tables 12 and 13 on pages 117 through 120 for the period of available record.

Ground water has been pumped and exported from the area mainly by the City of Los Angeles with minor amounts exported from the Verdugo Subarea by La Canada Irrigation District. Total annual export of ground water has varied from 32,010 acre-feet in 1932-33 to 90,750 acre-feet in 1956-57 and has averaged 57,600 acre-feet during the base period (Table 19, page 135).

Sewage

Sewage has been exported from the area via the North Outfall sewer since 1928 and the San Fernando Valley Sewer Relief tunnel since 1956. Total annual sewage exported, including a minor amount of ground water infiltration, has varied from 6,320 acre-feet in 1928-29 to 63,960 acre-feet in 1957-58 and averaged 24,670 acre-feet during the base period. A portion of the water delivered in the area is disposed to the ground water table through local disposal units including cesspools. This amount has increased in recent years from 3,950 acre-feet in 1934-35 to 20,550 acre-feet during 1956-57 and has averaged 9,330 acre-feet annually during the base period (Table 26, page 151).

Surface Outflow and Native Runoff Spread

Annual total surface outflow passing Gage F-57, which is comprised of storm runoff, Owens River water, rising ground water and industrial waste, including a small amount of spilled sewage, ranged from 1,660 acre-feet in 1929-30 to 164,960 acre-feet in 1940-41 and averaged 39,940 acre-feet during the base period (Table 28, page 155).

A portion of the mountain and hill runoff reaching the valley fill has been spread for direct recharge of the ground water. Annual spreading of runoff water ranged from zero in several years to 30,380 acre-feet in 1957-58 and averaged 3,060 acre-feet during the base period (Table 30, page 158).

Subsurface Outflow

Subsurface flow leaves the Upper Los Angeles River area at two locations, one southerly through the Los Angeles Narrows and the other easterly in the vicinity of Pickens Canyon. Subsurface outflows at these locations have averaged about equal amounts for a total of 650 acre-feet per year during the base period (Table 31, page 160).

Consumptive Use

Disposal of water from the valley fill area through the combined consumptive use of precipitation, delivered water and ground water has been computed in Chapter V by the Inflow-Outflow Method. Consumptive use determined in this manner averaged 227,200 acre-feet per year for the base period from 1928-29 through 1956-57 (Table 34, page 169).

Effect of Water Supply and Use on Ground Water Recharge and Storage

"I.2. THE COMPLETE GEOLOGY, INSOFAR AS IT AFFECTS THE OCCURRENCE AND MOVEMENT OF GROUND WATER, AND THE SURFACE AND GROUND WATER HYDROLOGY OF SAID AREA, INCLUDING BASINS AND SUB-BASINS THEREIN. INCLUDING BUT NOT LIMITED TO:"

The net effect of water supply and disposal is reflected by the ground water levels in the ground water reservoir. Water levels in the westerly portion of the valley fill in San Fernando Subarea have had relatively minor fluctuation indicating a net gain of about 10 feet during the 29-year base period. In contrast, levels in the easterly portion of that subarea dropped slightly and recovered between 1928-29 and 1934-35 and then generally increased to a maximum in 1944, at which time the basin contained the maximum amount of water in storage during the 1928-29 through 1957-58 period. After 1944 levels dropped at a rapid rate to record lows in 1957-58, when water in storage was the minimum of record to that time. Water levels in the Sylmar and Eagle Rock Subareas have had relatively minor fluctuations during the period, with those in the former indicating a small net drop and in the latter reflecting little net change. Water levels in the Verdugo Subarea followed the same general pattern as those in the easterly portion of San Fernando Subarea but with fluctuations of less magnitude.

Concentration of pumping activity in the Los Angeles Narrows area has resulted in a reversal of the ground water gradient in that area subsequent to 1958 (see Plates 27, 28, 29, 30, 31, 31A, 31B, 32, 33, 34A, 34B and 34C).

The maximum annual change in ground water storage during the base period occurred in 1940-41 with an increase of water in storage of 128,020 acre-feet. The average annual change in storage during the base period was a decrease of 11,950 acre-feet (see Table 33, page 166).

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A summary of the items comprising the water supply and disposal on the valley fill is presented in the following tabulation in terms of the range in each item during the 30-year period 1928-29 through 1957-58 and the average of each during the 29-year base period 1928-29 through 1956-57.

During the 29-year base period 1928-29 through 1956-57, total annual historic ground water recharge has ranged from 58,700 acre-feet in 1928-29 to 247,200 acre-feet in 1940-41 and averaged 112,200 acre-feet (see Table 43, page 203).

WATER SUPPLY AND DISPOSAL ON THE VALLEY FILL

In 1,000 Acre-Feet Per Year

Item	Average during base period 1928-29 thru 1956-57	Range in Values During Period 1928-29 through 1957-58					
		Maximum		Minimum		Reference	
		Amount	Year ending	Amount	Year ending	Table No.	Page No.
WATER SUPPLY TO VALLEY FILL AREA							
Precipitation on Valley Fill	173.1	409.8	'41	80.1	'48	34	169
Import to Valley Fill	124.6	170.7	'57	68.8	'41	34	169
Hill and Mountain Runoff	44.0	191.4	'41	3.5	'51	34	169
Surface Diversions from Hill Areas	0.5	1.3	'44	0.1	'29	34	169
Water from Ground Water Storage	12.0					34	169
Total Water Supply (rounded off)	354						
WATER DISPOSAL FROM VALLEY FILL AREA							
Ground Water Transfers							
Out of Upper Los Angeles River Area	57.6	90.8	'57	32.0	'33	34	169
To Hill and Mountain Areas	5.9	8.0	'46	2.3	'29	34	169
Subtotal (rounded off)	63						
Surface Outflow							
Net Storm Flow	30.8	139.0	'41	1.3	'30	28	155
Rising Water	6.8	28.6	'42	0		28	155
Wastes	0.8	2.4	'56	0		28	155
Owens River Water	1.6	8.7	'43	0		28	155
Subtotal (rounded off)	40						
Net Sewage Export and Sewer Infiltration							
Net Sewage Export	20.3	55.1	'58	5.1	'29	26	151
Sewer Infiltration	2.7	6.3	'41	0.2	'30	26	151
Subtotal (rounded off)	23						
Subsurface Outflow	0.6	0.8	'39	0.4	'58	34	169
Consumptive Use	227.2	323.9	'43	141.4	'57	34	169
Total Water Disposal (rounded off)	354						

Safe Yield and the Effect of Import

"I.2.H. THE SAFE YIELD, AND THE EFFECT THEREON OF THE IMPORTATION OF FOREIGN WATERS, SHALL BE DETERMINED FOR THE WATER YEAR IMMEDIATELY PRECEDING THE FILING OF THE REPORT FOR WHICH DATA IS AVAILABLE, AND FOR THE WATER YEARS ENDING 1950 AND 1955."

The safe yield of the Upper Los Angeles River area ground water reservoir has been determined as the maximum average annual pumpage draft which can be continually withdrawn for useful purposes under a given set of conditions without causing an undesired result.

Safe yield has been based on cultural conditions existing during the water years 1949-50, 1954-55 and 1957-58. The latter is the last year preceding the filing of the report for which data are available.

Safe yield has been determined through the evaluation of the average net ground water recharge which would occur if the culture of the safe yield year and the average historic import and export for that year had existed over a period of normal native supply. All items of supply and disposal responsive to both precipitation and economic conditions were based on the 9 year period from 1949-50 through 1957-58, whereas items responsive primarily to precipitation on the valley fill area were based on the 29 year base period 1928-29 through 1956-57. Base ground water levels used were those existing as of the end of 1957-58 (See pages 208 through 243).

Availability of regulatory ground water storage space does not impose any limitation on safe yield under the conditions adopted (see page 207).

The safe yield, in acre-feet per year, of the Upper Los Angeles River area ground water reservoir, determined under the conditions adopted, is 100,800, 100,400 and 97,600 for the years 1949-50, 1954-55 and 1957-58 respectively. That portion of the safe yield derived from native sources, in acre-feet per year, is 62,100, 57,700 and 54,700 for the years 1949-50, 1954-55 and 1957-58 respectively. That portion of the safe yield derived from import sources, in acre-feet per year, is 38,700, 42,700 and 42,900 for the years 1949-50, 1954-55 and 1957-58 respectively (see Table 55, page 246b).

Importation of foreign waters increased the safe yield of the ground water reservoir by 38,700, 42,700 and 42,900 acre-feet for the respective safe yield years of 1949-50, 1954-55 and 1957-58. As a result there was a decrease in deficiency of supply to meet the water requirements of the culture existing during the safe yield years to less than the deficiency which would have occurred had local sources been the sole supply (see Table 56, page 249 and page 250).

To eliminate the total water requirement not satisfied by total water available under safe yield conditions of 33,900, 52,800 and 63,800 acre-feet per year for the respective safe yield years of 1949-50, 1954-55 and 1957-58, it would be necessary to modify the import, export and/or demand (see Table 56, page 249). The foregoing deficiencies of water requirements are equivalent to a consumptive demand of 25,200, 38,500 and 46,800 acre-feet per year for the respective safe yield years of 1949-50, 1954-55 and 1957-58 (see Table 56, page 249).

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Use of Water by the City of Los Angeles and Others

"I.5. THE USE OF WATER BY THE CITY OF LOS ANGELES AND ITS INHABITANTS:

(a) SINCE 1948 WITHIN THE TERRITORY OF THE ORIGINAL PUEBLO; AND

(b) FOR THE PERIOD OF AVAILABLE RECORDS WITHIN THE EXPANDED BOUNDARIES OF SAID CITY AS THE SAME EXISTED FROM TIME TO TIME UP TO THE DATE OF THE REPORT HEREIN.

"I.6. THE AMOUNT OF WATER DISTRIBUTED BY PLAINTIFF FOR THE PERIOD OF AVAILABLE RECORDS AND INFORMATION TO AND INCLUDING THE DATE OF THE REPORT, FOR USE OUTSIDE ITS BOUNDARIES AS SUCH BOUNDARIES HAVE EXISTED FROM TIME TO TIME.

"I.7. ALL SOURCES OF WATER SUPPLY OF PLAINTIFF AND DEFENDANTS, AND THE QUANTITY THEREOF FOR THE PERIOD OF AVAILABLE RECORDS AND INFORMATION TO AND INCLUDING THE DATE OF REPORT:

(a) DIVERTED AND USED; AND

(b) AVAILABLE FOR DIVERSION AND USE."

Sources of water supply of the City of Los Angeles are the Owens and Mono Basins via the Los Angeles Aqueduct, Colorado River via The Metropolitan Water District Aqueduct, surface diversions from the Los Angeles River in the Upper Los Angeles River area and ground water extractions from that area and from Central and West Coast Basins located outside the Upper Los Angeles River area. Location of the Los Angeles and The Metropolitan Water District Aqueduct systems and of well fields outside the Upper Los Angeles River area are depicted on Plates 13, 14 and 35. Flow chart of the import-export system in the Upper Los Angeles River area is depicted on Plate 21. The Los Angeles Aqueduct has operated at full capacity since prior to 1949-50. Design capacities along The Metropolitan Water District's Santa Monica feeder which conveys Colorado River water to the area are shown on the profile depicted on Plate 13.

Total annual water use by the City of Los Angeles within its expanded boundaries, including all import and local supplies from West Coast Basin, Central Basin and San Fernando Valley has varied since 1928-29 from 227,992 acre-feet in 1934-35 to 477,634 acre-feet in 1956-57 and averaged 336,128 acre-feet during the 29-year period. Annual amounts of water used by the City of Los Angeles and its inhabitants within its expanded boundaries are shown on pages 255 through 257 by sources.

Deliveries by the city for use outside its boundaries varied during the period 1950-51 through 1954-55 from 4,316 acre-feet in 1950-51 to 5,386 acre-feet in 1953-54. Annual amounts of water served by the City of Los Angeles outside its boundaries are shown on page 258.

Use of water by the city within the territory of the original Pueblo ranged from 73,533 acre-feet in 1949-50 down to 60,692 acre-feet in 1957-58 and averaged 65,750 acre-feet during the nine-year period. Annual amounts of water delivered by the City of Los Angeles within the original Pueblo are shown on page 252 for the period 1949-50 through 1957-58.

Sources of water supply of defendants are Colorado River water through The Metropolitan Water District Aqueduct and from the Upper Los Angeles River area through surface diversions and ground water extractions from wells. The amounts imported or diverted from these sources are set forth in Tables 12 and 13 on pages 117 through 120 and in Tables J-3, J-4 and J-5 on pages J-12 through J-17 of Appendix J.

Watershed of Los Angeles River Tributary to South Boundary of Pueblo Exclusive of the Upper Los Angeles River Area

"I.3. THE GEOGRAPHIC AND HYDROLOGIC (SURFACE AND GROUND WATER) BOUNDARIES OF ALL WATERSHEDS SUPPLYING THE LOS ANGELES RIVER BELOW LOS ANGELES COUNTY FLOOD CONTROL DISTRICT GAUGING STATION NO. F57 AND ABOVE THE SOUTHERN BOUNDARY OF THE ORIGINAL PUEBLO."

All of the area draining to the portion of the Los Angeles River above the southern boundary of the Pueblo is shown on Plate 35. The only large channel draining to the Los Angeles River between Gage F-57 and the southern pueblo boundary is the Arroyo Seco which drains a portion of the Raymond Basin area (Monk Hill Basin). The watershed boundary of the Los Angeles River system below Los Angeles County Flood Control District gaging station F-57 and above the southerly boundary of the original Pueblo is depicted on Plate 35.

CHAPTER I. INTRODUCTION

This report has been prepared for and pursuant to orders of the Superior Court of California in and for the County of Los Angeles in action No. 650,079 entitled "The City of Los Angeles, a Municipal Corporation, Plaintiff, vs. City of San Fernando, a Municipal Corporation, et al., Defendants." The complaint in the action requests a decree determining that the plaintiff has a pueblo right paramount to the right of all defendants; that the City has a prior right to all foreign water imported by it, spread within the drainage area of the Los Angeles River, and transmitted to the City's wells and other diversion works by the "surface and subsurface channel" of the Los Angeles River; and that an injunction be issued terminating pumping by the defendants within the watershed boundary of the Los Angeles River above the confluence of Arroyo Seco.

Authorization

The basic Court order, pursuant to which this report has been prepared, consists of the "Order of Reference to State Water Rights Board to Investigate and Report Upon the Physical Facts (Section 2001, Water Code)," entered on June 11, 1958, as modified by: (1) Interim Order entered on November 19, 1958, which directed that no further investigations, studies, proceedings, or reports be made with respect to Paragraph II of the Reference Order of June 11, 1958 unless further ordered; and (2) Orders made in open Court on February 15, 1960, September 20, 1960 and November 15, 1960, Reporter's Transcript, pages 5470, 6377, and 6756, respectively, and ex parte orders extending the time for serving the draft report on the parties, the last such extension being to November 20, 1961, but ordering that copies

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of the proposed draft report be made available to the parties at least 60 days prior to that date.

The Order of Reference of June 11, 1958, had been preceded by an Interim Order of Reference entered by the Court on March 19, 1958, pursuant to which the Board had studied the availability of records and data and had given the Court its estimates of time and expense of reporting thereon. In Paragraph I of the Order of Reference, the State Water Rights Board is requested to investigate, find, provide data and report upon physical facts in accordance with the authorization of Section 2001 of the Water Code, as follows:

"1. The geographic and hydrologic (surface and ground water) boundaries of the watershed of the Los Angeles River and its tributaries above the junction of the surface channels of the Los Angeles River and the Arroyo Seco at a point now designated as Los Angeles County Flood Control District Gauging Station No. F57. (Note: If said boundary differs from that depicted on and described in Appendices 'A' and 'B' attached to plaintiff's Amended Complaint, then the areas included within both boundaries shall be studied and shall be included in the term 'said area' as hereinafter used.)

2. The complete geology, insofar as it affects the occurrence and movement of ground water, and the surface and ground water hydrology of said area, including basins and sub-basins therein, including but not limited to:

A. The topography and soils.

B. The surface location of the bed and banks of the channels of the Los Angeles River and its tributaries.

C. The areas, limits and direction of flow of all ground water in said area, including, but not limited to, any and all waters percolating therein.

D. The area, location, nature, characteristics and limits of any and all basins and sub-basins and the interconnection or interdependence thereof, within said area.

E. The quality of all waters within said area, and the effect thereon of the importation of Owens Valley Water.

F. The source and quantity of all waters, and the places of application and use of foreign waters, entering said area each water year for the period covered by available records and information.

G. The nature and quantity of all water loss and diminution within and from said area, each water year for the period covered by available records and information.

H. The safe yield, and the effect thereon of the importation of foreign waters, shall be determined for the water year immediately preceding the filing of the report for which data is available, and for the water years ending 1950 and 1955.

3. The geographic and hydrologic (surface and ground water) boundaries of all watersheds supplying the Los Angeles River below Los Angeles County Flood Control District Gauging Station No. F57 and above the southern boundary of the original pueblo.

4. As to each party to the within action for the period of available records and information:

(a) The location and capacity of his or its diversion works;

(b) The character of his or its use or uses of water; and

(c) The amount of his or its taking and use of water.

5. The use of water by The City of Los Angeles and its inhabitants:

(a) Since 1948 within the territory of the original pueblo; and

(b) For the period of available records within the expanded boundaries of said city as the same existed from time to time up to the date of the Report herein.

6. The amount of water distributed by plaintiff, for the period of available records and information to and including the date of the report, for use outside its boundaries as such boundaries have existed from time to time.

7. All sources of water supply of plaintiff and defendants, and the quantity thereof for the period of available records and information to and including the date of the report:

(a) Diverted and used; and

(b) Available for diversion and use."

Copies of the Interim Order of Reference, the Order of Reference, and the Interim Order suspending further investigations, studies, or reports pursuant to Paragraph II of the Order of Reference, are included in Appendix S.

History of Proceeding

The case of City of Los Angeles, Plaintiff, vs. City of San Fernando, City of Glendale, City of Burbank, et al., Defendants, is an action for declaratory relief, to quiet title to waters and water rights, and for an injunction to restrain defendants from doing any act which may interfere with the free and uninterrupted flow of the surface and subsurface waters of the Los Angeles River and its tributaries and of the foreign waters brought by the City of Los Angeles from sources outside the watershed of the Los Angeles River and spread within the watershed or served to customers of the City of Los Angeles from its wells and other diversion works where such waters can be taken and used by the City of Los Angeles for its inhabitants.

The complaint names some 214 defendants and includes numerous Does alleged to have facilities which are operated and maintained for the taking of water, both surface and underground, from the Upper Los Angeles River drainage area as defined in Appendix A of the amended complaint.

Answers filed in the proceeding by various defendants allege that the water taken and diverted has been necessary for the purposes for which it has been taken and that each of them has a right to the water so taken.

The initial or Interim Order of Reference to State Water Rights Board made by the Court on March 19, 1958 directed the Board to study the availability of any and all public and private records, documents, reports and data relating to a proposed order of reference in the case and to approximate the time required for, and to estimate the cost of obtaining, correlating and reporting upon, such records, documents, reports, and data, and to report the results of its investigation and study to the Court on June 9, 1958.

The Board, in making its report, presented an estimate that two years would be required to complete the studies and prepare a report of referee pursuant to the proposed order of reference.

On June 11, 1958, the Court by its Order of Reference to the State Water Rights Board, appointed the Board as referee to investigate and report within two years on the physical facts enumerated in the Order of Reference in accordance with Section 2001 of the Water Code. The Board was further instructed under Paragraph II of the Order of Reference to investigate the nature, extent and availability of any and all records and data reasonably necessary for the study of the Board with respect to water years from and including that ending 1900 to the year preceding the Board's report, and to report the results of such investigation to the Court on November 17, 1958.

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On November 17, 1958, the State Water Rights Board reported to the Court, pursuant to Paragraph II of the Order of Reference, that in its opinion insufficient data are available to justify a valid base period of study or of safe yield determination prior to the water year 1928-29, and that as to other items in Paragraph II, a report would be made at a later date after the Board had proceeded further with its studies.

By Interim Order of November 19, 1958, the Court accepted the Board's report of November 17, 1958 and released the Board from any further investigation pursuant to Paragraph II of the Order of Reference until and unless further ordered by the Court. The Court as a part of its order instructed the Board to appear at pre-trial conference sessions in the proceeding and to render progress reports, oral and written, on the matters on which it is required to report.

Representatives of the State Water Rights Board, in accordance with the Order of November 19, 1958, appeared before the Court on March 16, 1959, June 1, 1959, and February 15, 1960, and presented written and oral reports as to the Board's progress in investigating and compiling the data and information required under the Order of Reference.

Upon being advised on the latter date that deficiencies in available data had required additional time and added investigation by the parties and by the Board of certain items of information essential to answering portions of the Order of Reference, such added investigation having been made with knowledge and approval of engineering representatives of the parties, the Court by oral order in open Court extended the time allowed the Board for service of its Draft of Report of Referee on the parties to December 12, 1960. The date for service of the draft was further extended from time to time by verbal orders of the Court and by ex parte order upon being advised that additional time was required to fully comply with the Order of Reference. The last order designated November 20, 1961 as the date for service and directed the Referee to make available to the parties or their engineering representatives copies of the proposed draft report at least 60 days prior to November 20, 1961. The Court further directed that distribution of the proposed draft 60 days prior to the date of service of the draft was not to constitute a mailing of notice and copies of the draft under Section 2014 of the Water Code.

The Draft of Report of Referee was approved and adopted by the State Water Rights Board on November 13, 1961, and was served on the parties on November 20, 1961. The parties had thirty days to make formal objection to the draft. At the request of the parties, the Court extended the time to make objection an additional ninety days to March 20, 1962.

On February 23, 1962, the Referee transmitted to the parties a document entitled "Errata to Draft of Report of Referee". The errata which contained a list of errors, minor omissions and clarifications, was submitted to assist the parties in their review of the draft and to eliminate the necessity for objecting to many minor items.

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Objections to Draft of Report of Referee

Objections (dated March 19, 1962 through March 21, 1962) to the Draft of Report of Referee (November 1961) were received from the following parties:

City of Los Angeles, Plaintiff.

City of San Fernando, Defendant No. 1.

City of Glendale, Defendant No. 2 and City of Burbank, Defendant No. 3.

La Canada Irrigation District, Defendant No. 7, Crescenta Valley County Water District, Defendant No. 8, and from Defendants Nos. 131, 171, 201 and 202.

Southern California Edison Company, Defendant No. 75.

Sparkletts Drinking Water Company, Defendant No. 78.

Deep Rock Artesian Water Company, Defendant No. 34, and from Defendants Nos. 12, 36, 37, 38, 39, 40, 43, 54, 64, 97, 100, 101, 102, 104, 106, 113, 117, 123, 140, 141, 142, 164, 168, 172, 181, 182, 186, 187 and 204.

Consideration of Objections to Draft of Report of Referee

All objections have been considered by the Referee. As a result of objections by the parties and review by the Referee, the Report of Referee contains the revisions to the Draft of Report of Referee set forth in the following paragraphs.

A. The changes specified in "Errata to Draft of Report of Referee" have been made to the draft and carried through the various tables, diagrams and plates, with the exception of items listed in the errata as Nos. 11, 34, 37, 43, 45, 46, 47, 56, 57 and 58, which were superseded by other changes or made ineffective because of other corrections.

B. Modifications by clarification of language, due to objections, have been made to the following pages in Volumes I and II:

Pages xxxi, xxxiv, 10, 23, 53, 54, 82, 106, 115, 135, 138, 138a, 173, 189, 199, 233, 247, 248, 249, A-46, A-48, E-6, I-3, I-8, J-20, K-19 through K-24 and M-16.

C. Further clarification has been made by the Referee to improve language, more clearly state meaning or to correct errors on the following pages and plates in Volume I:

Pages xxiv, xxvi through xxxiii, xxxv through xxxix, xlii through li, 10, 14, 26, 29, 39, 40, 42, 43, 45, 52, 56, 57, 58, 59, 61, 68, 69, 70, 76, 79, 80, 88, 90, 93, 97, 101, 123 through 126, 130, 131, 135, 136, 137, 139, 145, 151a, 155, 160, 166, 168, 169, 176 through 179, 181 through 187, 189 through 197, 200 through 203, 205, 207, 208, 209, 211, 212, 217, 220, 221, 223, 226, 227, 229, 233, 235 through 239, 242 through 247, 249, 250, 255, 256, and on Plates 1, 2, 5A through 5H, 11 through 16, 22, 23, 28, 30, 31, 31A, 31B, 32, 33 and 35.

Further clarification has been made in the appendixes on the following pages:

Pages A-29, A-45, C-12, D-7, E-3, E-6, E-8, E-10, E-12, E-15, F-2, F-4, F-7, F-8, F-13, F-17, F-18, F-24 through F-27, F-29 through F-32, G-8, G-9, G-12, I-8, I-19, I-23, I-24, I-30, I-40, I-41, I-56, J-6, J-7, J-12 through J-17, J-21, J-34, K-15, K-17, K-20, L-6, L-19, L-25, L-31, L-32, L-33, L-40, L-43, L-44, L-45, L-47, L-49, L-50, L-53, L-56 through L-68, L-70, L-71, L-75, M-7, M-8, M-10, M-12, M-14, M-18, N-4, N-9, N-34, N-36, O-7, O-12, Q-5, Q-6, R-4, R-5, R-8, R-9, R-10, R-13, R-14, R-16, R-17, R-18, and by adding pages L-49a and L-71a.

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D. Certain objections required more than clarification or language improvement and material has been added or deleted in connection with such objections. This has been done in regard to water supply and disposal by subareas by adding Appendix T; in regard to the description of the Little Tujunga syncline by adding Plate 5J; in regard to the description of boundaries by adding material to pages 17 and 18; in regard to imported water by adding material on surplus Northern California water on page 95; and in regard to the presentation of information on geologic defenses on pages A-61 through A-65 by changing the form of presentation.

E. Revisions of the Table of Contents to reflect the foregoing changes as well as those necessary to change from "draft report" to "report" have been made.

Investigation by Referee

The Board started its investigation as Referee immediately after entry of the Order of Reference on June 11, 1958 and contacted all parties named in the action regarding the availability of records and data pertinent to the proceeding.

Continuing contact was thereafter maintained with the parties and with Los Angeles County Flood Control District, State Department of Water Resources, State Bureau of Mines, United States Department of Agriculture and other sources, both private and public, through which added material was provided from time to time as deficiencies became apparent in the records and data first made available.

Detailed investigation was made of the area referred to in the Order of Reference as the watershed of the Los Angeles River and its tributaries above the junction of the surface channels of the Los Angeles River and the Arroyo Seco at a point now designated as Los Angeles County Flood Control District Gaging Station No. F-57. This area is referred to in this report as the Upper Los Angeles River area. Investigation was made outside the Upper Los Angeles River area as necessary to provide information required by the Order of Reference concerning the Pueblo of Los Angeles and of other sources of water supply available to the parties.

Investigation of physical facts indicated that records and data prior to 1928 were lacking or incomplete regarding a number of phases of the investigation, and that utilization of a period of analysis or base period for water supply and disposal and safe yield prior to the 1928-29 water year would be difficult and costly to make. This was reported to the Court on November 17, 1958. It was apparent also that any study extending into the period of poor and inadequate records could not be supported when compared to the results of a study over a period of more complete records as were available beginning with the 1928-29 water year. Consideration of these factors and release by the Court from reporting on other than the requirements set forth in Paragraph I of the Order of Reference, resulted in the adoption of a base period of study beginning with the 1928-29 water year and continuing through the 1956-57 water year. However, all readily available data of which the Referee has knowledge for years prior to 1928-29 and after 1956-57 have been compiled and included in the report and accompanying basic data for reference and such use as may be justified.

The Referee utilized material from all readily available published and unpublished reports and other sources to determine the geologic and the hydrologic factors applicable to the area of investigation. Factors thus developed are believed to be appropriate for the particular area under study although they may not be applicable elsewhere unless similar conditions prevail.

The Referee, in using the records, data and information provided as described, reviewed the material and where possible verified its acceptability for the Referee's purposes and made field checks where data permitted.

The need became apparent from time to time during the investigation for added work to establish facts under controversy between engineering representatives of certain of the parties and where uncertainties existed as to the application of available data. Such work included the drilling of 20 test holes by the parties and the Referee to determine the physical characteristics of the southerly boundary of the Sylmar Subarea; a detailed soil survey of the San Fernando cienaga area to determine the historic extent of the moist area associated with the cienaga; pump tests and water analyses, as well as an extended study of existing data relating to water origin in the Eagle Rock Subarea; the observation of new well drillings and continued study of existing wells throughout the period to provide more complete information concerning the specific geologic contentions of the parties; and analyses by different procedures to assure proper recognition of all factors relating to various specific studies.

Nomenclature

The term hydrologic subarea has been used herein to designate certain regions within the area of investigation for which the Referee was instructed to ascertain the location, area, nature, characteristics, limits and hydrologic and geologic interdependence thereof. For this reason the area within the boundary of valley fill (Plate 5) of the Upper Los Angeles River area was divided for study purposes, according to geologic and topographic conditions, into four subareas referred to in the report as the San Fernando, Sylmar, Verdugo and Eagle Rock "Hydrologic Subareas" or simply as "Subareas". These are shown on Plate 5 and further described in Chapter III.

The wells referred to in this report are designated by Los Angeles County Flood Control District numbers which had previously been assigned to wells known to have existed in the area and which were and are presently being utilized by local agencies to index well data. The well number consists of four digits, the first two designating one of a series of 6-minute U.S.G.S. quadrangles beginning at the southwest corner of Los Angeles County, and the last two being rectangular coordinates within the quadrangle with the coordinates beginning in the northwest corner of the quadrangle. The well number is followed by a letter to identify the actual well when more than a single well is located in that subdivision. The first well in a subdivision is usually identified by the number only and designated on the map by a short line drawn from the dot signifying the well location. Locations of all wells referred to in this report, with the guide to the well numbering system, are shown on Plate 18.

Stream flow stations and precipitation stations, referred to in the report and shown on Plate 9, have been designated by the same numbers assigned to them by the Los Angeles County Flood Control District.

The hydrologic "water year", which has generally been used throughout this report, is from October 1 through the following September 30 and is indicated as "1957-58". Whenever the calendar year is referred to for any purpose it is designated in the conventional manner, e.g., "1954". Whenever a period different from those noted above is intended, that period is identified at the place used in the report.

Engineering Advisory Committee

In accordance with recommendations by the Court in the Order of Reference, the engineers of the parties and representatives of the Board have maintained close contact and have met as a group to discuss procedures utilized by the Board's representatives and to review results of computations and of the material to be included in the Board's report to the Court. This group, referred to in the proceeding as the "Engineering

Advisory Committee", held a total of 22 meetings beginning September 23, 1958, spaced at approximately monthly intervals. In addition, conferences were held from time to time with engineering representatives of two or more of the parties on special problems. The information developed as a result of the meetings and conferences aided the staff of the Board materially.

The names of the engineering representatives attending the various meetings were as follows:

City of Los Angeles
- Samuel B. Morris (deceased)
- Milton Anderson
- Harold Conkling (resigned)
- Raymond A. Hill
- John F. Mann, Jr.
- E. C. Marliave
- Richard H. Gilman
- Gerald W. Jones
- Eldridge B. Lowry
- G. Marvin Litz
- Stanley A. Wilfong

City of San Fernando
- R. E. James
- Stuart E. Bergman
- A. L. Sonderegger (resigned)
- Ray Walker

City of Glendale
- Harold E. Butler (retired)
- Max Bookman
- A. W. Jagow
- Charles H. Lee

City of Burbank
- Clarence Shadel
- Max Bookman
- Alan Capon
- Charles H. Lee

Crescenta Valley County Water District
- A. L. Sonderegger (resigned)
- V. B. Tipton

California Materials Company
- Vernon E. Lohr

Consolidated Rock Products Company
Byron P. Weintz

Forest Lawn Company
H. O. Adair
John S. Clough
Luis E. Kemnitzer
R. G. Spencer

Knickerbocker Plastic Company, Inc.
Rudolph W. Chaplar

Livingston Rock and Gravel Company
E. Misenheimer

Lockheed Aircraft Corporation
H. D. Pinkney (deceased)
G. W. Stosskopf

Southern California Edison Company
Leonard Longacre
E. L. Kerry

Southern Pacific Railroad Company
J. G. Sinclair
R. E. Frame
M. J. Stephens

Sparkletts Drinking Water Corporation
R. Bruce Lockwood
G. Austin Schroter
Max Alex
O. R. Angelillo (through 18th meeting)

Technicolor Corporation
T. A. Tarr

Sidney Smith
K. Q. Volk

In addition to the representatives of parties as named, various representatives of interested public agencies attended meetings to supply information and to make suggestions regarding data and material provided through their respective agencies as follows:

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United States Department of Agriculture
Harry F. Blaney

State Department of Water Resources

Jack J. Coe	Robert Y. D. Chun
H. C. Kelly (retired)	Robert Thomas

Organization of Report of Referee

The Report of Referee contains Summary of Findings and nine chapters as follows:

I. Introduction

II. Description of the Upper Los Angeles River Area

III. Geology

IV. Water Supply, Upper Los Angeles River Area

V. Water Utilization and Disposal of Water

VI. Historic Ground Water Recharge

VII. Determination of Safe Yield

VIII. The Use of Water by the City of Los Angeles and Its Inhabitants

These chapters present discussion and summary illustrations of information developed by the Referee in answer to the requirements of the Order of Reference. They are supported by tables and a group of 36 plates containing 52 sheets immediately following the text. Twenty appendixes wherein detailed methods and procedures followed by the Referee are set forth, accompanied by extensive tabulations from which text summaries were prepared, are included in Volume II. Included in the appendixes are copies of relevant Orders of the Court.

The basic data upon which the Board bases its report and findings will be available and filed with the Court in accordance with Paragraph III of the Order of Reference dated June 11, 1958, and will be tabulated as listed in the table of contents of this report.

CHAPTER II. DESCRIPTION OF THE UPPER LOS ANGELES RIVER AREA

A general description of the geographic and hydrologic boundaries, physiography, soils, climate and culture of the Upper Los Angeles River area is presented in this chapter. In addition, the geographic and hydrologic boundaries of all watersheds supplying the Los Angeles River below Los Angeles County Flood Control District Gaging Station No. F-57 and above the southern boundary of the original pueblo are described.

The location of the Upper Los Angeles River area within the State and its relationship to Los Angeles County is delineated on Plate 1. The area, with the exception of small portions of the Simi Hills and the Santa Susana Mountains in Ventura County, is located within Los Angeles County.

Boundaries

The watershed boundary shown on Plate 2 is the boundary of the Upper Los Angeles River area and is based on data shown on the United States Geological Survey topographic maps covering the area. Maps of $7\frac{1}{2}$-minute series, dated from 1951 through 1953, were used wherever available with maps of the 6-minute series, dated from 1933 through 1948, being used for the northeastern portion of the area. A field check was made of locations where more than one interpretation of the topographic maps was possible. The watershed boundary of the area as determined by the referee conforms generally to that depicted on and described in Appendixes "A" and "B" attached to the Plaintiff's Amended Complaint. The description of the watershed boundary of the Upper Los Angeles River area is as follows:

Beginning at the most southerly point of said boundary at a point on the Los Angeles River at Los Angeles County Flood Control District gaging station F-57; thence westerly toward Elysian Hills to a point on Figueroa Street approximately 500 feet westerly of where said street crosses the Los Angeles River; thence northwesterly along the drainage divide of the Elysian Hills to the Santa Monica Mountains at a point on Los Feliz Boulevard approximately 4,000 feet southwesterly of where said boulevard crosses the Los Angeles River; thence northwesterly along the drainage divide of the Santa Monica Mountains to Cahuenga Peak, thence westerly along said divide through San Vicente Mountain, southerly of a number of small stream systems, which drain into the Upper Los Angeles River area, including Caballero and Calabasas Creeks, to an unnamed peak (elevation 1,689), in Sec. 33, T. 1 N., R. 17 W., S.B.B.&M.; thence in a northerly direction along said divide along the westerly watershed boundary of the Arroyo Calabasas stream system to the Simi Hills crossing Ventura Boulevard at a point approximately 8,000 feet westerly of the westerly boundary of the City of Los Angeles, as of October 1, 1958; thence in a northerly direction and following the crest of the Simi Hills through Laskey Mesa, Burro Flats and Chatsworth Peak, along the westerly watershed boundary of the Chatsworth stream system, to the Santa Susana Mountains at Santa Susana Pass and Highway 118; thence in a northerly direction and following said drainage divide to an unnamed peak (elevation 3,670) in Sec. 13, T. 3 N., R. 17 W., S.B.B.&M., thence easterly along said divide, northerly of several small stream systems which drain into the Upper Los Angeles River area, including Browns Canyon and Aliso Canyon; thence passes through Oat Mountain Lookout to the San Gabriel Mountains at U. S. Highway 99, approximately 5,000 feet northwesterly of the western boundary of the City of Los Angeles, as of October 1, 1958; thence easterly along the drainage divide of the San Gabriel Mountains, following the northerly watershed boundary of the Pacoima and Big Tujunga stream systems, passing through Magic Mountain and Mt. Gleason to Pacifico Mountain; thence southeasterly along said divide to an unnamed peak (elevation 6,192) in Sec. 13, T. 3 N., R. 11 W., S.B.B.&M.; thence southerly along said divide to an unnamed peak (elevation 5,410) in Sec. 10, T. 2 N., R. 11 W., S.B.B.&M.; thence westerly along said divide, passing through Barley Flats, Strawberry Peak, southerly of the Big Tujunga stream system to an unnamed peak (elevation 4,306) in Sec. 14, T. 2 N., R. 13 W., S.B.B.&M.; said peak being common to the drainages of Big Tujunga, Verdugo Wash and Arroyo Seco; thence southerly along a drainage divide, easterly of the Hall-Beckley Canyon stream system to the base of the San Gabriel Mountains; thence southerly along the drainage divide, which is approximately 6,000 feet easterly and parallel to Pickens Canyon Channel,

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to the San Rafael Hills; thence southerly along the crest of the San Rafael Hills, passing through Eagle Rock, to the Repetto Hills at the intersection of Colorado Boulevard and Avenue 64; thence in a southwesterly direction along the drainage divide of the Repetto Hills, passing through Mt. Washington to the base of the Repetto Hills at a point approximately 2,000 feet northeasterly of the intersection of Figueroa Street and San Fernando Road; thence southwesterly to the point of beginning.

The hydrologic (ground water) boundary is the areal boundary of the major water-bearing formations within the Upper Los Angeles River area and is delineated as the boundary of valley fill on Plate 5. This boundary is more completely described on pages 43 and 44 of Chapter III. Boundaries of hydrologic subareas within the hydrologic boundary of the area and the criteria used in their determination are described on pages 44, et seq., of Chapter III.

The surface drainage area tributary to the portion of the Los Angeles River below gaging station F-57 and above the southern boundary of the original Pueblo of Los Angeles, along with hydrologic (ground water) boundaries within the area, are shown on Plate 35.

Physiography

The Los Angeles River drainage system comprises a portion of the coastal watershed of Southern California. The general location of the area is shown on Plate 1. The Upper Los Angeles River area is that portion of the drainage system above the junction of Arroyo Seco at the lower end of the Los Angeles River Narrows. Plate 2 shows the important physiographic features associated with the area. Elevations range from a high of 7,124 feet above mean sea level at Pacifico Mountain to a low of 293 feet at Gage F-57.

The San Fernando Valley in general includes the alluvial-filled portion of the Upper Los Angeles River area. The valley is composed primarily of the complex surfaces of coalescing alluvial fans formed by subaerial deposition from the various streams tributary to the Los Angeles River above the Los Angeles Narrows. It is roughly elliptical in shape with a major axis of approximately 23 miles and a minor axis of approximately 12 miles, comprising 123,428 acres of valley floor lands and 205,709 acres of hill and mountain lands for a total of 329,137 acres.

Hill and Mountain Areas

The valley is bounded on the northeast by the San Gabriel Mountains, on the northwest by the Santa Susana Mountains, on the west by the Simi Hills, on the south by the Santa Monica Mountains and on the east by the San Rafael Hills and the Repetto Hills. The Verdugo Mountains, located in the northeast portion of the area, separate the Sunland-La Crescenta area from the main valley.

The San Gabriel Mountains are the highest as well as the largest mountain group in the area. They rise precipitously from the valley floor and contain many steep-sided canyons and to a large degree are composed of nonwater-bearing Basement Complex rocks which have been fractured and faulted. These rocks form a portion of the basement, which with other nonwater-bearing rocks, underlie at various depths the water-bearing formations in the area.

The Santa Susana Mountains lie westerly of the San Gabriel Mountains and are separated from them by an area of low relief in the vicinity of State Highway 99. The Santa Susana Mountains attain a maximum elevation of 3,747 feet within the area. They are composed mainly of sedimentary nonwater-bearing rocks which have been faulted and folded. Petroleum production is obtained within the Santa Susana Mountains primarily from the Aliso Canyon field.

The Simi Hills are separated from the Santa Susana Mountains at the pass crossed by Highway 118. The Simi Hills are a relatively low-lying group with a maximum elevation of 2,314 feet. These hills are composed of essentially sedimentary nonwater-bearing rocks.

The Santa Monica Mountains are separated from the Simi Hills by the area of low relief which is traversed by Highway 101. These mountains separate the San Fernando Valley from the Coastal Plain. The maximum elevation of 1,961 feet lies on the drainage boundary south of Encino Reservoir. The Santa Monica Mountains are composed of nonwater-bearing rocks of sedimentary, igneous and metamorphic types which have been extensively faulted and folded. Rocks of the sedimentary type predominate in the portion of these mountains within the Upper Los Angeles River area. In general these formations dip underneath the adjoining water-bearing series. The eastern end of the Santa Monica Mountains is considered to be the divide at Los Feliz Boulevard in the vicinity of the Los Angeles River Narrows.

The Elysian Hills (maximum elevation 753 feet) form the southerly boundary of the Los Angeles River Narrows. These hills consist of intensely folded nonwater-bearing materials.

The Verdugo Mountains represent a large block of nonwater-bearing Basement Complex rocks which have been isolated from the main portion of the San Gabriel Mountains by faulting. This block has a maximum elevation of 3,126 feet. The San Rafael Hills (maximum elevation 1,888 feet) southeast of Verdugo Mountains and across Verdugo Wash are composed of crystalline materials similar to those of the Verdugo Mountains. A small group of hills southerly of Colorado Boulevard, comprised largely of nonwater-bearing sedimentary rocks, is also considered a part of the San Rafael Hills.

The Repetto Hills are located south of the San Rafael Hills and easterly of the Los Angeles River Narrows. These hills are composed of sedimentary nonwater-bearing materials which have a maximum elevation of about 880 feet.

Features Related to the Valley Floor

In addition to the surrounding hill and mountain formation there are nine prominent physiographic features which are in contact with or related to the valley floor. These are: The Burbank Piedmont Slope, Pacoima Hills, Mission Hills, Northridge Hills, Chatsworth Hills, Woodland Hills, Chalk Hills, Van Nuys Plain and the Sunland-La Crescenta Piedmont Slope.

The Burbank Piedmont Slope is a series of coalescing alluvial fans which have the Verdugo Mountains as their source area. The higher degree of

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weathering on the surface of this feature indicates that it is somewhat older than the deposits of the Van Nuys Plain.

The Pacoima Hills are composed of nonwater-bearing materials and form one of the six hill groups in the valley. These hills probably represent the northwesterly extension of the Verdugo Mountains which has been eroded from the main mountain block by flows in Big Tujunga and Little Tujunga Washes. Exploratory work for Hansen Dam, which connects the Pacoima Hills to the Verdugo Mountains, indicates existence of sandstones at relatively shallow depths along the axis of the dam.

The Mission Hills are low hills which essentially surround Upper and Lower San Fernando Reservoirs. They are composed of water-bearing and nonwater-bearing materials which structurally are on the south flank of the Little Tujunga syncline which has extensively affected the topography of these portions of the valley.

The Northridge Hills constitute a short chain of low-lying hills which owe their existence to movements along the Northridge Hills fault. Tectonic disturbances have formed a complex structural pattern of anticlines and synclines in the nonwater-bearing series which have been of interest to oil companies in recent years. The upper surfaces of the hills are composed of Older alluvium which is underlain by Saugus formation.

The Chatsworth Hills comprise a group of low hills in the vicinity of Chatsworth Reservoir. They are composed essentially of nonwater-bearing Modelo shales and Cretaceous sandstones. These formations are capped in several places with a thin veneer of Older alluvium.

The Woodland and Chalk Hills are located in the southwestern portion of the valley. They are nonwater-bearing and are composed essentially of the diatomaceous shale member of the Modelo formation.

The Van Nuys Plain constitutes the major portion of the recently alluviated valley floor. The surficial deposits vary from relatively impermeable clays in the western part of the valley to permeable sands and gravels in the eastern portion of the valley. The Los Angeles River Narrows area which passes through the topographic constriction between the Elysian Hills on the west and the San Rafael and Repetto Hills to the east is considered to be a feature genetically related to the Van Nuys Plain. Other associated features on the valley floor are the incised channels of several streams, the major ones being Tujunga and Pacoima Washes and the Los Angeles River.

The Sunland-La Crescenta Piedmont Slope is a series of coalescing alluvial fans which have had their source areas in the San Gabriel Mountains. The fans are composed of coarse detritus with some boulders reaching a size of four feet in diameter.

Surface Drainage System

The Los Angeles River stream system is the surface drainage medium of the Upper Los Angeles River area. The main stream extends along the southerly side of the valley floor in a southeasterly direction through the Los Angeles Narrows and out of the area. The major drainage network is composed of the main stream and its principal tributaries draining Big Tujunga, Little Tujunga, Pacoima, Aliso, Browns,

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Bull and Arroyo Calabasas Canyons. Historic changes in the drainage system are discussed in Chapter IV.

Soils

Soils are related to the water supply insofar as they, in combination with other factors, influence the rate of recharge to the ground water. This is particularly true of the soils on the valley fill. However, it is not feasible nor is it required for the purposes of the investigation to make a quantitative evaluation of the infiltration capacities of the various soils known to exist in the area. Therefore, only the relative infiltration characteristics of the valley soils have been evaluated.

In general, the soils in the valley fill areas can be grouped with respect to relative infiltration capacities in a manner utilized by Musgrave (Water, the Yearbook of Agriculture, 1955, U.S.D.A.), which takes into account the depth of soil, relative drainage, ability to retain moisture and the degree of permeability based on grain size. The U. S. Department of Agriculture Soil Surveys of 1917 and 1919 give a detailed description of all soils found in the Upper Los Angeles River area. These soils have been classified into High, Medium and Low infiltration groups on the basis of Musgrave's criteria. Individual soils contained in each group are shown in Appendix B and areal extent of each of the three soil groups is shown on Plate 3.

In general the soils present in the Upper Los Angeles River area consist of three types. First is the residual type soils including the Holland, Altamont, Sites and Diablo soil series occupying the hill and mountain areas which are derived in place by the weathering of granitic or sedimentary rocks. Secondly is the Ramona series, which in contrast, are old valley fill soils derived from ancient weathered, fluvial deposits. The third type consists of the recent alluvial soils including the Hanford, Tujunga, Yolo and Dublin soil series.

Climate

The Upper Los Angeles River area has the climate of an interior coastal valley and is hotter in the summer and wetter in the winter than the coastal area which has a Mediterranean type climate. The range of temperature and occurrence of fog and frost vary within the valley with the west and north sections being subject to the highest temperatures.

The variations of temperature and frost conditions within the area is sufficient to have influenced the location of citrus orchards. The northern edge of the valley along the base of the mountains where most of the groves are located, is higher, warmer and more frost free than areas of lower elevation in the westerly portion.

The central portion of the valley is at times swept by hot, dry and strong winds of short duration.

Culture

The San Fernando Valley, prior to the importation of water from Owens River by the City of Los Angeles, was mainly an area of large holdings devoted to dry farming. The importation of water in 1915 brought about a shift to irrigated agriculture and subdivision of the large holdings into smaller farm and home acreages. The cities of Burbank, Glendale and San Fernando were incorporated prior to 1915. During 1915 the City of Los Angeles annexed large areas in the San Fernando Valley which resulted in the greater portion of the valley fill and lower hill area being included in incorporated areas.

Urbanization of the area has been a continuous process except for the depression period from 1932 to 1938. Growth was further accelerated after the end of World War II by the general trend toward suburban living and more recently by the development of new industries in the central and west portions of the valley.

Continuing growth is evidenced by the filing during 1959 of tentative subdivision maps for 8,100 lots on 5,500 acres of land within the portion of the City of Los Angeles located west and north of Burbank. The same area had 29,000 building permits, totaling $300 million in valuation, issued during 1959.

CHAPTER III. GEOLOGY

This chapter is an evaluation of geologic features and conditions insofar as they affect the occurrence and movement of ground water and the surface and ground water hydrology of the Upper Los Angeles River area and any subdivisions which may exist and the interconnection or interdependence thereof. It is designed to satisfy in part, paragraphs I. 1, I. 2A, I. 2C, I. 2D, and I, 2G, of the Order of Reference. Items such as water-bearing and nonwater-bearing rocks, faults and folds which affect the water-bearing materials, and the configuration of the valley fill and its characteristics are discussed. The various hydrologic subareas and their interrelation are described.

Areal Geology

A map of the areal geology compiled from published sources and supplemented by unpublished Masters and Doctors theses from the graduate schools of the colleges and universities in Southern California and through investigation by the Referee, is presented on Plate 4. This map, entitled "Areal Geology", presents the general geologic framework necessary for the study of ground water and its movement within the Upper Los Angeles River area. Plate 4 also shows the relative ages and briefly describes the various lithologic units found within the area. The plate also shows the relationship of mountain areas which are for the most part composed of nonwater-bearing materials, and the valley fill which comprises most of the water-bearing material.

The approximate depths of the nonwater-bearing materials below the valley floor are indicated on Plate 6, entitled "Contours on Base of Valley Fill". The geologic cross sections on Plates 5A through 5H have been plotted to aid the understanding of the relationship between the water-bearing and nonwater-bearing formations. The location of the various cross sections is shown on Plate 5.

Previous Investigations

The many bulletins and papers published on the geology of various portions of the Upper Los Angeles River area have been related primarily to the rocks which surround the valley fill area of the basin. State Division of Water Resources Bulletin 45 (1934) reports on the only investigation which has studied the water-bearing properties of alluvial materials. This bulletin has been studied in detail and information therein pertaining to geology, specific yield and ground water storage capacity, modified in the light of additional and more recent data, has been incorporated into this report.

Present Investigation

The present geological investigation has been limited to the determination of the hydrologic units or subareas existing in the Upper Los Angeles River area and to studying the nature and distribution of alluvial materials which would be considered a source of ground water. Numerous wells and test holes were inspected and logged during the course of the investigation. Many cuts, trenches and gravel pits were studied to become familiar with the composition of the sediments in the various portions of the basin and to aid in the interpretation of well logs. Geologic mapping was mainly confined to the alluviated areas with special attention being given to the contacts between the water-bearing and nonwater-bearing units.

Detailed descriptions of the items covered in this chapter, as well as a discussion of field investigations made during the investigation, are contained in Appendix A.

Geologic Formations

The ages of geologic rock units and formations of the Upper Los Angeles River area represent a long span of geologic time. Rock units of the Basement Complex have been assigned an age of Pre-Cambrian, whereas other units within the Basement Complex represent various periods through the upper Jurassic or Lower Cretaceous. The sedimentary formations present in the area of investigation are represented by the Cretaceous Chico, lower Eocene Martinez, middle Eocene Domengine, middle Miocene Topanga, upper Miocene Modelo, lower Pliocene Repetto, upper Pliocene Pico and lower Pleistocene Saugus formations. Upper Pleistocene, Older alluvium and Recent alluvium are unconsolidated deposits which are of special interest in this study. The location of the different formations with geologic legend is shown on Plate 4.

Nonwater-Bearing Series

The nonwater-bearing series are rocks which do not absorb, transmit or yield water readily; however, they may contain a limited amount of water in fractures. The nonwater-bearing series comprise the following

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lithologic units: Basement Complex granitic and metamorphic rock types; Chico sandstone and some conglomerates; Martinez shales and sandstones; Domengine sandstone and conglomerate; Topanga conglomerate sandstone with interbedded volcanics, Modelo shale, sandstone and conglomerage; Repetto siltstone, sandstone and conglomerate; and Pico shale and siltstone.

The Basement Complex yields small flows (20-30 gpm) of good quality water from tunnels, while water wells drilled into the Chico, Topanga and Modelo formations have very poor yields of generally poor quality water. The Martinez and Domengine formations are of limited areal extent and therefore of minor importance as possible sources of water.

Water-Bearing Series

The water-bearing series consist of rock units which absorb, transmit and yield water to wells readily. The Saugus formation (including Sunshine Ranch formation), Older alluvium (including Pacoima formation) and Recent alluvium comprise this group.

Alluviation. Sedimentary deposits may originate from one of three environments: marine, transitional or continental. The water-bearing deposits of the Upper Los Angeles River area are classified as primarily continental. They may be further subdivided as alluvial stream deposits.

In late Pleistocene and Recent time, when most of the water-bearing deposits were being laid down, the valley area was above sea level and was lowering with respect to the continued rising of the San Gabriel Mountain block. As the block rose, increased stream gradients resulted and heavier loads of debris were transported down the mountain block face. Upon reaching the gentler piedmont slope at the mountain front, gradients and velocities were sharply decreased with a resultant lessening of load carrying capacity and deposition of the transported load commenced along the mountain front.

Materials were deposited by the individual streams as large and small alluvial fans. The coarser debris was normally deposited near the conal apices while the finer materials were carried farther out toward the distal portions of the cones. During wet and dry years or cycles when stream carrying power varied considerably, coarse deposits might be deposited over fines or vice versa, resulting in fine materials near the apices in dry periods and coarse material in the distal portions in wet periods.

Changes in stream position on the developing conal surfaces caused centers or axes of deposition to shift from time to time. Overlapping and interfingering of the conal deposits both laterally and axially occurred. Frequent incision of the developing conal surfaces by the streams resulted in reworking and redeposition of some of the original conal material during the alluviation process. Crude stratification exists locally, though in general the deposits are lenticular in shape with the long axis roughly parallel to the main stream course.

During and after deposition, alternate wetting and drying of buried material due to a fluctuating water table and other normal weathering

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processes allowed accelerated weathering with a resultant development of more clay in the coarser deposits than might be normally expected. Weathering continues to occur at the surface and at depth, slowly increasing the clay content of these materials. The increase in clay content has the effect of reducing the specific yield and general permeability. The latter two items have been further reduced as a result of consolidation by load.

The most recent streams (present day) have incised their channels in the older conal deposits, which have coalesced near the mountain front. The most permeable deposits are now found in these channels. These channel deposits are the best means of percolating stream flow to the underground and transmitting underflow through the area.

Saugus Formation. The Saugus formation crops out in the hills and southern slopes of the mountains along the northern part of the valley floor and underlies the other members of the water-bearing series. The maximum thickness of this unit as measured in Lopez Canyon is 6,400 feet. From here the formation thins rapidly in an easterly direction to 2,000 feet thick two miles east of little Tujunga Canyon and in a westerly direction to 3,000 feet of thickness at San Fernando Reservoir. There are no outcrops of the Saugus formation in the Simi Hills, Santa Monica Mountains or Verdugo Mountains, indicating that this formation probably underlies only the northern portion of the valley floor. Only those portions of the Saugus formation which are overlain by Older and Recent alluvium and are below the water table are considered herein to be part of the ground water reservoir. The Saugus formation has been included in the water-bearing materials comprising the ground water reservoir within the Sylmar Hydrologic Subarea and in the northern portion of the San Fernando Hydrologic Subarea. Those portions of the exposed Saugus formation located in the hill and mountain area to the east and west of the Sylmar Hydrologic Subarea have in general been considered as part of the nonwater-bearing series because the change in storage and extractions from those areas were negligible and the areas of recharge are of limited extent.

The Saugus formation is composed of uncemented continental and marine deposits of conglomerates, sands, silts and clays. Some of these materials make good aquifers under saturated conditions whereas others are aquicludes. The materials of the Saugus formation have been derived from the Basement Complex in the eastern part of its exposures and from Tertiary sedimentary formations in the area adjacent to the Santa Susana Mountains. There is a marked difference within the formational materials derived from the different source areas in terms of porosity and permeability, with those deposits having their source areas in the San Gabriel Mountains being the most permeable.

Older Alluvium. The Older alluvium is composed of generally coarse-grained unconsolidated or uncemented deposits of modern streams laid down in earlier cycles of erosion. The source areas of the streams during earlier and present stages of erosion have undergone little change. With the exception of remnants (terrace deposits) which have been isolated by erosion around the margin of the valley floor, deposition has been nearly continuous to the present time.

The materials that comprise Older alluvium consist of red-brown to gray, dirty, unsorted, angular to subangular debris which is of local origin. During the numerous intervals of time between periods of deposition weathering played an important role in forming horizons which represent ancient soils.

The water-bearing properties of these materials are variable, depending upon the source areas; however, the permeabilities are generally greater than that of the Saugus formation due primarily to the fact that the Older alluvium is less compacted and less consolidated and also generally contains less residual clay.

Recent Alluvium. Recent deposits east of Pacoima Wash and north of the Los Angeles River consist of predominantly coarse accumulations of boulders, gravels and sands in the form of coalescing alluvial fans derived primarily from Basement Complex sources. The median particle diameter of the fan deposits decreases as the distance increases from the canyon mouths. Westerly of Pacoima Wash and south of the Los Angeles River the sediments are derived primarily from sedimentary rocks and are finer grained and deposited in much the same manner as the underlying Older alluvium. Well logs from the western portion of the valley floor indicate an average of about 75 percent clay, 5 percent sand and 20 percent gravel, whereas the materials underlying the eastern portion of the area average 20 percent clay, 35 percent sand and 45 percent gravel.

Structural Features

The geologic structure of the Upper Los Angeles River area is very complex. Extensive faulting and folding of the rocks that surround the ground water reservoir indicate that the rocks beneath the valley fill materials are also faulted and folded. The major faults and folds which affect the movement of ground water within the valley fill are discussed below.

Faulting

Faulting in the area of investigation is dominated by the San Gabriel fault system. Faults of the Sierra Madre system are important features in the Santa Susana and San Gabriel Mountains; however, only those faults which may affect the movement of ground water are described in this report. The Verdugo, Eagle Rock and Raymond fault zones have an effect on the movement of ground water in certain locations. The Northridge Hills fault or folds are believed to have an effect on ground water movement, but data to evaluate this effect are lacking. The locations of the faults are shown on Plate 4. Detailed discussions of the faults and fault zones are contained in Appendix A.

Verdugo Fault Zone. The water levels southerly of the City of Glendale's submerged dam suggest a gradient steeper than would normally be expected. The Verdugo well 3963A, and well 3954 which is about 7,000 feet southerly of the Verdugo well, show a difference in water levels of approximately 300 feet. Measurements at well 3963 (destroyed in 1944) indicate a water level above a hydraulic grade line connecting the two aforementioned wells. Depth to bedrock is 54 feet in the Verdugo well (3963A), more than 535 feet at well 3954, and unknown at well 3963, although this well is reported to be 100 feet deep. Water levels given in Water Supply Paper 219 (1908) for Verdugo Canyon indicate a similar condition existed at that time. On the basis of the foregoing information, a ground water cascade controlled by offsets in bedrock along the Verdugo fault zone has been postulated as the reason for the anomalous water level condition (Plates 4 and 5G).

Movements on this fault system during the Quaternary period have had some effect on the aquifers by the formation of clayey gouge seams in the sands and gravels which extend between the Verdugo Mountains and Pacoima Hills. The effect of the faulting has been to create a zone of lower permeability which causes a distinct break in the ground water surface when the Hansen spreading grounds are in operation. When the spreading grounds are not in operation the difference in ground water elevations on either side of the fault are of a much smaller magnitude.

<u>Eagle Rock Fault</u>. Presence of the aforementioned step-like ground water cascade at the mouth of Verdugo Canyon may have been caused by a northwesterly extension of the Eagle Rock fault to the Verdugo fault. Although no surface alluvium appears to have been displaced by the Eagle Rock fault in this vicinity, the general structural pattern suggests that the Eagle Rock fault may be related to the Verdugo fault system (Plates 4, 5G and 5H). There has been some conjecture by previous workers that this fault may extend westerly under the valley fill

passing near the junction of the Los Angeles River and Verdugo Wash. Such an inferred extension would explain the abrupt rise in the nonwater-bearing rocks which underlie the water-bearing series where the Los Angeles River turns southerly into the Los Angeles River Narrows. This feature is shown on Section M-M' on Plate 5E. A scissors-type movement on the Eagle Rock fault would be necessary to explain the relationship of the blocks on either side of the fault. More detailed geologic information is needed before the relationship can be established between the Eagle Rock fault and the fault in the nonwater-bearing series that underlies the alluvium near the south side of the Los Angeles River immediately upstream from its confluence with the Verdugo Wash.

Raymond Fault. The surface of the Older alluvium which overlies the trace of the Raymond fault (Plate 4) has not been disturbed by movement on this fault within the area of investigation; however, movement along this fault zone prior to the deposition of the uppermost strata of the Older alluvium has faulted the water-bearing sediments against the nonwater-bearing rocks of the Puente formation (Plate 5H) and thus forming a barrier to the movement of ground water from the Eagle Rock Subarea. The movement necessary to bring about this condition is contrary to the general direction of movement on the fault to the east of the area of investigation.

Older movements on this fault have also affected the configuration of the base of the valley fill in the central part of the Los Angeles River Narrows. A small knob of nonwater-bearing rocks (Plate 6) is present north of the fault and a depressed area lies immediately south of the fault. The knob has created a constriction in the water-bearing materials and

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probably is the cause of the rising water that has been reported in the past near Los Feliz Boulevard.

Smaller Unnamed Faults. In the Sunland area, which is adjacent to Big Tujunga Wash, there is an offset in the nonwater-bearing formations below the valley fill amounting to about 30 feet (Plate 5F). The location of this offset is in well grid coordinates 4983 (Plate 6). This feature may be due to faulting which is evident in the hills to the northeast and southwest of this feature. This feature has also caused a ground water cascade of similar magnitude in the water-bearing materials.

In the western portion of the San Fernando Subarea, there are several faults which may or may not have an effect on the movement of ground water in the vicinity of Devonshire Street and Topanga Canyon Boulevard (Plate 4). The most prominent of these faults extends northeasterly beneath the valley fill. This fault has displaced the nonwater-bearing materials forming a ground water cascade on the order of 80 feet in height. The area is underlain at shallow depths by Cretaceous sandstones northwest of the fault and by the Modelo shale at greater depths south of the fault. There is a small northwesterly-bearing fault inferred in the water-bearing series paralleling the Northridge Hills fault to the northeast and extending into the nonwater-bearing Cretaceous sandstones to the northwest. The existence of such a feature is substantiated by the difference in ground water levels in this area.

Faults have affected the movement of ground water within the Upper Los Angeles River area by formation of ground water cascades as a result of offsetting nonwater-bearing series; by forming relatively impervious gouge along fault planes during movement; by folding strata so that their position is unfavorable for the percolation of water through them; and by the tilting associated with fault movement which has caused a reduced cross-sectional area for underflow.

Folding

The dominant fold structures affecting the storage and flow of ground water in the San Fernando Valley are located in the northern portion of the valley and delineated on Plate 4. Other folds have little or no effect on the ground water and no extensive study was made of them.

The Little Tujunga syncline (Plate 5J), located between the Verdugo Mountains and the San Gabriel fault, is one of the principal structural features along the north edge of the valley. The effects of this feature on the movement of ground water are of interest in the Sylmar Hydrologic Subarea and are discussed under the description of that subarea. The axis of this fold closely parallels the trace of the Sierra Madre fault zone, following it with a west northwest trend in the area from Tujunga to the Veterans Hospital at Pacoima Canyon, where it may have been overridden by the crystalline rocks along the Hospital fault. Continuing westward, the axis changes to a southwest trend paralleling the northeastern end of the Santa Susana fault. The dip of formations along the south limb ranges from 25 to 80 degrees; the north limb is very steep to overturned and has minor folds

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superimposed on it. Saugus beds are overturned in several places along the Lopez fault, particularly in upper Lopez Canyon (see Plate 5J). Overturning of the Saugus formation also occurs along the Sunland fault where the north limb of the syncline has been almost completely cut out by the fault.

The anticlines and synclines associated with the Northridge Hills fault undoubtedly affect the movement of ground water; however, the extent of the effect is unknown due to an absence of wells. A small anticline is located in the southeast portion of the Mission Hills. This fold may be related to movement on the inferred Mission Hills thrust fault and as a result may not extend under the alluvium easterly of the hills.

Configuration of the Base of the Valley Fill

The configuration of the base of the valley fill is shown by the generalized contours on Plate 6 and by means of geologic cross sections which are indexed on Plate 5. The base of the valley fill was determined by plotting the elevation of the nonwater-bearing materials indicated by various well logs throughout the area of investigation.

The contours on the base of the valley fill (Plate 6) in the western portion of the San Fernando Subarea (Plate 5 and pages 46 to 50) in the vicinity of Arroyo Calabasas and southerly of Bell Creek indicate the existence of an old drainage system. This ancient drainage appears to have flowed northerly, east of Aliso Canyon Wash into the deep portion of the basin which is traversed by the Southern Pacific Railroad (S.P.R.R.).

The depth of water-bearing material is unknown in the central and eastern portion of the subarea, but probably extends to depths of 1,000 to 1,500 feet. An anomalous dome-like feature is present in the vicinity of Lankershim Boulevard and Vanowen Street. The cause of this feature and its relationship to the geology of the area are unknown.

In the vicinity of the confluence of Verdugo Wash and the Los Angeles River, the depth to nonwater-bearing material rapidly decreases as the Los Angeles River enters the Los Angeles River Narrows. The reason for this rapid change in the bedrock profile is not known; however, it has been postulated that this feature is caused by a westerly extension of the Eagle Rock fault or an unnamed fault, the scarp of which was modified by erosion prior to burial. This feature is located in well grid coordinates 3914 and 3924 on Plate 6.

The Elysian Hills anticline, which is located on the southerly side of the Los Angeles River Narrows, is of interest in that continued movement on this feature after the mid-Pleistocene orogeny may have caused the "reversed gradient" on the base of the water-bearing series in the Los Angeles Narrows area. This "reversed gradient" feature shown in profile on Section M-M', Plate 5E, indicates that the base of the water-bearing materials is lower in elevation near Colorado Boulevard than at Figueroa Street or Gage F-57. This is also shown by contours on the base of valley fill on Plate 6. Another possible explanation of this feature is that the Arroyo Seco flowed northerly into the San Fernando Subarea for a period of time in the mid-Pleistocene, as postulated by Homer Hamlin in United States Geological Survey Water Supply and Irrigation Paper 112 (1905).

The Sylmar Hydrologic Subarea (Plate 5 and pages 51 to 55) is almost entirely underlain by the folded Saugus formation which extends to great depths. Immediately below the Saugus formation is the nonwater-bearing Repetto formation which is exposed in both banks of Pacoima Wash at the Pacoima submerged dam, located in the vicinity of well 5989A. These outcroppings and their westerly extension constitute the eastern portion of the southern boundary of the subarea. In the Mission Hills and possibly in the adjacent portion of the Sylmar Hydrologic Subarea, the Saugus formation is underlain directly by the Pico formation. The Repetto formation dips approximately 70 degrees to the north and drops rapidly in elevation under the water-bearing materials.

Contours of the base of the valley fill (Plate 6) in the Verdugo Hydrologic Subarea (Plate 5 and pages 55 to 58) show several interesting features. The most important of these is the existence in the Basement Complex of the buried erosion channel of an ancestral Pickens Wash draining easterly into the Monk Hill Basin (Plate 35). Under low water table conditions this buried channel carries all tributary percolating water to the Monk Hill Basin. Under high water table conditions the southwesterly bedrock ridge, which is the westerly bank of the buried erosion channel, has been overtopped and it is therefore believed that percolation in a westerly direction has occurred.

A second important feature is the depression in the buried bedrock surface in the vicinity of well 5058J. The bedrock elevation in this depression is some 80 feet lower than the lowest bedrock surface in the mouth of Verdugo Canyon. This depression may be due to displacement on the La Crescenta Valley fault. Maximum depth of water-bearing materials is about 54 feet at Verdugo well (3963) adjacent to the Verdugo submerged dam, while upstream approximately 1-1/2 miles the depth of fill material has increased to a maximum of 190 feet.

The configuration of the base of the valley fill in the Eagle Rock Hydrologic Subarea (Plate 5 and pages 58 to 61) is not shown in detail on Plate 6 due to the small area involved and to the 100-foot contour interval which was utilized on the plate. A more graphic representation of the valley fill in the subarea is shown on Geologic Cross Section S-S' on Plate 5H. This section shows the deepest portion of the fill in this subarea to be located in the vicinity of the Raymond fault. The configuration of the base of the valley fill along Colorado Boulevard in the subarea is not known; however, the depth to bedrock at a well located just northwest of the intersection of Colorado Boulevard and Eagle Rock Boulevard was stated as 140 feet (well No. 333, U.S.G.S. Water Supply Paper 219 field notes). The depth to the nonwater-bearing Topanga formation near the Raymond fault is about 200 feet.

Description of Hydrologic Subareas

The valley fill area of the Upper Los Angeles River area comprises with a few minor exceptions, the areal extent of all Recent alluvium and Older alluvium known to have been saturated or to overlie water-bearing materials. Isolated areas of Saugus and Recent alluvium in

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upper Little and Big Tujunga Canyons, as shown on Plate 4, have been excluded from the valley fill area because of lack of information on water-bearing properties, minor extractions and isolation from the main ground water body. The valley fill boundary was mapped on $7\frac{1}{2}$-minute U.S.G.S. quadrangles from field observations and other available information concerning extent and thickness of water-bearing materials. This boundary was generalized across the mouths of minor canyons to exclude thin tongues of alluvium which would not contain any appreciable amounts of ground water in storage. The valley fill boundary so determined is delineated on Plate 5.

Both the Basement Complex pre-Quaternary sediments and volcanics, which are known to underlie the valley fill area, are deep-seated and relatively impervious and any contribution by ground water movement from them must therefore be small. This investigation has not revealed evidence of any appreciable subsurface inflow from these rocks although records of extractions from wells in these rocks indicate the existence of small amounts of water therein. Water elevations in wells and water inflows encountered in tunnels attest to the fact that where water surfaces exist in these materials they are at elevations substantially higher than the water levels in the valley fill areas. The yield from these rock formations is apparently limited because of the very small specific capacity of wells in these materials, ranging from 0.036 to 0.38 gallons per minute per foot of drawdown as compared to a range in specific capacity for wells located within the valley fill of from three to more than 264 gallons per minute per foot of drawdown.

The aforementioned valley fill area of the Upper Los Angeles River area, exclusive of the portion of the Monk Hill Basin located therein, has been divided into four hydrologic subareas: San Fernando, Sylmar, Verdugo and Eagle Rock, containing 112,047, 5,565, 4,400 and 807 acres respectively. The total valley fill area, including the 609 acres in the Monk Hill Basin portion, is 123,428 acres. Each of these subareas has been defined on the basis of the existence of an apparent impairment of ground water flow from one to the other, caused by man-made works and physiographic or geologic features. The boundaries of the various subareas are shown on Plate 5.

The source of ground water supply in the Upper Los Angeles River area is percolation of rainfall, surface runoff from adjacent valley areas, and hill and mountain areas, spread waters, imported waters, and possibly some underground percolation of water from the mountain masses to the alluvium. Supply from this latter possible source is believed to be minor for the reasons heretofore stated and is not feasible to evaluate. Disposal of the supply, other than by export, evaporation from reservoirs, consumptive use and surface runoff, is by underflow out of the area at the Los Angeles Narrows and in the Pickens Canyon area. These amounts are relatively small and amount to an average of 340 and 300 acre-feet per year at the Los Angeles Narrows and from the Pickens Canyon areas, respectively. Determinations of these amounts are discussed in detail in Appendix P and annual values tabulated in Chapter V.

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San Fernando Hydrologic Subarea

The boundaries of the San Fernando Hydrologic Subarea, as shown on Plate 5, are the alluvial contacts with the nonwater-bearing series along the San Rafael Hills and Verdugo Mountains on the east and northeast, the Santa Susana Mountains and Simi Hills on the northwest and west, and the Santa Monica Mountains on the south. The Los Angeles River Narrows area, also part of the San Fernando Hydrologic Subarea, is bounded on the east by the alluvial contact with the San Rafael and Repetto Hills and on the west by this contact with the Elysian Hills. The southern boundary of this subarea has been established at Los Angeles County Flood Control District gaging station F-57, which is about 300 feet upstream from the Figueroa Place (Dayton Street) bridge. The San Fernando Subarea is separated from the Sylmar Subarea to the north by the eroded south limb of the Little Tujunga syncline which causes a break in the water surface of about 40 to 50 feet. This latter boundary is discussed in detail under the Sylmar Hydrologic Subarea.

The portion of the San Fernando Hydrologic Subarea westerly of Pacoima Wash is generally composed of valley fill materials that have a high clay content, whereas the portion that lies easterly of Pacoima Wash is generally composed of coarse deposits of sand and gravel. The valley fill westerly of Pacoima Wash is essentially fine-grained material derived from the surrounding sedimentary rocks. This material transmits water at a relatively slow rate, whereas easterly of Pacoima Wash the material is composed of coarse detritus eroded mainly from the granitic Basement Complex of the San Gabriel Mountains and transmits water at a relatively rapid rate. The eroded debris of the eastern portion is generally very coarse; in places boulders up to three feet in diameter are relatively common. The deposits are essentially sand and gravel with some fines in the interstices. These materials constitute about one-third of the surface area of the ground water reservoir and contain approximately two-thirds of the ground water storage capacity of the San Fernando Hydrologic Subarea. Transition from the fine-grained materials in the western portion to the coarse-grained materials in the eastern portion is depicted on Section M-M' on Plate 5E.

An area of high ground water level is present in the western portion of the hydrologic subarea. The area is bounded on the east by Reseda Boulevard, on the south by the Los Angeles River and to the west by De Soto Avenue. The northern boundary is somewhat L-shaped following Saticoy Street to the vicinity of Tampa Avenue then northerly to Parthenia Street. This area was studied by the United States Department of Agriculture Soil Conservation Service, Research, during the period 1947 through 1950 and is further discussed in Appendix L.

The aforementioned investigation pointed out the following: water level fluctuations in the piezometers installed by the Soil Conservation Service are cyclic with precipitation; these water levels also respond to irrigation water applied in excess of the consumptive use; and deep artesian and/or pressure wells within the area apparently leak into the shallow zone to the extent that small ground water mounds are developed around certain wells. The source of the confined water derived through these wells appears to be from aquifers in the older materials which presumably underlie the alluvium at relatively shallow depths and are recharged by precipitation.

Because of the existence of more permeable gravel stringers in the fine-grained deposits found in the western portion of the subarea, small localized pressure effects can be observed. These gravel stringers represent the former stream channels which have braided over the fine-grained deposits and in turn have been buried by additional fine-grained material.

The eastern portion of the San Fernando Subarea is composed of very permeable deposits. It is in this area that the majority of the large pumping plants are located. In addition to the pumping plants of the City of Los Angeles, shown on Plate 21, the Cities of Burbank and Glendale also extract large quantities of water from this portion of the subarea. The pumping patterns existing in 1930-31 and 1957-58 are shown on Plates 31A and 31B, respectively. This heavy concentration of pumping is reflected by the large depression in ground water levels occurring in the area during the period 1944 to 1958, as indicated on Plate 33.

The water-bearing deposits of the Los Angeles River Narrows are very permeable. The City of Los Angeles has two pumping plants in the area. Due to heavy pumping, large depressions or pumping holes have been created in the ground water surface. The largest of these pumping depressions is located at the bend in the Los Angeles River where the river begins its southerly course through the Narrows. This well field, called the Crystal

Springs well field, along with the City of Glendale's Grandview wells immediately north of the City of Los Angeles' Crystal Springs well field, have created the ground water depression indicated by the ground water contours shown on Plate 30. The heavy pumping of the Pollock well field of the City of Los Angeles has caused a second such depression to develop during 1959 and 1960 and has caused a reversal of the ground water gradient in the Los Angeles Narrows.

Rising water which has occurred historically in reaches of the Los Angeles River along the south side of the valley is due in part to the reduction in the cross-sectional area of the water-bearing material as the stream approaches the F-57 gage. The maximum depth of water-bearing materials at Huron Street (Gage F-57) is about 110 feet, whereas the maximum depth at the Pollock well field is 260 feet. A comparison of the two areas is shown by sections K-K' and L-L' on Plate 5D.

Ground water moves in the direction of the hydraulic gradient or slope of the ground water surface from areas of recharge to points of discharge. General direction of ground water flow is from the recharge areas in the alluvial cones along the edges of the valley fill toward the discharge area in the Los Angeles River Narrows.

Pumping large quantities of water for municipal uses has greatly modified the predevelopment condition in the eastern portion of the San Fernando Subarea with respect to the depths to water, hydraulic gradients and local direction of ground water movement.

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Ground water elevation contours for the fall of 1931, 1938, 1944 and 1958 are shown on Plates 27, 28, 29 and 30, respectively. These contours were based upon the water level measurement data which were collected from the various parties and the Los Angeles County Flood Control District. The depths to water at the wells have been converted to elevation above sea level (U.S.G.S. datum) by subtracting them from the surface elevation or reference point elevation obtained by direct surveying methods or by interpolation between contours on U.S.G.S. 7½-minute quadrangles. The ground water contours are solid where a satisfactory degree of control and accuracy exists and dashed where there is a paucity of information. The notations "area of no control" and "area of poor control" are in valley fill areas where there are insufficient measurements or lack of well information from which to draw satisfactory contours.

The subsurface outflow from the San Fernando Subarea averaged about 340 acre-feet per year during the 29-year base period. A detailed discussion of this item is contained in Chapter V and Appendix P.

Water level fluctuations in the subarea are depicted by the hydrographs of wells considered generally representative and are shown on Plates 34A and 34B.

Sylmar Hydrologic Subarea

The Sylmar Hydrologic Subarea comprises the area enclosed by the boundary of valley fill contacting the San Gabriel Mountains on the north, the Mission Hills on the southwest, the Upper Lopez Canyon Saugus formation on the east along the east bank of Pacoima Wash, and the eroded south limb of the Little Tujunga syncline on the south. The boundary of this subarea is delineated on Plate 5. The topographic divide in the valley fill lying between the Mission Hills and San Gabriel Mountains has been utilized as the subarea boundary because of lack of data with which to determine the ground water divide. Although the eastern boundary has been taken as the east bank of Pacoima Wash, it is possible that movement of ground water in a westerly direction can occur in the Saugus formation from the Upper Lopez Canyon and Upper Kagel Canyon area which lies immediately to the east of Pacoima Wash. Available data are insufficient to evaluate this possible movement; however, if such movement does occur it is believed to be minor in amount because of the small tributary drainages and rain consumption of native cover. The southern boundary of the subarea is taken along the contact between the Saugus formation and underlying Repetto formation in the vicinity of Pacoima Wash, thence westerly to the intersection of Foothill Boulevard and Fernmont Street, thence in a southwesterly direction following the break in the ground water surface, as defined by the test drilling performed during the course of the investigation. This boundary intersects the Mission Hills immediately southeast of the Mission well field.

The geology of the Sylmar Subarea is greatly complicated by faulting and folding. The nonwater-bearing materials to the north of the subarea have been faulted and in part thrust southerly over portions of the water-bearing Saugus formation. The compressive forces that are related to the thrust faulting are also related to the formation of the Little Tujunga syncline, (See Plate 5J for Block Diagram) which is the most important feature of the subarea. At least 6,000 feet of Saugus formation and an even greater thickness of older nonwater-bearing sediments have been folded into an asymmetric syncline with the north limb overturned. This syncline has been truncated by erosion and covered by a relatively thin blanket of Older and Recent alluvium. The southeastern boundary of the subarea, as hereinbefore noted, is formed by the steep northerly dipping beds of the nonwater-bearing Repetto and Pico formations that are part of the same synclinal structure. The Repetto formation is exposed in both banks of the Pacoima Wash at the topographic constriction, which is the site of the Pacoima submerged dam located about 2.5 miles south of Pacoima Dam. These strata continue westerly under the cover of the Older alluvium and are exposed in roadcuts near the intersections of Gladstone Avenue and Maclay Avenue and Foothill Boulevard and Fernmont Street (see Figure A-1 for street locations).

The valley fill material in the gap between outcrops of nonwater-bearing materials extending from Foothill Boulevard to Mission Hills contains a very marked discordance in water levels. In order to more accurately locate the break in the water surface and the eroded south limb of the Little Tujunga syncline, 20 bucket auger holes were drilled. Nine of the twenty holes were drilled under the direction of and at the expense of the City of San Fernando, five by the City of Los Angeles, and the remaining six by the Referee. Representatives of the Referee were present at the drilling of all holes and prepared detailed logs of each boring. The locations of the test holes are shown on Figure A-1 of Appendix A, and relative locations of the formations are shown on Section H-H' (Plate 5C) and Sylmar Notch (Plate 5H). The logs of the test holes are included in the well log section of the basic data. The boundary of the subarea was delineated in the gap area on the basis of water levels.

The analysis of available water level data, data obtained from the test holes and the geology of the area indicate the following:

1. Water levels northwesterly of the break in the water surface are about 50 feet higher than those to the southeast of the break. (See Plate 30).

2. Water levels northwesterly of the break are related to the eroded ends of confined aquifers in the Saugus formation.

3. Water levels southeasterly of the break are free ground water levels and are associated with coarse alluvial deposits which had the Pacoima drainage as a source area.

4. The discordance in water levels is related to the eroded south flank of the Little Tujunga syncline which has been covered with a thin veneer of alluvium.

5. Subsurface flow from the Sylmar Subarea into the San Fernando Subarea occurs only at two places; namely, the Sylmar and Pacoima Notches (see Plates 5 and 5H). There is hydraulic continuity between the confined aquifers and the veneer of alluvium that overlies the eroded south flank of
63 the Little Tujunga syncline.

6. Continuity exists between the Sylmar and San Fernando Subareas through the saturated alluvium in the two notches.

7. The configuration of the break in water surface through the Sylmar and Pacoima Notches is not sharp as would be caused by a fault but is a steep gradient which is similar to that found in a ground water cascade.

The average underflow from Sylmar Subarea to the San Fernando Subarea through the Pacoima and Sylmar Notches is estimated at 160 and 400 acre-feet per annum, respectively, during the base period. The Pacoima submerged dam which is located at the Pacoima Notch was constructed in 1888. Prior to its construction and under conditions equivalent to those occurring during the base period, it is estimated that 350 acre-feet per annum would have moved southerly from Sylmar into San Fernando Subarea through the Pacoima Notch. It is therefore concluded that when the Pacoima submerged dam was not in place there was less opportunity for the underflow of Pacoima Wash to move westerly within the Sylmar Subarea.

The information obtained from the test holes was necessary to evaluate the occurrence and movement of ground water within the subarea. The noticeable pressure rise of the water surface which took place in several of the test holes during and immediately after drilling, coupled with the fact that there are historic records of artesian flows for the Mission well field of the City of Los Angeles and the City of San Fernando well field at Fourth and Hubbard Streets, indicates that confined water exists within the Sylmar Subarea. The existence of an area of free ground water between the aforementioned well fields was also determined during the test drilling. All wells in the subarea, however, derive their water supplies from the confined aquifers of the Saugus formation. In 12 of the test holes, the Saugus formation was penetrated before saturated materials were reached.

There was a decline in water levels in the free ground water area coincident with heavy pumping of the Mission well field. Therefore, on the basis of the short period of record available (since December 1958), it appears that the free ground water area is in hydraulic continuity with the confined aquifer system.

The exact location and extent of the forebay or recharge area for the confined aquifers are not definitely known; however, the porous alluvial materials in the Pacoima Wash are in a favorable position to recharge along the strike of the westerly plunging aquifers of the Saugus formation. These aquifers are in contact with the stream gravels in the incised and backfilled portion of Pacoima Wash. These permeable deposits, which are 50 to 60 feet in depth, hold water behind the submerged dam, increasing the possibility of percolation into the aquifers of the Saugus formation. Ground water elevation contours (Plates 27 through 30) indicate that there is a slope of the water surface from Pacoima Wash toward the lower portion of the subarea where the majority of extractions are made.

Water level fluctuations within Sylmar Subarea during the base period are represented by hydrographs of wells 5939, 5969 and 5989A, which are shown on Plate 34C.

Verdugo Hydrologic Subarea

The Verdugo Hydrologic Subarea, as shown on Plate 5, is located in the northeastern portion of the San Fernando Valley. It is a narrow

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alluvial-filled trough bounded by the alluvial contact with the nonwater-bearing hill and mountain groups. This contact is against the San Gabriel Mountains on the north, the Verdugo Mountains to the south and west, and the San Rafael Hills to the southeast. The western boundary has been taken as the topographic divide between the drainage area that is tributary to Big Tujunga Wash to the west and Verdugo Wash to the east. Location of the eastern hydrologic boundary is variable dependent on whether ground water levels are higher or lower than the bedrock ridge westerly of Pickens Canyon as described on page 42. Geologic cross sections O-O', P-P' and Q-Q' on Plates 5F and 5G, and contours showing the elevation of the base of the valley fill on Plate 6, indicate that bedrock to the east of Pickens Canyon is lower than this ridge and that a buried ancestral Pickens Canyon channel slopes to the east.

Available ground water elevations indicate that the bedrock ridge diverts ground water to the east under low water table conditions as existed in the fall of 1958, (see Plate 30) and is the ground water divide under these conditions. During high water table periods, such as occurred in 1944, (see Plate 29) ground water levels are above the ridge and water would also flow across the ridge into the Verdugo Subarea. The ground water divide under this condition would be situated to the east of Pickens Canyon toward the location of the watershed boundary of the Upper Los Angeles River area. Because of this variation in actual location of the ground water divide, depending on water table elevations, the location of the Raymond Basin Reference boundary (i.e. a line extending southerly along the east bank of Pickens Canyon to Foothill Boulevard, thence easterly along Foothill Boulevard to the edge of the valley fill, see Plate 5) was adopted as the eastern hydrologic boundary of the Upper Los Angeles River area and the Verdugo Hydrologic Subarea.

The ground water elevation contours in Verdugo Subarea shown on Plates 27 to 30 indicate a movement of ground water in a southerly direction from the mouths of canyons in the San Gabriel Mountains toward Verdugo Canyon. The surface and subsurface drainage from the Verdugo Subarea would thus naturally flow southerly through the relatively long and narrow Verdugo Canyon into the San Fernando Hydrologic Subarea. The boundary between these subareas has been taken at the submerged dam of the City of Glendale. The submerged dam which was originally constructed in 1895 was reconstructed in 1935 when the Verdugo Wash Channel was improved. The dam, as rebuilt, is shown in profile on Plate 5H. The effect of the dam is discussed in Appendix P.

The water-bearing materials of the Verdugo Subarea are surrounded by a complex of granitic and metamorphic rocks which have been highly fractured. This Basement Complex yields only small amounts of water to springs and tunnels from fracture systems which in turn are supplied by infiltration of precipitation. Nine tunnels drilled into the Basement Complex in the Verdugo area were observed to have flows ranging from 4 to 30 gallons per minute with an average flow during September 1959 of 20 gpm.

The valley fill is composed essentially of coarse ditritus which has been deposited in a series of coalescing fans. The principal source area has been the San Gabriel Mountains. Well logs indicate a fairly high content of sand, gravel and boulders; however, numerous clay designations in well logs indicate that there is considerable clay in the matrix of some of these materials. Well log information indicates that the material in the area north of Foothill Boulevard has a lower specific yield than elsewhere in the subarea with the result that wells in this area have a much smaller specific capacity than those located in the southerly portion of the
65 subarea.

Most of the ground water extractions in the Verdugo Subarea are by wells of Crescenta Valley County Water District located along the southwest side, by wells of the City of Glendale at the Glorietta well field (see Plate 31A), in Verdugo Canyon, and by the Verdugo submerged dam and Verdugo well (3963). Studies described in Appendix P indicate that the subsurface outflow from Verdugo Subarea to San Fernando Subarea has become very small in magnitude as a result of the diversion and pumping at the submerged dam by the City of Glendale.

Water level fluctuations within the Verdugo Subarea during the base period are represented by the hydrograph of well 5058 shown on Plate 34C.

Eagle Rock Hydrologic Subarea

The Eagle Rock Hydrologic Subarea, shown on Plate 5, is located in the eastern portion of the Upper Los Angeles River area, adjacent to the east side of the Los Angeles River Narrows. The subarea is bounded by the valley fill contact with the nonwater-bearing materials of the San Rafael Hills on the north and west and the Repetto Hills to the east and south, with the exception of the small alluviated area on the southeastern boundary of the subarea which has been taken as the topographic divide. All surface drainage easterly of the topographic divide in this alluviated area is tributary to the Arroyo Seco via the Avenue 50 storm drain. Little subsurface flow enters the Eagle Rock Subarea at this location due to the limited cross-sectional area, low permeability materials and a very flat hydraulic gradient through the valley fill materials from east to west.

The surface drainage within the subarea flows generally toward the alluviated area between the San Rafael and Repetto Hills, then southwesterly to the Los Angeles River. Glassell Creek, a tributary to the Los Angeles River, drained the area prior to urbanization and the installation of drains. Spot measurement made by J. B. Lippincott from 1898 through 1900 show a maximum discharge of 1.35 second-feet for Glassell Creek at the Los Angeles River.

The southern boundary of the subarea has been taken to be along the buried trace of the Raymond fault zone. Southerly of the fault zone the nonwater-bearing Puente formation is at or near the ground surface. The total drainage area of the subarea above the Raymond fault zone (see Plate 4) is about 2,910 acres. Of this total 807 acres constitute valley fill area.

There is no direct hydraulic connection indicated between the ground water in the main aquifer of the subarea and the ground water in the Los Angeles River Narrows. The subarea is an artesian basin (see Section S-S', Plate 5H) in which all present day pumping is located at the lower end of the pressure area in the vicinity of well 3987F. This well develops about 22 feet of artesian head over week ends when there is no pumping. It should be noted that in the computation and description of hydrologic items of supply and disposal, the Eagle Rock Subarea has been combined with the San Fernando Subarea.

The water-bearing materials are essentially composed of older alluvial deposits of sand, gravel and considerable clay. Recent alluvium occurs only as a thin veneer along stream channels. There is no surface indication that movement on the Raymond fault zone has affected the Older alluvium in the subarea although this has occurred to the east in the Raymond Basin. Some movement, with the direction of the throw being reversed, must have occurred after the deposition of the gravelly aquifer materials to cause the change to the essentially fine-grained materials of the upper aquiclude. The lower aquiclude and aquifer terminate abruptly against the nonwater-bearing Puente formation south of the Raymond fault zone. The upper aquiclude may not have been affected by faulting and may extend southerly of the fault zone. The pressure area extends northerly from the fault zone toward Colorado Boulevard. Hydraulic continuity exists between wells that are located immediately north of the fault and a well which is 3,000 feet north of it in the pressure area. All wells located within the pressure area, estimated at 250 acres in extent, have had a historic record of artesian flows. There are no wells with water level measurements within the forebay or recharge portion of the subarea.

The Eagle Rock artesian system is supplied from percolation of runoff and deep percolation of applied water into the forebay area. This area extends along Colorado Boulevard and easterly of Eagle Rock Boulevard along Yosemite Drive. These waters recharge the pressure aquifer which has lost about four feet of pressure head since 1941 (measured at well 3986B).

The ground waters in the Eagle Rock Subarea move southerly from the forebay areas into the pressure area. The direction of movement within the pressure aquifer is southerly to the vicinity of the pumping wells located above the Raymond fault. There is presently no known subsurface escape of ground water from the pressure aquifer.

Water level fluctuations in the Eagle Rock Subarea are represented by the hydrograph of well 3986B, which is shown on Plate 34C.

Specific Yield of Water-Bearing Materials

To select specific yield values applicable to the various materials described in driller's logs in the Upper Los Angeles River area, the Referee evaluated previous investigations and presently available data. A direct measurement of specific yield by laboratory methods was not considered feasible due to time limitation.

The specific yield of water-bearing materials is defined as the volume of water drained by the force of gravity from a saturated material over a reasonably long period of time, expressed as a percentage of the total volume of the saturated material.

The specific retention of a material is the ratio, expressed as a percentage, of the volume of water which will be retained by the material against the force of gravity to its own volume. The sum of specific yield and specific retention thus equals the total porosity of the saturated materials.

The particle size is an important textural element in fragmental materials because it is related to the dynamic conditions of transportation and deposition. The most common method of measuring particle size is by sieving. This method consists of taking a sample, a sand for example, and shaking it through a series of sieves. The particles are sorted into size groups controlled by the openings in the sieves. The Wentworth grade scale (1922) provides a means of standardizing terminology. Wentworth's grade scale is used by the majority of sedimentologists. This is a geometric scale which is well adapted to the description of sediments because it gives equal significance to the ratios of sizes, regardless of whether these ratios occur in gravel, sand, silt or clay. The difference of a centimeter in the size of a boulder is negligible, whereas a difference as small as one micron in the size of a clay particle may be enough to double or halve it.

The original work on specific yield reported upon in Bulletin 45* utilized the Wentworth system for describing the various particles. This system has also been utilized in the present investigation. The following tabulation shows the grade limits of the various material classifications by Wentworth size class and the comparable nomenclature used in this investigation:

* See Appendix A

WENTWORTH'S PARTICLE SIZE CLASSIFICATION

Grade Limits (Diameters in mm.)	Name	Grade Limits (Diameters in mm.)	Name
Above 256	Boulder	1/2-1/4	Medium sand
256-128	Large cobble	1/4-1/8	Fine sand
128-64	Small cobble	1/8-1/16	Very find sand
64-32	Very large pebble	1/16-1/32	Coarse silt
32-16	Large pebble	1/32-1/64	Medium silt
16-8	Medium pebble	1/64-1/128	Fine silt
8-4	Small pebble	1/128-1/256	Very fine silt
4-2	Granule	1/256-1/512	Coarse clay
2-1	Very coarse sand	1/512-1/1024	Medium clay
1-1/2	Coarse sand	1/1024-1/2048	Fine clay

After consideration of available information in previous investigations, values similar to those used in Bulletin 45 were adopted as being the most representative of the area of investigation. The reasons for minor modifications of the Bulletin 45 values and the method developed are discussed in Appendix D.

The specific yield values utilized in this investigation are as follows:

Material	Specific yield, in percent
Clay	3
Silty clay	5
Clayey sand	5
Fine sand	16
Medium sand	21
Coarse sand	26
Fine gravel	26
Medium gravel	21
Coarse gravel	14

CHAPTER IV. WATER SUPPLY, UPPER LOS ANGELES RIVER AREA

This chapter contains evaluations of the gross water supply of the Upper Los Angeles River area from all sources, which satisfies in part the requirements of paragraphs I, 2. E., I, 2. F. and I, 7. of the Order of Reference. Included are the amounts of precipitation and import, the historic quality of native and imported waters in the Upper Los Angeles River area, and the selection of base study periods used in determining the safe yield.

The gross water supply to the Upper Los Angeles River area comprises precipitation falling within the watershed and imports through the Colorado River and Los Angeles Aqueducts. The water supply available for ground water recharge is derived from precipitation on the valley floor, runoff from precipitation on tributary hills and mountains, and imports.

Precipitation

Precipitation in the Upper Los Angeles River area is generally in the form of rainfall with snow occurring at times on the higher ridges of the San Gabriel Mountains. Precipitation varies noticeably with elevation and topographic influence as well as from season to season. The mean seasonal precipitation varies from about 14 inches at the western end of the valley to about 35 inches in the San Gabriel Mountains. Precipitation in maximum seasons may be over twice the mean seasonal rainfall while in minimum seasons it may be only one-half the mean. On the average, approximately 80 percent of the annual rainfall occurs during the four winter months of December through March.

Precipitation Characteristics

The greater portion of winter precipitation is derived from rain storms which move inland from the Pacific Ocean. The storms, cyclonic in nature, generally originate in the North Pacific and approach the Pacific Coast moving generally in southeasterly and easterly directions. The storm centers most frequently reach the coast north of San Francisco and in such instances may cause only moderate precipitation in Southern California. However, storm centers which strike the coast farther south often bring intense precipitation to Southern California. Tropical storms which originate in the South Pacific also can bring rain to the Los Angeles area. These storms are irregular in occurrence and the resulting precipitation varies considerably, often bringing warm and heavy rain. During the summer season

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thunderstorms have occurred in the mountains and although the precipitation may be of high intensity the areal extent of such storms is usually small. Occasionally during the late summer season tropical air from Mexico moves northward and produces heavy but short duration showers over the mountain portion of the Upper Los Angeles River area.

The United States Weather Bureau has reported the distribution of rain* as follows:

> "In the case of the Los Angeles area, the orographic barriers determine to a great extent the general distribution of the highest amounts of rainfall. In the ten major storms there was some variation in the location of the highest centers of rainfall, but there was little variation in the location of the 10,000 square mile area over which the maximum precipitation occurred. This fact demonstrates that the orographic features are the major controlling factors for precipitating the moisture and determining its distribution over area. However, there is one important exception: Intense local rainfall associated with the convergent processes of the cyclonic system itself can and does occur over any area irrespective of topography. In the Los Angeles area this rainfall usually has a relatively short duration (less than 12 hours); for longer periods the largest amounts of precipitation occur over the windward slopes or ridges, where precipitation continues as long as moist air flows in any direction that will force it up slope.
>
> "Obviously, the topography of the region is effective in producing precipitation only when the wind is blowing up slope, any downslope motion being rain-inhibiting rather than rain-producing. Also to be considered is the fact that air coming into the Southern California region from a direction other than between south-southeast (157.50°), and west-northwest (292.5°), clockwise, is either flowing down slope or is considerably drier than air coming from those directions. Examination of all storms showed that when the wind was from any direction outside this SSE-WNW range no appreciable rain occurred and therefore all winds outside this range could be disregarded, except in cases where a front or marked trough extending in a west-to-east direction moved southward over California. During these conditions appreciable rain could occur in the air preceding the front or trough passage even though the isobars indicated movement of air from a direction slightly north to west-northwest."

* Hydrometeorological Report Number 21B, United States Department of Commerce, December 29, 1945.

The isohyetal map (see Plate 9) clearly indicates the orographic effects on the distribution of rainfall in the Upper Los Angeles River area from storms which predominantly come from southerly and westerly directions. The mean annual precipitation increases with increasing elevation on the windward slopes of the San Gabriel and Santa Susana Mountains and then diminishes on the leeward slopes.

As noted by the United States Weather Bureau, intense local rainfall can occur over any area irrespective of topography. It is possible that this rainfall may or may not be recorded at a precipitation station, and in either case, because of the local nature of the rainfall, could induce an undeterminable error in the quantity of precipitation determined from such records.

Quantity of Precipitation

The mean depths of precipitation over the Upper Los Angeles River area, as shown on Plate 9, are based on the 85-Year Mean Seasonal Isohyetal Map for Los Angeles County for the period from 1872-73 through 1956-57, prepared by the Los Angeles County Flood Control District. The isohyetal map is based on 130 master precipitation stations established by the District. The Los Angeles and Pasadena precipitation stations have records throughout the 85-year period and all other master station records were extended to that period by methods described in Appendix E.

The 85-year mean precipitation was computed by applying the Isohyetal Method to the 85-year isohyets within polygons of a Thiessen network. The Thiessen network was constructed by utilizing 22 controlling precipitation stations (see Plate 9 and Table E-1) located within the Upper Los Angeles River area. A more detailed discussion of this procedure is presented in Appendix E. The Isohyetal Method was used to compute the 85-year normal amounts of precipitation rather than applying the normal annual depth of precipitation at the controlling station over the entire polygon area because of the variable effect on occurrence and amount of precipitation resulting from topography and other influences. Some of these influences, particularly those caused by topography, are generally reflected by the isohyets.

The annual amount of precipitation during any year was computed as the product of the index of wetness for that year at the controlling station (see Table E-5), the normal annual depth of precipitation on the polygon containing the station (as determined from the isohyets), and the area of the polygon. The controlling station was considered to be representative of the index of wetness at any point within the polygon because the resulting area of influence is not large compared to the extent of most of the winter storms from which the major portion of the precipitation is derived.

The annual amounts of precipitation on the valley floor hydrologic subareas and the hill and mountain areas were computed separately and are shown in Table 1 for the 30-year period 1928-29 through 1957-58. Annual precipitation in percent of 85-year normal is shown in Table 2. It should be noted that the average values shown in Table 2 indicate that the mean annual precipitation on the valley floor for the 29-year period 1928-29 through 1956-57 is slightly greater than the 85-year normal; however, the combination of valley fill and hill and mountain precipitation for this period is practically the same as the 85-year normal for the total area.

TABLE 1

ANNUAL PRECIPITATION

In Acre-Feet[a] and Inches

Year	Hydrologic subareas						Upper Los Angeles River area					
	San Fernando[b]		Sylmar		Verdugo[c]		Valley fill		Hill and mountain		Total	
	Acre-Feet	Inches	Acre-Feet	Inches	Acre-Feet	Inches	Acre-Feet	Inches	Acre-Feet	Inches	Acre-Feet	Inches
1928-29	108,970	11.59	6,190	13.35	7,280	17.44	122,440	11.90	260,010	15.17	382,450	13.94
29-30	112,130	11.92	7,090	15.29	6,500	15.58	125,720	12.22	276,060	16.10	401,780	14.65
1930-31	140,410	14.93	8,070	17.40	7,280	17.44	155,760	15.14	311,010	18.14	466,770	17.02
31-32	186,030	19.78	10,350	22.32	11,070	26.51	207,450	20.17	440,210	25.66	647,660	23.61
32-33	119,750	12.73	6,360	13.71	7,380	17.67	133,490	12.98	283,120	16.52	416,610	15.19
33-34	132,680	14.11	7,170	15.46	10,190	24.42	150,040	14.59	300,100	17.51	450,140	16.41
34-35	184,260	19.59	10,430	22.49	12,420	29.76	207,110	20.14	461,580	26.93	668,690	24.38
1935-36	115,460	12.28	7,580	16.34	7,960	19.07	131,000	12.74	284,090	16.57	415,090	15.13
36-37	215,710	22.94	12,470	26.88	13,980	33.48	242,160	23.54	549,310	32.04	791,470	28.86
37-38	228,990	24.35	12,870	27.76	16,690	39.99	258,550	25.14	595,540	34.74	854,090	31.14
38-39	197,910	21.04	10,350	22.32	10,870	26.04	219,130	21.30	418,050	24.39	637,180	23.23
39-40	155,230	16.50	8,230	17.75	8,540	20.46	172,000	16.72	322,680	18.82	494,680	18.04
1940-41	371,580	39.51	18,250	39.36	19,990	47.90	409,820	39.84	811,180	47.32	1,221,000	44.52
41-42	124,200	13.21	6,360	13.71	7,180	17.21	137,740	13.39	279,120	16.28	416,860	15.20
42-43	229,220	24.37	12,710	27.41	17,080	40.92	259,010	25.18	587,100	34.25	846,110	30.85
43-44	230,250	24.48	11,980	25.83	12,030	28.83	254,260	24.72	553,860	32.31	808,120	29.46
44-45	131,020	13.93	7,660	16.52	9,800	23.48	148,480	14.44	352,800	20.58	501,280	18.28
1945-46	125,990	13.40	7,250	15.64	8,060	19.30	141,300	13.74	342,760	19.99	484,060	17.65
46-47	137,690	14.64	8,390	18.10	9,900	23.72	155,980	15.16	377,670	22.03	533,650	19.46
47-48	71,730	7.63	3,990	8.61	4,370	10.46	80,090	7.79	190,890	11.14	270,980	9.88
48-49	75,680	8.05	4,970	10.72	5,920	14.18	86,570	8.42	212,450	12.39	299,020	10.90
49-50	97,480	10.36	6,360	13.71	7,380	17.67	111,220	10.81	247,900	14.46	359,120	13.09
1950-51	79,700	8.47	5,300	11.42	4,860	11.63	89,860	8.74	180,000	10.50	269,860	9.84
51-52	281,800	29.96	15,890	34.26	17,280	41.39	314,970	30.62	647,000	37.74	961,970	35.07
52-53	107,200	11.40	6,190	13.35	5,530	13.25	118,920	11.56	228,930	13.35	347,850	12.68
53-54	122,260	13.00	7,010	15.11	9,120	21.86	138,390	13.45	302,930	17.67	441,320	16.09
54-55	129,180	13.74	6,600	14.23	7,080	16.97	142,860	13.89	278,180	16.23	421,040	15.35
1955-56	153,270	16.30	8,960	19.33	9,020	21.62	171,250	16.65	324,980	18.96	496,230	18.09
56-57	120,000	12.76	6,760	14.58	7,280	17.44	134,040	13.03	270,760	15.79	404,800	14.76
57-58	249,700	26.55	14,260	30.75	14,660	35.11	278,620	27.09	608,250	35.48	886,870	32.33
29-Year Average[d] 1929-1957	154,680	16.45	8,680	18.72	9,730	23.30	173,090	16.82	368,630	21.50	541,720	19.75
85-Year Average[e] 1873-1957	149,880	15.94	8,150	17.57	9,710	23.25	167,740	16.31	377,110	22.00	544,850	19.86

a. Annual water crop rounded off to nearest 10 acre-feet.
b. Includes Eagle Rock Subarea.
c. Includes portion of Monk Hill Basin within Upper Los Angeles River Area.
d. 29-year base period 1928-29 through 1956-57.
e. 85-year period of normal precipitation 1872-73 through 1956-57.

TABLE 2

ANNUAL PRECIPITATION
IN PERCENT OF 85-YEAR NORMAL[a]

Year	Valley fill area: Hydrologic Subarea: San Fernando[a]	Sylmar	Verdugo[b]	Total	Hill and mountain areas	Upper Los Angeles River area
1928-29	73	76	75	73	69	70
29-30	75	87	67	75	73	74
1930-31	94	99	75	93	82	86
31-32	124	127	114	124	117	119
32-33	80	78	76	80	75	76
33-34	89	88	105	89	80	83
34-35	123	128	128	123	122	123
1935-36	77	93	82	78	75	76
36-37	144	153	144	144	146	145
37-38	153	158	172	154	158	157
38-39	132	127	112	131	111	117
39-40	104	101	88	103	86	91
1940-41	248	224	206	244	215	224
41-42	83	78	74	82	74	77
42-43	153	156	176	154	156	155
43-44	154	147	124	152	147	148
44-45	87	94	101	89	94	92
1945-46	84	89	83	84	91	89
46-47	92	103	102	93	100	98
47-48	48	49	45	48	51	50
48-49	51	61	61	52	56	55
49-50	65	78	76	66	66	66
1950-51	53	65	50	54	48	50
51-52	188	195	178	188	172	177
52-53	72	76	57	71	61	64
53-54	82	86	94	83	80	81
54-55	86	81	73	85	74	77
1955-56	102	110	93	102	86	91
56-57	80	83	75	80	72	74
57-58	167	175	151	166	161	163
29-Year Average[c] 1929-57	103.3	106.6	100.2	103.2	97.9	99.5
85-Year Average[d] 1873-57	100.0	100.0	100.0	100.0	100.0	100.0

a. Includes Eagle Rock Subarea.
b. Includes portion of Monk Hill Basin within Upper Los Angeles River area.
c. 29-year base period 1928-29 through 1956-57.
d. Normal based on 85-year period 1872-73 through 1956-57.

Selection of Base Study Period

The desirable base study period is one during which precipitation characteristics in the Upper Los Angeles River area approximate the 85-year period of record, 1872-73 through 1956-57. A further requirement of such a period is that additional hydrologic information is available sufficient to permit an evaluation of the amount, occurrence and disposal of the normal water supply under recent culture conditions. The desirable base period includes both wet and dry periods similar in magnitude and occurrence to the normal supply, and during which there are sufficient measurements and observations to relate the hydrology to recent culture.

Subsequent to 1927-28, records of stream outflow, culture distribution and water utilization on the valley floor, and ground water levels at wells are fairly comprehensive and adequate. In contrast, earlier records concerning these items are available only on a limited basis. There is a paucity of earlier measurements required to determine basin-wide ground water levels and continuous stream outflow. Because of the aforementioned requirements and limitations, the selection of a base period was restricted to years subsequent to 1927-28.

To determine the regimen of occurrence of rain in the Upper Los Angeles River area, selected precipitation stations on the valley floor having long periods of record were studied for an indication of periods with an occurrence of rain equivalent to the normal period. The 85-year mean seasonal precipitation was used to compute the indices of wetness for these selected stations, and annual averages of these indices of wetness were utilized to construct the cumulative percentage deviation mass diagram for the Upper Los Angeles River area, shown on Plate 10.

Comparison of the precipitation trends in the Upper Los Angeles River area with those reflected by the longer record of precipitation at Los Angeles, Pasadena, Acton and Sawtelle Soldiers Home, also shown on Plate 10, indicates that even though the magnitude of the annual deviation varies, the cyclic trends of these four stations are generally in agreement with the trends indicated by precipitation records within the area.

The 29-year period, 1928-29 through 1956-57, was selected as the base study period for the following reasons:

1. It was a period of normal precipitation during which sufficient records were available for purposes of determining safe yield.
2. It was a representative period of normal precipitation including both wet and dry periods of magnitude and occurrence similar to long-time mean supply conditions of 1872-73 through 1956-57. A wet period occurred from 1936-37 through 1944-45, and a predominantly dry period from 1945-46 through 1956-57. The 29-year period 1928-29 through 1956-57 contains nine years when precipitation was predominantly above average, that is, 115 percent of normal or greater. These nine years comprise 31 percent of the 29-year period as compared to 29 years of similar wetness occurring during the 85-year or normal period which comprise about 34 percent of that period. The average annual amount of precipitation during the 29-year period approximates the long-time mean

having the following average annual deviation from the 85-year mean expressed as a percentage thereof:

Valley lands	+3.5 percent
Hill and mountain areas	-2.2 percent
Combined	-0.4 percent

3. The years immediately preceding the first and last years of this period were of below normal wetness, which thereby minimized the difference of unaccounted-for water in transit to the water table at the start and end of the period.

4. It includes a period of record of supply and disposal under conditions of culture which approximate those existing in 1949-50, 1954-55 and 1957-58, the years during which safe yield is to be determined.

Special Study Periods

The period 1933-34 through 1948-49 is of significance in that it can be used to check change in storage computations. During this 16-year period a substantial rise and fall of ground water levels occurred with average levels at the beginning and end of the period being approximately the same elevation.

The 29-year base study period contains periods of differing practices as to the use of water which are related to change in land use, economic conditions, living standards and technological improvements. Thus, to properly evaluate the use of water under current conditions, a study period during recent years having a rain supply equivalent to the long-time mean was desirable. The 9-year period 1949-50 through 1957-58 was selected as a special study period for the valley floor area since the average annual precipitation on the valley floor was 99.7 percent of the 85-year mean and this period included economic conditions and water use practices prevalent during the safe yield years. Hill and mountain precipitation and resulting runoff were less than normal during this same period; because of this the 9-year period was restricted to evaluation of the effects of rain on culture in the valley.

Hill and Mountain Runoff

The surface runoff from 205,709 acres of hill and mountain lands contributes to the water supply on the valley fill. The average annual surface runoff during the base period from these areas was 43,100 acre-feet per year. In a dry year such as 1947-48, the runoff from hill and mountain lands was less than 4,000 acre-feet, while in a wet year such as 1940-41, it was approximately 190,000 acre-feet. This wide variation in the annual amount of runoff is the result of changes in both precipitation and the retentive characteristics of the watersheds.

Surface runoff from about 42 percent of the hill and mountain areas is measured by two stream gaging stations (Plate 9). They are located on Pacoima Creek above Pacoima Dam and Big Tujunga Creek at Gold Canyon. The remaining hill and mountain areas consist of smaller watersheds at lower elevations. The amount of surface runoff contributed by these watersheds under native conditions has been estimated by correlating the surface runoff and index of wetness with runoff measurements of comparable watersheds located in and near the Upper Los Angeles River area (see Appendix F). It was determined from this study that under native conditions the long-time mean runoff for these watersheds was equal to nine percent of the long-time mean precipitation. The annual quantities of surface runoff thus estimated for these smaller watersheds were further adjusted by applying an annual factor based on the difference between the measured and the estimated runoffs of the control watersheds.

Residential development along the foothills produces a larger amount of runoff than would have occurred under native conditions. The amount of increased runoff was calculated as the difference between runoff on impervious areas of residential lots, as shown in Appendix L, and the runoff under native conditions as detailed in Appendix F.

The methods of estimating hill and mountain runoff under native and developed conditions, as well as the amount of runoff tributary to water supply reservoirs, are contained in Appendix F.

Annual amounts of surface runoff from hill and mountain lands to the hydrologic subareas and the entire valley floor are shown in Table 3 for the base period. The total amounts shown include contributions to water supply reservoirs from this source.